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# **Inequality, Communication and the Avoidance of Disastrous Climate Change**

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## **Abstract**

International efforts to provide global public goods often face the challenges of coordinating national contributions and distributing costs equitably in the face of uncertainty, inequality, and free-riding incentives. In an experimental setting, we distribute endowments unequally among a group of people who can reach a fixed target sum through successive money contributions, knowing that if they fail they will lose all their remaining money with 50% probability. We find that inequality reduces the prospects of reaching the target, but that communication increases success dramatically. Successful groups tend to eliminate inequality over the course of the game, with rich players signalling willingness to redistribute early on. Our results suggest that coordinative institutions and early redistribution from richer to poorer nations may widen our window of opportunity to avoid global climate calamity.

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# Inequality, Communication and the Avoidance of Disastrous Climate Change

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## Abstract

International efforts to provide global public goods often face the challenges of coordinating national contributions and distributing costs equitably in the face of uncertainty, inequality, and free-riding incentives. In an experimental setting, we distribute endowments unequally among a group of people who can reach a fixed target sum through successive money contributions, knowing that if they fail they will lose all their remaining money with 50% probability. We find that inequality reduces the prospects of reaching the target, but that communication increases success dramatically. Successful groups tend to eliminate inequality over the course of the game, with rich players signalling willingness to redistribute early on. Our results suggest that coordinative institutions and early redistribution from richer to poorer nations may widen our window of opportunity to avoid global climate calamity.

Preserving the global climate commons is one of the biggest collective action problems humanity has ever faced (1); evidence suggests that we have already exceeded the planet's "safe operating space" in the climate system (2). Containing the rise in global mean temperature is a global public good, where the benefits of efforts to reduce emissions are shared by all, irrespective of individual contributions. Such disconnect between individual and collective interest is a prime cause of public goods under-provision (3-7). Whereas public goods experiments under controlled conditions oversimplify the complexity of international climate action (8), they nonetheless shed light on the relative importance of factors that affect its success (9). Standard public good games are concerned with the creation of a collective gain (10-15). Climate change, however, is about avoiding an uncertain public bad. This has been framed as a "collective-risk social dilemma" of sequential contributions to a public climate fund aimed at avoiding a probabilistic loss arising if the target is missed (16). Participants in this threshold public goods experiment behaved less rationally than theory predicted, often failing to avoid simulated dangerous climate change due to miscoordination in final rounds (17). But what will be the outcome if participants can communicate with one another? And what is the effect of inequality on effort coordination?

International progress in reducing CO2 emissions has been remarkably slow, not least because of free-riding incentives, as partly captured by the threshold public goods game of loss avoidance (16). The core of this game, however, is a problem of coordination: players are best off when synchronizing contributions in the face of multiple equilibria (3, 18). The game therefore calls for communication. The latest climate agreements negotiated in Copenhagen and Cancun introduced

a pledge and review system of voluntary emission reduction commitments for 2020 (19). Can such a simple mechanism of communicating intentions be effective to enhance coordination?

Optimism from reaching a global agreement following Cancun is shadowed by concerns over implementation and particularly whether richer nations will go far enough in financing abatement and adaptation for poorer nations (20). Equity concerns over the distribution of emission cuts and associated costs are at the heart of the sustainability of international climate change action (21). Inequality has been studied extensively in the context of collective action problems: the presence of inequality is often found to complicate cooperation (22-25), though communication between users tends to improve the likelihood of cooperation (26, 27). Different patterns of interaction are observed depending on the type and cause of inequality and on the type of resource at stake (28). Given these findings we examine whether and how inequality and potential differences in equity concerns between rich and poor affect their ability to coordinate efforts.

An essential feature of the global climate change game is that inequality in endowments is mirrored by inequality in past appropriation of the climate commons; roughly speaking, the richer a nation is, the more it has “used” the atmosphere by emitting CO<sub>2</sub> (29, 30). We introduce and test in the lab the effects of inherited inequality in wealth and appropriation on coordination success in reaching a safety target, and how this is mediated through communication of contribution intentions. 240 students took part in the experiment, and were randomly assigned to groups of six. As in (16), each player was endowed with €40 which could be invested in climate protection. Players could choose between an investment of either €0, €2 or €4 per round. The target was to collectively invest €120 by the tenth and final round, in order to avoid simulated dangerous climate change and to secure what was left on the private account. Groups that failed to invest at least €120 lost all their savings with a 50% probability. Players did not know the identity of their team’s members; after each round they were informed about the others’ contributions, the aggregate group contribution in that round and the cumulative past contribution of each player and of the group as a whole (31).

To capture the idea of inheritance of past wealth and debt, we started the game with three inactive rounds where players had no freedom to choose, as contributions were determined by the computer. In the control treatment (“*Base*”), the computer allocated symmetrically to all players €2/round. In the “*Base-Unequal*” treatment, the computer allocated asymmetrically to half of the group €4/round and to the other half €0/round. “Rich” players hence entered round four with €40 and “poor” players with €28. In separate treatments players were given the option to announce what they planned to invest during the game, one time at the end of the three inactive rounds and again at the end of round seven. Pledges were nonbinding. The “*Pledge*” treatment introduced the pledges to the symmetric case while the “*Pledge-Unequal*” treatment implemented the pledges in the asymmetric case.

The multiplicity of equilibria in the game makes classification virtually impossible. The game is a modified n-person stochastic threshold public goods game, with a total of ten rounds of which only seven allow freedom of choice over the three possible actions. Both contributing nothing and 2€ in each round are (symmetric) Nash equilibria, since unilateral deviations are non-profitable (32, Table 1). Depending on the round and the path that led to it, a round contribution of €4 bringing the individual sum above €20 may still be optimal if successful in guaranteeing that past investments are not wasted. Conversely, if at a certain stage the target becomes out of reach because of insufficient members’ contributions, one’s best response is to stop contributing and play the odds.

Treatment type	0€/active round	2€/active round	4€/active round
Symmetric wall=€34	17* (36)	20 (120)	6 (204)
Asymmetric wrich=€40 wpoor=€28	20* 14* (36)	26 14 (120)	12 0 (204)

Table 1: End payoffs in € (and corresponding climate account values for the group) arising if the 3 pure strategies were adopted by all players for the 7 active rounds. Asterisks refer to expected values based on the 50% probability of account loss when the target sum of €120 is not reached. In the symmetric treatments (*Base* and *Pledge*), all group members begin the active play having contributed €6 in the previous 3 rounds, leaving them with a disposable endowment of €34; in the asymmetric treatments (*Base-Unequal* and *Pledge-Unequal*), three rich players have no prior contributions and the three poor players have prior contributions of €12, leaving them with €40 and €28 respectively.

In the symmetric treatments each group trajectory leading to a cumulative contribution of €120, irrespective of individual contributions provided that each subject invests at most €22 overall, is a Nash equilibrium. This is the case since the latter investment translates into a payoff of €18, which is above the €17 that is expected when all players choose not to contribute to the public good (second column in Table 1). Therefore, individuals can maximize the payoff of the game by choosing the intermediate level of contribution, invest a further €14 over rounds 4 to 10 and secure the €20.

In the asymmetric treatments, due to the different disposable endowments of rich and poor players, the former gain the most when the climate is protected with equal burden sharing in the active rounds (€26, resulting from an investment of €14). Relative to the no contribution equilibrium, it is more appealing as the rich will be at least as well off when investing at most €20. The poor, on the other hand, do not stand to gain from the equal burden sharing equilibrium in the active rounds, assuming risk neutrality: given the early rounds contributions of €12, only by investing less than €14 in the active rounds (and the group still reaching the threshold) can these players have a higher expectation than by not investing in the public good.

The game design allows for such redistribution. The rich have a surplus of €6 in the 2€/active round equilibrium relative to the poor, and can in principle forgo part or all of it by investing more and allowing the poor to correspondingly decrease their investment. An average of €3/round for the rich and €1/round for the poor almost exactly equalize contributions (and expected payoffs) among the players. With full redistribution, rich and poor have a final payoff of €20, which for the rich is still rational in the sense of not being welfare diminishing relative to not contributing anything.

Results show that inequality makes success harder, but that the pledge option increases success dramatically (Figure 1). Both pledge treatments were well above the corresponding ones without pledges. Income inequality reduced the prospects of success: 5/10 groups succeeded in the *Base* treatment, vs. 2/10 in *Base-Unequal*. In the latter, investment by the failing groups was €15 higher ( $n=13$ ,  $P=.0393$ , two-sided Mann-Whitney-Wilcoxon (MWW) test), indicating that inequality also led to poorer coordination on the non-provision outcome. The pledge option had more effect

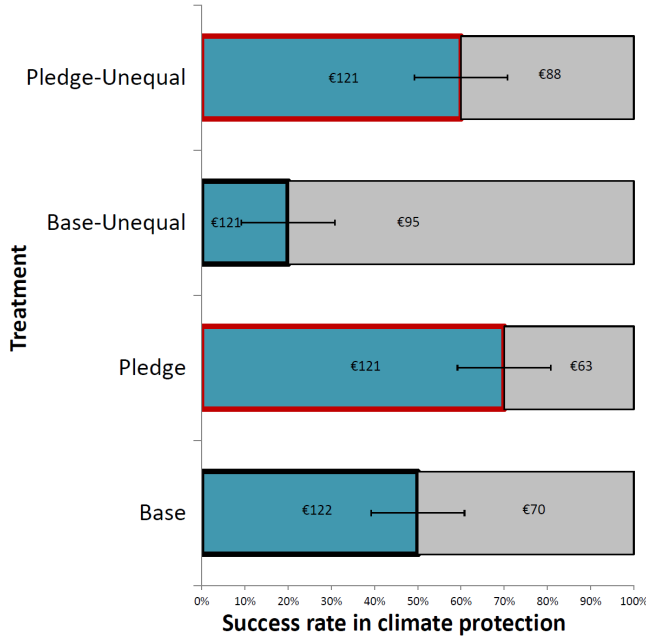


Figure 1: Success rate in avoiding dangerous climate change. The bottom two treatments are symmetric, the top two are asymmetric. The blue sections of the bars indicate the % of successful groups (with red contours for the treatments with communication), while the grey sections indicate the corresponding failing rate. For both group classes, error bars and the average investment (inclusive of the €36 collected in the first three rounds) are shown in the insets. Only in Pledge was the outcome somewhat close to the rational prediction of all groups reaching the target ( $n=10$ ,  $P=.0816$ , binomial test). Further regressions in the Supporting material.

under conditions of inequality: success rates tripled from 2/10 in *Base-Unequal* to 6/10 in *Pledge-Unequal* ( $n=20$ ,  $P=.085$ , one-sided Fisher's exact test). The latter success rate (6/10) is not significantly different from the 7/10 achieved by participants of the symmetric *Pledge* treatment ( $P=.500$ ), indicating that inequality is a less serious threat once a better coordination mechanism is introduced.

Although nonbinding, players respected pledges: following the second pledge, average cumulative contributions in rounds 8-10 were €31.8 and €30 in *Pledge-Unequal* and *Pledge* respectively, and the stated amounts were €32.6 and €29.6. The closer the pledges to actual contributions, the higher the probability of group success: as the difference between cumulative contributions and pledged amounts increases, the probability of a player being in a successful group decreases significantly (Figure 2).

Successful groups were strikingly effective in eliminating the inherited inequality: in the two *Unequal* treatments, the difference in contributions between rich and poor players belonging to successful groups is not significant (€20 contributed by both, two-sided MWW test,  $n=16$ ,  $P=0.8195$ ). Even in the absence of communication, participants of successful groups tacitly coordinated on an equalizing redistribution, which offset the original endowment asymmetry (Figure 3). Conversely, the difference in contributions between rich and poor is significant in failing groups (€16 by the rich and €21 by the poor,  $n=24$ ,  $P=.0138$ ), indicating that such redistribution did not take place. Signalling early on willingness to invest in the public good rather than to gamble was critical for the fate of the game. Successful groups provided on average €1.92 in round four, while failing groups provided €1.25 (significant difference, two-sided MWW test,  $n=40$ ,  $P=0.0001$ ). Early sig-

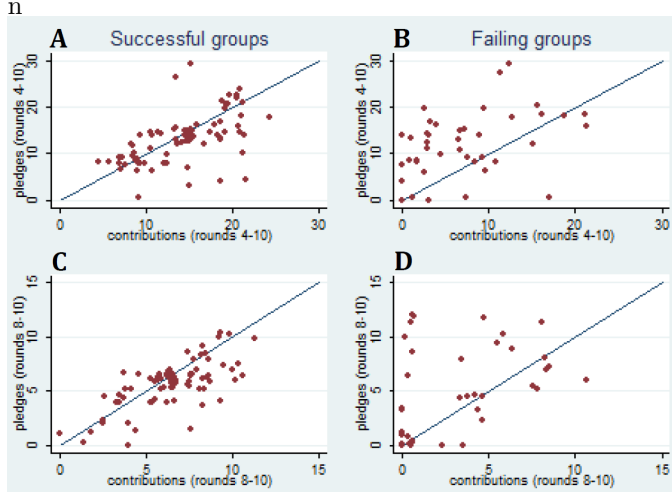


Figure 2: The probability that a player belongs to a successful group decreases with the contribution-pledge gap, i.e. with the differences between cumulative contributions and the corresponding amounts pledged both early (rounds 4-10, Probit,  $P=.0019$ ) and later in the game (rounds 8-10, Probit,  $P=.0324$ ). All regressions with group-cluster robust standard errors to take in account outcome interdependence among participants; see (29) for regression tables and marginal effects interpretation. The top panels visually confirm the link between success and adherence to the initial pledge: for the groups that provided the public good (A) the gap is tighter than for the unsuccessful ones (B), as indicated by the dispersion around the bisector. Similarly for the second pledge, greater clustering around the bisector takes place in (C) than in (D); a small random noise (5%) has been inserted to make all data points visible.

nals by the rich of willingness to redistribute were decisive in the asymmetric games. On average, rich players in successful groups contributed €3.17 in round 4, while they contributed €2.06 in failing groups (significant difference, two-sided MWW test,  $n=20$ ,  $P=0.0054$ ). Cumulative contributions by the rich over rounds 4 to 6 were €9.83 in successful groups, while the rich in failing groups appeared to be unwilling to commit to early redistribution and invested only €6.67 ( $n=20$ ,  $P=0.0040$ ).

The questionnaire which followed the game (31) confirms that the rich’s fairness perceptions and willingness to redistribute were decisive for success: being confronted with the statement that “the rich players should contribute more during the active rounds than the poor players”, 75% of the rich in successful groups but only 53% of the rich in failing groups agreed with that claim (one-sided Fisher’s exact test,  $n=60$ ,  $P=0.071$ ). Therefore the rich’s opinion in that question and the group’s success are significantly correlated (Spearman’s correlation test,  $n=60$ ,  $P=0.0855$ ). Subjects’ responses furthermore show a clear self-serving bias of fairness perceptions: the acceptance of the above claim is highly dependent on the player’s wealth (Spearman’s correlation test,  $n=120$ ,  $P=0.0002$ ). In numbers: 90% of the poor but only 62% of the rich support the claim for redistribution (one-sided Fisher’s exact test,  $n=120$ ,  $P=0.000$ ). This bias, which has been found also in climate negotiations (21), appears to be an important determinant for effective coordination.

Extrapolation from our results should be cautious (33): controlling CO2 emissions is a much more complex task than the one of coordination on a known threshold faced by the subjects of this experiment (3, 18). Yet, the finding that inequality hampers coordination and makes a coordinative institution indispensable is important: countries can be expected to coordinate their national efforts to reach a common goal provided that they agree on a common fairness notion. Disagreement



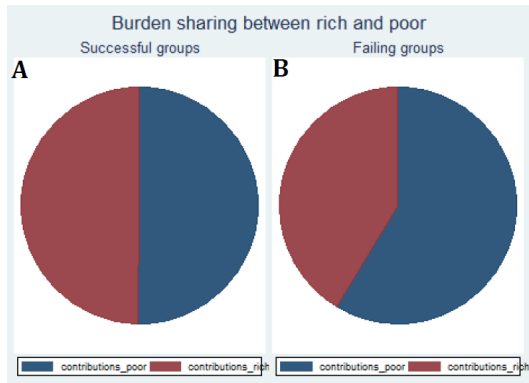


Figure 3: In successful groups partaking in the treatments with unequal endowments (*Base-Unequal* and *Pledge-Unequal*), the rich compensated the poor by investing more in the active rounds and equalized cumulative contributions over the entire game at €20 (A). In failing groups such wealth redistribution didn't take place to the same extent: the initial gap of €12 between the rich and poor was not fully offset, as the former invested €16 on average while the latter €21 (B).

in contrast may lead to early political lock-ins and disastrous consequences. Future research is needed to bring more realism and complexity in the collective-risk social dilemma, introducing uncertain thresholds and gradual climate change for instance. Climate change also entails not only asymmetry in wealth and carbon debt, but also asymmetry in adaptation capacity and risk exposure (34). Losses, even under catastrophic climate change, will be unequally distributed depending on countries' income or location (35, 36). Different types of inequality stand to have different effects, more so when in concert (37). The shape of the wealth distribution may also affect outcomes: while an increase in inequality may well enhance the incentives for the rich to contribute more, such increase may simultaneously reduce the incentives for the poor (29). The behavior of players also changes depending on the origin of inequality, as shown in experiments comparing merit-based to random wealth allocation (38, 39).

Nevertheless, it is tempting to relate the basic structure of this game to the current stage of climate talks. Signaling commitment to contribute early on appears decisive for coordination. The Cancun agreement is short in abatement ambitions, but its success in restoring confidence in the commitment of nations to take action rather than gamble may prove decisive. Success in providing the global climate protection good is inextricably related to the willingness of the rich to take up early on a sizeable share of the burden. We find evidence that the poor are not willing to compensate for the rich's inaction. These findings suggest that early leadership by the richer nations and appropriate coordination mechanisms are instrumental to the avoidance of disastrous climate change.

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Supporting Online Material

This appendix includes:

Materials and Methods

SOM Text

Figs. S1 to S2

Tables S1 to S7

References

## 1 Methods and Materials

### 1.1 Methodological details

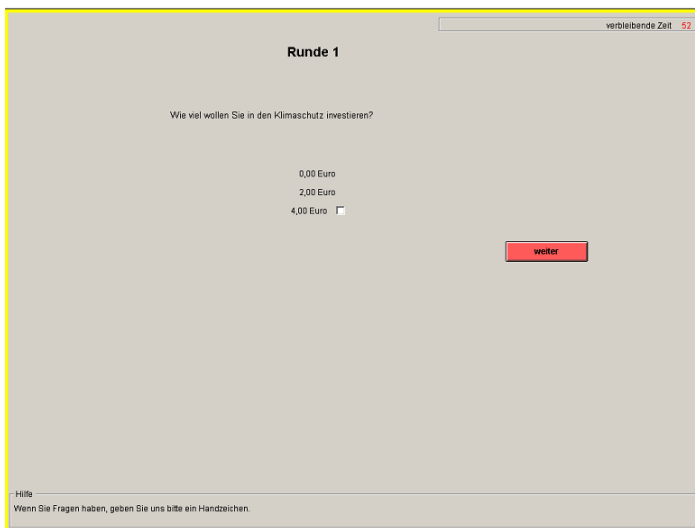
Most experiments on public goods utilize linear public goods games, where participants have the option to invest a fraction of their endowments in a public good by means of a voluntary contributions mechanism (*S1*). Typically, the returns to the investment are equally shared among the participants according to the marginal per capita return. We depart from this standard formulation in many ways. First, the provision of the public good is sequential, as multiple stages of contributions (10 rounds) are performed before the assessment of the group effectiveness in preventing simulated catastrophic climate change. Second, the objective of the game is to avoid a loss rather than creating a surplus by contributing to a public good (with higher group contributions leading to higher returns to the players). Here players' contributions to the public good make them collectively better off only insofar they are sufficient to reach a threshold by the final round (€120). All contributions below (or above) it are wasted, as they fail to secure the keeping of the private accounts by the participants (or have no additional benefit if above the threshold). This feature leads to the next salient one, concerning the probabilistic nature of the losses. To account for the uncertainty involved in climatic change, the actions of the six players forming a group taking part in the game have consequences that are not deterministic. If they collectively fail to reach the target required to avoid climate catastrophe, they will lose their savings on the private account (what is left of the initial €40 endowment after the contributions to the public good) with a probability of 50%. As both the climate threshold and the probability of the climate catastrophe are known, the players' primary challenge here is to *coordinate* rather than to just increase their contributions (*S2*).

The probability of the climate catastrophe was chosen in the light of the results of the experiment by Milinski et al. (*S3*), who developed and tested the above departures, and which we aim to enrich with features that will be discussed below. It is therefore worth taking a closer look at their experiment. In a nutshell, they implemented the above setup, with individuals deciding in each of the ten rounds of the game whether to contribute either €0, €2, or €4 to the climate account, with each group being presented with one of three different treatments corresponding to three probabilities of savings' loss: 90%, 50% and 10%. These yielded the following levels of success in avoiding simulated climate change: 50%, 10% and 0%. That is with the highest stakes, due to the larger gains in expected value from reaching the target, coordination was most effective and half of the participating groups were successful in collecting at least €120, while only one group out of ten succeeded in the 50% treatment and no group succeeded in the treatment with 10% probability of incurring the loss. Note that the last result is not surprising from a rationality standpoint, as a player contributing €0 in all rounds would have expected earnings of €36 compared to earnings of

€20 and €0 by following the remaining two pure strategies of €2/round and €4/round contributions. Only in the 90% treatment the social optimum coincides with the strategy of €2/round, as it would lead to certain earnings of €20 if adopted by all subjects, compared to expected earnings of €4 if all adopt the €0/round strategy and a certain outcome of €0 if they follow the €4/round strategy.

Our basic experimental design closely follows (*S3*), with six individuals playing together in a group, each endowed with €40. The players decided in each of the active rounds of the game whether to contribute either €0 (“no contribution”), €2 (“intermediate contribution”), or €4 (“high contribution”) to the climate account. All groups were presented with the probability of savings’ loss of 50%. This was chosen because, as illustrated in Table 1 in the main text, it favors the symmetric equilibrium where all contribute €2/round (at least in symmetric treatments and in asymmetric treatments for rich players) over the no contribution equilibrium, while retaining a high temptation to defect and take a gamble. Further, we avoided extreme probabilities (such as 10% and 90% in *S3*) to avoid confusion with certain outcomes and in particular for the following reasons: 10% disaster probability makes the game trivial, from a game theoretic perspective, as players are better off by not providing the public good; 90% probability, on the other hand, makes the noncooperative equilibrium unattractive due to almost certain loss in case of failure to reach the target. After each round the players were informed about all individual contributions and the aggregate group contribution in that round as well as the cumulative past contribution of each player and the group. As in (*S3*), players were assigned nicknames in order to keep their identity private. Since the focus of this paper is to test in the lab for the role of inherited inequalities in informing the debate on climate change, we introduced a series of treatments aimed at capturing features of asymmetry among participants in terms of wealth, past contributions and future commitment announcements.

In order to induce subjects to perceive the inequalities among them as the result of past actions, we modified the game described above by replacing the first three rounds with three *inactive* ones where half of the group had only the option of choosing a €0/round contribution, while the remaining three players were bound to a €4/round contribution, as follows:



That is, rather than externally imposing different endowments from the beginning of the experiment, players were all told they had the full €40 endowment before the start, but witnessed

through the first three rounds a growing divergence between high and low contributors. As a result of these three inactive rounds, the players began the active play consisting of seven rounds with substantial ‘*inherited*’ differences: those who forcefully contributed €12 prior to round 4 had €28 left in their private accounts, while those who previously did not contribute anything to the public good found themselves with the entire endowment available for the ensuing seven rounds. We call this treatment “*Base-Unequal*”. The current generation inherited wealth (and “debts”) from the first generation without having a say on it, but simply as the result of past actions. This situation is reminiscent of global CO2 emissions, with developed countries owing much of their prosperity to past carbon-intensive industrialization, relative to developing countries with historically and proportionately smaller carbon footprints and wealth.

To single out the effect on coordination of the introduced asymmetry, a “*Base*” treatment has been performed without such unequalizing redistribution. In it, subjects went through three inactive rounds where they all had no other option than to choose the intermediate contribution of €2 per round. These three inactive rounds might render the intermediate strategy more focal; for a more in depth discussion, refer to Section 2.2.

Finally, since in coordination games, communication is not simply ‘cheap talk’ but may have an important effect on the ability to coordinate, we implemented two treatments in which the subjects had the opportunity to make future commitment announcements. The “*Pledge*” treatment introduced two pledge stages to the symmetric case while the “*Pledge-Unequal*” treatment implemented two pledge stages in the asymmetric case. In both pledge treatments it was common knowledge that the pledges were nonbinding. The first pledge stage was after the (fixed) first three rounds. The subjects simultaneously and independently announced their intended contributions for the subsequent seven rounds. Afterwards the players saw the “intended climate account” which contained the individual contributions from the first three (inactive) rounds plus the individual pledges. Thereby they immediately detected whether the intended contributions would be sufficient to avoid catastrophic climate change. The second pledge stage took place after round seven. Similar to the first pledge, the players simultaneously and independently announced their intended contributions for the last three rounds and were subsequently informed about the “new intended climate account” that included past contributions and the pledges. Table S1 summarizes the key features of our experimental design and the number of participants in each session.

The experiment was run in May 2010 at the MaxLab laboratory at the University of Magdeburg, Germany. In total, 240 students participated in the experiment, whereby the pool consisted of a mixture of students with an economic or business major (60%) and students with a non-economic major (40%). Most of the students were experienced as they had participated in three or more experiments before (88%) while only few students were inexperienced (12%). Sixty subjects took part in each treatment. No subject participated in more than one treatment. Sessions lasted about 60 minutes. For each session, we recruited either 12 or 18 subjects. Each subject was seated at linked computer terminals that were used to transmit all decision and payoff information. We used the Z-tree software ( $S_4$ ) for programming. Once the individuals were seated and logged into the terminals, a set of written instructions were handed out. Experimental instructions (see Section 1.2) included a numerical example and control questions in order to ensure that all subjects understood the games. At the beginning of the experiment subjects were randomly assigned to groups of six. The subjects were not aware of whom they were grouped with, but they did know that they remained within the same group of players throughout the ten rounds. After the final round, the players were informed whether the group had successfully reached the threshold of

Treatment	Asymmetric players	Pledge stages	Probability of climate change	No. of subjects
<i>Base</i>	no	no	50%	60
<i>Pledge</i>	no	yes	50%	60
<i>Base-Unequal</i>	yes	no	50%	60
<i>Pledge-Unequal</i>	yes	yes	50%	60

Table S1: Summary of experimental design

€120. Afterwards they were asked to fill in a short questionnaire. The questionnaire was designed to elicit the players' impressions and motivation during the game (see Section 3.4). At the end of the experiment, one of two table tennis balls was publicly drawn from a bag by a volunteer student. If there was the number 1 on the ball, all players in the groups that had not reached the threshold kept the money (that was left on their private account). If there was the number 2 on the ball, these players lost their money. Out of the 20 groups which did not reach the threshold 11 groups were in good luck and kept their money while 9 groups were in bad luck and lost their money. No show-up fee was administered. On average, a subject earned €17.23 in the games; the maximum payoff was €40 and the minimum €0.

The money allocated to the climate account was used to buy and withdraw CO2 emission certificates traded in the European Union emission trading scheme (EU ETS, *S5*). If a group had successfully reached the threshold, all of the climate account money was used in this way. In case of a failing group only half of the climate account money was used for emission certificates. Thereby, we introduced a specific field context to the experiment which made the task more realistic and might have increased participants' motivation (although equally in all treatments). The experimental instructions contained a short explanation of the EU ETS and the above mentioned rules (see Section 1.2). We announced furthermore that the purchase and the suspension of certificates would be certified by a notary and that the overall amount of certificates and the notarial acknowledgment could be found at a permanent website (*S6*). Overall, we spent €3,248 for emission certificates which corresponds to 212 tons of CO2 given a price of 15.3 €/ton (*S7*).

## 1.2 Experimental instructions for the treatments *Pledge* and *Pledge-Unequal* (translated from German)

Welcome to the experiment!

### 1. General Notice

In this experiment you can earn money. To make this experiment a success, please do not talk to the other participants at all or draw any other attention to you. Please read the following rules of the experiment attentively. Should you have any questions please signal us. At the end of the instructions you will find several control questions. Please answer all questions and signal us when you have finished. We will then come to you and check your answers.

### 2. Climate Change

Now we will introduce you to a game simulating climate change. Global climate change is seen as a serious environmental problem faced by mankind. The great majority of climate scientists expect



the global average temperature to rise by 1.1 to 6.4 degrees Celsius until the year 2100. There is hardly any denial that mankind largely contributes to climate change by emitting greenhouse gases, especially carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> originates from burning of fossil fuels like coal, oil or natural gas in industrial processes and energy production, or combustion engines of cars and lorries. CO<sub>2</sub> is a global pollutant, i.e. each quantity unit of CO<sub>2</sub> emitted has the same effect on the climate regardless of the location where the emission has occurred.

### 3. Rules of Play

In total, 6 players are involved in the game, so besides you there are 5 other players. Every player faces the same decision making problem. At the beginning of the experiment you will receive a starting capital (= EUR 40) credited to your private account. During the experiment you can use money from your account or not. In the end your account balance will be paid out to you in cash. You will be making your decisions anonymously. To guarantee for this you will be assigned a nickname for the playing time. The nicknames are the moons of our solar system (Ananke, Telesto, Despina, Japetus, Kallisto or Metis). You will find your name on the lower left side of your screen. During the course of the experiment you will be playing exactly 10 climate rounds. In these rounds you can invest into the attempt to protect the climate and to evade dangerous climate change. Among others, dangerous climate change will result in significant economic losses which will be simulated in this experiment. In each climate round of the game all six players will be asked simultaneously:

*"How much do you want to invest into climate protection?"*

Possible answers are EUR 0, 2 or 4. Only when each player has made his choice, all decisions will be displayed simultaneously. After that the computer will credit all invested amounts to an account for climate protection ("climate account"). At the end of the game (after exactly 10 rounds) the computer will compare the climate account balance with a predetermined amount (= EUR 120). This amount must be earned to evade dangerous climate change. It will be earned if every player averagely pays EUR 2 per round into climate protection. If this is the case, EUR 12 are be paid into the climate account per round. If the necessary EUR 120 have been earned, all players will be paid out the amount remaining on their private accounts. The remaining amount consists of the starting capital of EUR 40 minus the sum paid into the climate account. If the necessary EUR 120 have not been earned, dangerous climate change will occur with a probability of 50% (in 5 out of 10 cases) and this will result in significant economic losses. If this probability arises you will lose all money left on your account and no one will be paid out anything. With another probability of 50% (in 5 out of 10 cases) you will keep your money and will be paid out the amount on your private account after the game. We will draw the probability by lot in your presence. The payout will be made anonymously. Your fellow players will not learn about your identity. Please note the following two particularities in the game: First, the decisions of the six players in the first three rounds are predetermined by the computer. Meaning, you - and your fellow players - cannot decide freely how much you want to invest into climate protection in the first three rounds. You will be offered an option instead which you have to choose.

Please note that the predetermined investments of the first three rounds will already change the amounts on the climate account and the players' accounts! Starting in round 4 you will decide freely which amounts you want to invest into climate protection. Second, all players can issue declarations of intent about how much they want to invest into climate protection in the following rounds. The declarations are not binding for the investment decisions in the following rounds. The first declaration of intent is issued after round 3. All players will simultaneously state how much

they plan to invest into climate protection in the next seven rounds in total. When all players have stated their declarations of intent, the “planned climate account” will be displayed. The planned climate account shows the investments of each player of the first 3 rounds plus the investments planned for the remaining seven rounds. After round 7 all players will be given the opportunity to revise their declarations of intent. All players then simultaneously state their planned total investments into climate protection for the next three rounds. When all players have stated their declarations of intent the “newly planned climate account” will be displayed. The newly planned climate account shows how much each player has already invested in the first seven rounds plus the planned investments for the remaining three rounds.

#### 4. Example

In this example you see the decisions made by the six players in one round ( 6).

geplantes Klimakonto		Investitionen		Investitionen	
Runden 1-10		Runden 1-6 insgesamt		Runde 6	
Ananke	20	Ananke	12	Ananke	0
Telesto	18	Telesto	12	Telesto	0
Despina	22	Despina	14	Despina	0
Japelus	18	Japelus	10	Japelus	4
Kallisto	20	Kallisto	12	Kallisto	4
Metis	14	Metis	8	Metis	4
<b>Gruppensumme</b>	<b>112</b>	<b>Klimakonto insgesamt</b>	<b>68</b>	<b>Gruppensumme Runde 6</b>	<b>12</b>

The column on the right side (“Investitionen Runde 6”) shows the investments made in the current round. Players Ananke, Telesto and Despina have not paid anything into the climate account, whereas players Japelus, Kallisto and Metis each have paid EUR 4. In total EUR 12 have been paid and by that been credited to the climate account. The column in the middle (“Investitionen Runden 1-6 insgesamt”) shows the total investments made by each player in rounds 1-6. Players Ananke, Telesto and Kallisto each have paid EUR 12 into the climate account in the first 6 rounds. Despina has paid EUR 14, Japelus EUR 10 and Metis EUR 8 in the first six rounds. By that a total of EUR 68 has been paid into the climate account.

The column on the left (“geplantes Klimakonto Runden 1-10”) shows the planned climate account after the first declaration of intent. The value stated per player shows the investments made in the first three rounds plus the planned investments for the remaining seven rounds. Exactly this information will be displayed after each climate round.

#### 5. Usage of the Money on the Climate Account

If the necessary EUR 120 have been earned to evade climate change, we will buy CO2 emission certificates of the total amount on the climate account and retire them. If the necessary EUR 120 have not been earned, we will use half of the amount on the climate account to buy CO2 emission certificates and retire them (we will keep the rest of the money). By purchasing and retiring the CO2 emission certificates we contribute to the abatement of climate change. We will now explain you how this works: In 2005 the European Union has implemented the emissions trading system for carbon dioxide (CO2). Emissions trading is the central instrument of climate policy in Europe. It follows a simple principle: The European Commission, together with the member states, has determined the amount of CO2 to be emitted altogether in the respective

sectors (energy production and energy intensive industries) until 2020. This total amount will be distributed to the companies by the state in the form of emission rights (“certificates”). For each quantity unit of CO<sub>2</sub> emitted, the company has to give a certificate to the state. The certificates can be traded between companies.

For each quantity unit of CO<sub>2</sub> emitted e.g. by a power plant, the plant operator has to prove his permission to do so in the form of a certificate. This leads to an important consequence: If the total amount of certificates is reduced, the total emissions will be lower, simply because plant operators do not possess enough emission allowances. That means if a certificate for one quantity unit is obtained from the market and is being “retired” (i.e. deleted) the total CO<sub>2</sub> emissions are reduced by exactly this quantity amount. The opportunity to retire certificates actually exists in the framework of the EU Emissions Trading System. In Germany the German Emissions Trading Authority (DEHSt) regulates Emissions trading. The authority holds a retirement account with the account number DE-230-17-1. If certificates are transferred to this account they will be withdrawn from circulation, i.e. deleted, by the end of each year. ZEW has opened an own account at the DEHSt (DE-121-2810-0). The purchasing and retiring of the certificates will furthermore be attested by a notary public. Summarizing: if all players have for example paid a total of EUR 120 into the climate account, we will buy certificates for about 8 tons of CO<sub>2</sub> (the price per ton is currently at about EUR 15). This equals the emissions of a ride in a VW Golf (1.4 TSI) one and a half times around the world.

#### 6. Control questions

If you have finished reading the instructions and do not have questions, please answer the following control questions.

a. Which total amount does each player have to averagely invest into climate protection in the 10 rounds to evade dangerous climate change (please tick the according box)?  EUR 12  EUR 20  EUR 40  EUR 120

b. Please assume that the necessary amount of EUR 120 to evade climate change has been earned and you have invested a total of EUR 16 in the 10 rounds. How much money will you be paid out? My payout is EUR \_\_\_\_\_.

c. In how many rounds can the players decide freely about their investments into climate protection (please tick the according box)?  in 3 rounds  in 5 rounds  in 7 rounds  in 10 rounds

d. Please refer to the example stated under point 4 for the numbers. What do the balances on Despina’s and Metis’ private accounts state? Despina’s balance states EUR \_\_\_\_\_. Metis’ balances states EUR \_\_\_\_\_.

e. Please refer to the example under point 4 again. How much would the group have to pay into the climate account in the next four rounds in total to abate dangerous climate change (please tick the according box)?  EUR 12  EUR 52  EUR 68  EUR 120

f. When do the players state their first declaration of intent and when can they revise this declaration? First declaration after round: \_\_\_\_\_. Revision after round: \_\_\_\_\_.

g. In your first declaration of intent after round 3 you are asked to state how much you want to invest in climate protection in the following seven rounds in total. If you want to invest averagely EUR 2 per round, which amount would you have to state in your declaration of intent (please tick the according box)?  EUR 2  EUR 12  EUR 14  EUR 20

h. Are the declarations of intent binding for the investment decisions in the following rounds (please tick the according box)?  Yes  No

i. Please refer to the example under point 4 again. What do the figures in the left column “Planned climate account” stand for (please tick the according box)?  the invested amounts of the first three rounds  the planned investments for the last seven rounds  the invested amounts of the first three rounds plus the planned investments for the last seven rounds

j. Please refer to the example stated under point 4 for the numbers again. Please assume that all players adhere to their declaration of intent (see “geplantes Klimakonto”). Would the investments be enough to evade dangerous climate change (please tick the according box)?  Yes  No

k. Please assume that the necessary amount of EUR 120 has not been earned. With which probability will you lose the remaining amount on your private account (please tick the according box)?  10%  30%  50%  70%  90%  100%

If you have answered all control questions, please signal us. We will come to you and check the answers. Once are no remaining questions, the game starts. Good Luck!

## 2 Supporting theoretical analyses

### 2.1 Game tradeoffs

As noted in S3, the multiplicity of equilibria in the game makes classification virtually impossible. The game utilized here is a modified n-person stochastic threshold public goods game, with a total of ten rounds of which only seven allow freedom of choice over the three possible actions.

For illustrative purposes, we provide a hypothetical scenario in Table S2. Assume the group has just completed round nine, with an aggregate contribution of €108 (i.e. they are on track); assume further that four players stick to €2 in round ten, unilaterally bringing the account to €116. If the two remaining players were convinced, say due to previous contribution patterns, that only the two of them would consider deviating from the intermediate €2 contribution in the last round, they would be facing the following figures:

	€0	€2	€4
€0	11* (116)	11* (118)	22 (120)
€2	10* (118)	20 (120)	20 (122)
€4	18 (120)	18 (122)	18 (124)

Table S2: End payoffs (and corresponding final climate account values in parentheses) to the *row player* given round-nine moves. Entries on or below the antidiagonal are certain, while the starred entries are expected values based on the 50% probability of account loss.

Ultimately, the decision depends largely, in this situation, on the degree of risk aversion and on mutual expectations. We argue that a third driver of behavior should not be overlooked, namely

moral heuristics. In particular, especially if previous departures from symmetric burden sharing introduced the need and led to altruistic acts by some of the players, inequity aversion might motivate the latter to refuse participation in an unfair outcome, even at a dear cost to them and the others. In our experimental setting, we expect these situations to arise more frequently in the treatments with initial unequalizing rounds, as they are likely to result in greater disparities among players (due to the constrained behavior in the early rounds).

Inequity aversion may be determinant in guiding the decision based on Table S2-type of scenarios. If for example a player is risk-averse but strongly resists disadvantageous inequity (has a high  $\alpha$  parameter, in the terminology of *S8*), he or she will be unwilling to compensate for the actions of the risk-seeker(s).

Let's return to the above example in order to evaluate how inequity aversion may steer the end result towards successful or unsuccessful coordination. In its absence, a risk-seeking player believing the opponent to be risk-averse (i.e. placing a high probability on his/her choosing the high round contribution of €4), might be inclined to take a chance and choose €0 in the last round. Symmetrically, a risk-averse individual, say the column player, fearing to see the certainty of a gain jeopardized as a result of free-riding, may well opt for contributing €4. In that case, the two contributions would offset each other and €120 would be reached (top right entry in Table S2). This situation is reminiscent of the snow drift game, which differs from the prisoner dilemma game in that unilateral action, while not as desirable as shared cooperation, still provides a benefit to its pursuer (*S9*). However, if risk aversion is dominated by inequity aversion, the column player may choose either the €2 or the €0 contribution, if believing row player to free-ride, thus leading to the highly inefficient outcome represented by the top left and top middle cells. Highly inefficient since they do not guarantee certainty of success, notwithstanding the substantial contributions, which on average are close to €2/round per player.

## 2.2 Impact of the computerized rounds

As discussed above, in two symmetric treatments the players witness three rounds of unavoidable €2 contributions, while in the remaining two asymmetric treatments the players undergo three unequalizing rounds resulting in half of the group being wealthier than the remaining half. At the group level, independent of the treatment, they contribute €36 to the public good before round four begins, keeping them on track with respect to the threshold. What is the impact of this mechanism on the attainable game equilibria? First of all, it makes the achievement of the threshold collectively optimal as otherwise the already invested €36 would have been wasted.

At the risk of oversimplifying the complexity of the 6-person, 10-round game, we present payoff matrices in Table S3, with the aim to highlight some key characteristics of the game in (*S3*) and in the present work. The left matrix concerns the former, while the centre and right matrices respectively summarize the outcome of interactions in the symmetric and asymmetric games introduced here. For the sake of presentational clarity, we have simplified the analysis by assuming that two subgroups of three players choosing the same strategy form, effectively reducing the type of interactions to those present in the familiar 2x2 formulation. That is, the three players in each subgroup act identically, as if they tacitly coordinated on the same choices. Moreover, in Table S3 players can only choose between either free-riding in all active rounds (no contributions), or always contributing the intermediate amount of €2/round (*S10*). This simplification allows analyzing the game as if it was a one shot game, where people simultaneously reason on the outcome from

		Fair	Selfish			Fair	Selfish			Fair	Selfish
Fair		20, 20 (120)	10*, 20* (60)	Fair		20, 20 (120)	10*, 17* (78)	Fair		14, 26 (120)	7*, 20* (78)
	Selfish	20*, 10* (60)	20*, 20* (0)		Selfish		17*, 10* (78)		17*, 17* (36)	Selfish	

Table S3: A coordination game situation: end payoffs (and corresponding final climate account values in parentheses). Selfish refers to the strategy of giving €0 in each of the active rounds (10 rounds in the left matrix, 7 in the remaining two), Fair to giving €2/active round. While all matrices are based on an initial endowment of €40, in the games introduced here the endowment before round 4 is either €34 for all players (centre matrix), or alternatively €28 for “poor” row players and €40 for “rich” column players (right matrix). Payoffs above the antidiagonal are certain, while the starred entries are expected values based on the 50% probability of account loss.

picking one of two strategies leading to the corresponding group level Nash equilibria (keeping in mind the above discussion on the no longer attainable Nash equilibria).

Comparing the three cases, we notice that, when choosing between no contribution and the intermediate contribution in the respective games, best response behavior leads to two pure strategy Nash equilibria where all players coordinate on either the free-riding or the intermediate €2 strategy, irrespective of which matrix we consider. However, while in the left matrix both are payoff equivalent, with the €2/round equilibrium being a weak Nash equilibrium and the €0/round equilibrium being strict, in the symmetric game in the centre of Table S3 the intermediate contribution equilibrium is payoff dominant (and both are strict). Lastly, in the asymmetric one, the intermediate contribution equilibrium is again payoff dominant, although it is weak, unlike the no contribution equilibrium which is strict. This analysis confirms that the games experimentally tested here can be seen as coordination games of the Stag Hunt kind, with the trade-off between social cooperation and safety being represented by the more rewarding €2/round strategy versus the safer €0/round strategy, which does not require coordination to succeed (*S11*).

Variables	Marg. Eff. (robust SE)	Marg. Eff. (robust SE)	Marg. Eff. (robust SE)	Marg. Eff. (robust SE)
<i>Base</i>	-0.100 (0.224)	0.320 (0.211)	-0.205 (0.218)	
<i>Pledge</i>	0.108 (0.230)	0.483*** (0.174)		0.205 (0.220)
<i>Base-Unequal</i>	-0.400** (0.187)		-0.479*** (0.168)	-0.318 (0.206)
<i>Pledge-Unequal</i>		0.404** (0.194)	-0.107 (0.229)	0.101 (0.224)
No. of observations	240	240	240	240

Table S4: Probit estimation of treatment effects. Dependent variable: success of player’s group. Numbers are marginal effects at the mean of the independent variables. Robust standard errors in parentheses (clustered at group level). Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

### 3 Supporting empirical analyses

#### 3.1 Contribution trajectories

What is not captured in the treatment-wise comparisons of success rates in public good provision (Fig. 1 in the main text, Table S4 and Table S7) is the difference in behavior between failing groups, which sheds light on the motivation (or lack of thereof) to provide the public good of climate protection. While in *Base* and *Pledge* failing groups provided only €70 and €62.7 respectively, failing groups participating in *Base-Unequal* and *Pledge-Unequal* contributed a remarkable €95.5 and €88, despite the lower success rate in the latter two (-30% in *Base-Unequal* w.r.t. *Base*, and -10% in *Pledge-Unequal* w.r.t. *Pledge*). This evidence, together with questionnaire analysis, suggests that the role of the asymmetric endowments is to render coordination more complex. However, the increased failure rate is not simply the result of a decision by a larger proportion of group members to opt for a no contribution strategy in the hope of high earnings. Many groups in these two treatments clearly tried to reach the €120 threshold until the last rounds, therefore increasing average contribution relative to the failing groups in *Base* and *Pledge*, who often behaved as if they tacitly agreed on gambling with the probability, due to low contributions in the early rounds. In fact 6/8 failing groups (75%) in *Base* and *Pledge* combined provided  $\leq$  €70, while in the corresponding asymmetric treatments only 2/12 failing groups (17%) provided  $\leq$  €70. In other words, the inequality undermined the groups’ ability to effectively coordinate on the prevention of simulated climate change damage, rather than their motivation, which is actually higher than in symmetric treatments.

#### 3.2 Contribution dynamics and role of pledges

Taking a closer look at *Base-Unequal*, an analysis of the dynamics of contributions provides a perspective on the patterns behind the high number of failures that characterized this treatment. Fig. S1 shows, for all treatments, the instances of €0, €2 and €4 contributions, respectively, in a given round. Note that, in order to have comparable figures, round four is not considered in the chart, which instead focuses on contributions in rounds five to seven and eight to ten.

The trend shaping in *Base-Unequal* between early and later rounds is quite pronounced: no contribution instances increase on average by 32%, intermediate contributions decrease by 14% and high contributions drop by 21% in the last three rounds. This account explains the almost ubiquitous coordination failure among participants: no contribution instances increase over time,

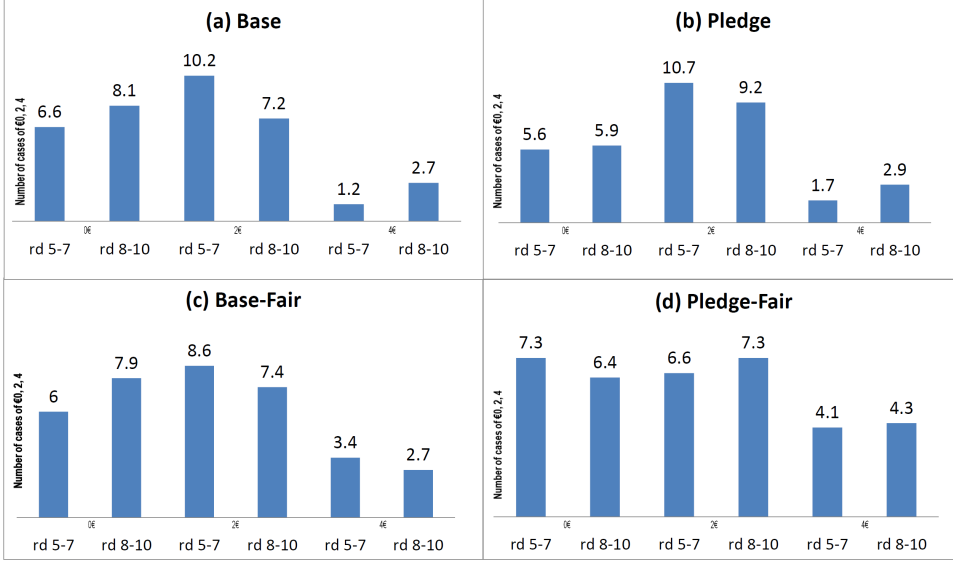


Figure S1: Contributions in early and late rounds. Amounts invested in rounds 5-7 and 8-10 to protect climate in: (a) *Base*; (b) *Pledge*; (c) *Base-Unequal*; (d) *Pledge-Unequal*

while both intermediate contributions and high contributions decrease over time, leaving little scope for catching up in the final rounds.

Unsurprisingly, the two treatments characterized by the highest success rate, *Pledge* and *Pledge-Unequal*, owe much of it to the different dynamics, since contributions in round four were similar across all treatments. Let us consider *Pledge* first: the 70% success rate is the result of maintaining the number of no contributions relatively constant, having a high number of intermediate contributions, and compensating the intermediate contributions decline with a 71% increase in high contributions in the last three rounds.

Let us now take a closer look at the dynamics in *Pledge-Unequal* and *Base-Unequal*, since both are subject to three unequalizing rounds at the beginning. Although the number of no contributions in *Pledge-Unequal* is higher in rounds five to seven relative to *Base-Unequal*, the number of selfish acts did reduce to 6.4 in the last three rounds. For what concerns the €2 count, the differences are not stark, as in the six rounds combined the *Pledge-Unequal* participants chose this contribution level close to 14 times, while the *Base-Unequal* participants chose it 16 times. What ultimately proved to be determinant for success were the number of high contributions, which in several instances sufficed to offset the no contributions. We read this as improved coordination stemming from a commitment that, while nonbinding, nevertheless was an important vehicle of intentions among the participants. As noted before, such “lubricant of coordination” was particularly effective in the presence of inequalities, which presumably increased the complexity of coordination by bringing fairness issues to the table, with potentially contrasting interpretations over the moral obligations stemming from them (see Section 3.3). It should be noted that the subjects took seriously the opportunity to express their planned contributions. In *Pledge-Unequal*, for instance, the average contributions are almost identical to the corresponding pledges: between round four and round ten, contributions amounted to €72 and pledges to €71; in the last three rounds, contributions amounted to €31.8 and pledges to €32.6.

As illustrated in Fig. 2 in the main text, the pledges were determinant for the success rate. The value -0.0397 of Pledge gap rd. 4-10 in Table S5 means that, at the mean of all three independent



Variables	Marg. Eff. (robust SE)
<i>Pledge-Unequal</i>	-0.244 (0.197)
Pledge gap rd. 4-10	-0.0397*** (0.0129)
Pledge gap rd. 8-10	-0.0629** (0.0299)
No. of observations	120

Table S5: Probit estimation of pledge effects (Fig. 2). Dependent variable: success of player’s group. Numbers are marginal effects at the mean of the independent variables, robust standard errors in parentheses (clustered at group level). Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

variables, an increase by 10€ in the difference between cumulative contributions and pledges in rounds 4 to 10 reduces the probability of being in a successful group by about 40%. Similarly, an increase by 10€ in the difference between cumulative contributions and pledges in rounds 8 to 10 reduces the probability of being in a successful group by about 63%.

So far we have only tangentially discussed contributions in the first active round of play, namely round four. While, as noted above, variation across treatments is limited, an interesting aspect is whether there are marked differences between average round four contributions in failing groups with respect to successful ones. The answer is yes (see also the main text): in all treatments success in the entire game is highly linked to contributions in round four. The twenty groups that were able to coordinate to protect the climate had average individual contributions of €1.9 (corresponding to €11.4 at the group level), while the remaining twenty groups had initial individual provisions of €1.2 (corresponding to €7.3 at the group level). We therefore conjecture that the first actions carry an important weight as they signal the members’ commitment in taking quantifiable efforts early on. In terms of feasible trajectories to reach the €120 target, this difference is a small burden, as it only takes slightly more than one contribution of €4 in the ensuing six rounds to compensate the gap accumulated in round four between successful and unsuccessful groups. Yet, we argue that this lack of early initiative has deep symbolic value and explains the resulting differences in success rate.

### 3.3 Inequality

We have seen that inequality impeded coordination among the players. Now we will analyze in more detail how the groups in the asymmetric treatments *Base-Unequal* and *Pledge-Unequal* handled the inequality and compare the handling between groups which successfully reached the threshold and groups which did not. The successful groups were strikingly effective in eliminating inequality (Fig. 3 in the main text). Both the rich players and the poor players contributed on average €20 to the climate account. Thereby, 92% of the rich players and also 92% of the poor players gave €20 or more. In case of failure, we do not consider the groups that abandoned the ship and decided to gamble but only the groups that actually tried (but failed) to reach the target. In these groups, the poor players paid on average €21 into the climate account while the rich players gave only €16. Thereby, 83% of the poor players but only 28% of the rich players paid €20 or more. However, the rich players did not completely refuse to invest. The majority (83%) invested €14 or more. That means they were willing to reduce but not to eliminate inequality. The poor players on the other

hand were not willing to accept inequality. Obviously the rich and the poor had different views on what is the appropriate contribution for each type of player. In the end, the persistence in their different viewpoints was crucial and caused the shipwreck of the group. The pledges appeared to be of great help in mitigating these differences since in the *Pledge-Unequal* treatment 75% of the groups managed to eliminate inequality and reach the target while in the *Base-Unequal* treatment only 33% of the groups managed to do so. We come back to this point in the next section, which discusses the questionnaire data.

### 3.4 Questionnaire

After the experiment subjects were asked to fill in a questionnaire about the motivation for their contribution decisions during the game and their general opinion about climate change (see Table S6).

The summary statistics of the players' motivation for their contribution decisions during the game is somewhat complicated because on the one hand we used open questions to elicit the motives and on the other hand the motives obviously depend on the respective group performance. The qualitative categorization of responses reveals that the majority of players is primarily motivated by the achievement of the threshold (43%), fairness considerations (18%), material self-interest (15%), and the past group performance (14%). Understandably, the poor players in the asymmetric treatments *Base-Unequal* and *Pledge-Unequal* care more about fairness than the rich players (22% versus 15%) and more about the past group performance (27% versus 14%). About 6% of all subjects state that they are particularly motivated by the climate protection realized through the purchase and retirement of the CO2 certificates. In the final round the players are primarily motivated by the achievement of the threshold (42%), material self-interest (18%), the hopelessness to reach the threshold (14%), and fairness considerations (11%). The self-reported motives are in line with the actual behavior in the game, e.g. people stating that fairness was the most important reason often contributed €20 to the climate account while people stating the self-interest was their primary motive mostly gave less than €20. The self-reported motives furthermore help to understand why some groups did not reach the threshold. Comparing the successful groups that reached the threshold and the groups that did not, fairness considerations were more important for the successful groups (23% versus 13%) as well as the achievement of the target (52% versus 35%) while self-interest (9% versus 20%) and the past group performance (8% versus 21%) were less important.

In order to elicit players' fairness perceptions, the subjects in the asymmetric treatments were asked whether they agree with the following statement: "Those who began in round 4 with a starting capital of €40 should pay more into the climate account in the following seven rounds than the other players". Overall, 76% of subjects agree with that statement, 10% disagree, and 14% neither agree nor disagree. However, there are significant differences between poor and rich subjects: out of the poor players, 90% agree, 5% disagree and 5% do neither of them while out of the rich players only 62% agree, 15% disagree and 23% do neither of them. In another question, subjects were asked "What would you consider a fair average investment for the last seven (active) rounds for those beginning with €40 and for those beginning with €28?" Possible answers include €0, €1, €2, €3, and €4. Almost all of the poor players (95%) perceive €3 as the fair amount for the rich players while only 72% of the rich players share this perception. Similarly, only 23% of the poor players perceive €2 as the fair average contribution for the poor players while 42%

of the rich players state that this would be the fair amount. These specific amounts (€3 for the rich and €2 for the poor) are relevant because they reflect the application of the different equity principles. In order to equalize the players' contributions and payments the rich should contribute €20 in the active rounds, i.e. on average €3 per round; conversely, if the past actions were to be discounted and only contributions in active rounds mattered, all players (including the poor) would be expected to give €2 in each round.

Question	Answer	No.	%	
(1) Do you agree with the following statement? "Those who began in round 4 with a starting capital of EUR 40 should pay more into the climate account in the following seven rounds than the other players."	Agree	91	75.83	
	Disagree	12	10.00	
	Neither	17	14.17	
(2) Please assume that three players of a group begin in round 4 with a starting capital of EUR 40 (because they have not paid anything into the climate account yet) whereas the other three players begin with a starting capital of EUR 28 (because they have paid EUR 4 into the climate account in each of the first three rounds).	What would you consider a fair average investment for the following seven rounds for those beginning with EUR 40?	0	2	0.83
	1	2	0.83	
	2	30	12.50	
	3	190	79.17	
	4	16	6.67	
	What would you consider a fair investment for the following seven rounds for those beginning with EUR 28?	0	9	3.75
	1	143	59.58	
	2	85	35.42	
(3) Please imagine the following situation: You have EUR 40. With a probability of 50 % you will lose all EUR 40. You could avoid the risk by giving away EUR 20 of the EUR 40. Would you pay EUR 20 to avoid the risk?	Yes	165	68.75	
	No	22	9.17	
	Indifferent	53	22.08	
(4) Please briefly describe the three most important reasons for your investment decisions in a descending order of importance. Possible examples are:				
- Group or own investments in the preliminary round,				
- Cumulated group or own investments starting in round 4,				
- Cumulated group or own investments starting in round 1,				
- Monetary self-interest,				
- Fairness consideration,				
- Achievement of the EUR 120 limit,				
- Adherence to declarations of intent,				
- Other reasons (please state).				
(5) What has been your motivation for your investment decision in the last round (round 10)? Please state your three most important reasons in a descending order of importance (for possible answers see previous question)				
(6) If you were to play the game again, would you make different decisions? Please state your three most significant changes in a descending order of importance.				
		$\Sigma$ 240	100.00	

Notes: Question 1 was asked in the asymmetric treatments *Base-Unequal* and *Pledge-Unequal* only. Question 2 was asked in all treatments; therefore it was hypothetical in the symmetric treatments *Base* and *Pledge* while it was real in the asymmetric treatments. No responses are provided for the open questions 4-6.

Table S6: Selected questions and responses from Questionnaire (translated from German)

A determinant of the subjects' willingness to invest in the public good was the presence of individuals who would overcome self-interest considerations. In Table S7 we report the results of regression analysis on the impact of some of the answers in Table S6 on contributions to the public good. Questions 4 and 5 in the former asked to describe the three most important reasons for subjects' investment decisions, over the entire game and in the last round, respectively. Having chosen altruistic compensation for free-riders as motivation for the contribution decision in round 10 positively and significantly explains players' average contributions over all rounds (variable "Altruism rd. 10" in Table S7,  $n=240$ ,  $P<.0001$ ). Conversely, if individuals were motivated by self-interest, both generally and when deciding the last round contribution, game contributions decreased ( $n=240$ ,  $P=.0006$  and  $P<.0001$  respectively). A similar negative effect arose when the

Variables	OLS	Tobit
	Coeff. (robust SE)	Coeff. (robust SE)
<i>Pledge</i>	1.107 (1.205)	1.110 (1.170)
<i>Base-Unequal</i>	1.169 (0.898)	1.132 (0.880)
<i>Pledge-Unequal</i>	1.237 (1.084)	1.202 (1.071)
Fair contribution (Q2a)	1.068 (0.639)	1.056* (0.622)
Risk seeker (Q3)	-6.686*** (1.357)	-6.815*** (1.382)
Risk neutral (Q3)	-1.614*** (0.546)	-1.614*** (0.535)
Self-interest (Q4)	-2.913*** (0.838)	-2.898*** (0.824)
Abandon ship (Q4)	-4.647*** (1.398)	-5.055*** (1.710)
Self-interest rd. 10 (Q5)	-4.107*** (0.747)	-4.094*** (0.731)
Abandon ship rd. 10 (Q5)	-6.328*** (0.855)	-6.330*** (0.833)
Altruism rd. 10 (Q5)	4.954*** (1.129)	4.927*** (1.104)
Constant	16.11*** (2.337)	16.16*** (2.270)
No. of observations	240	240

Table S7: Linear regression of individual contributions. Dependent variable: Player’s cumulative contributions over rounds 1-10. Tobit is bounded between 0 and 40. Robust standard errors in parentheses (clustered at group level). Significance: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

primary motivation for contribution decisions was identified as a belief that the €120 threshold would not be reached both generally and when deciding the last round contribution ( $n=240$ ,  $P=.0010$  and  $P<.0001$  for variables “Abandon ship” and “Abandon ship rd.10” respectively).

Lastly, we visualize the effect of risk aversion as elicited in question 3 on players’ overall contributions in Fig. S2: as expected, contributions increase with risk aversion.

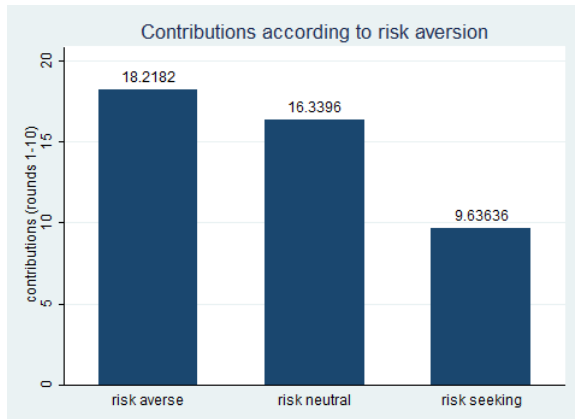


Figure S2: Mean investment in avoiding simulated dangerous climate change declines when the subjects are more prone to “gambling for global goods”

## Notes and references

- S1.** J. Ledyard, in *Handbook of Experimental Economics*, J. H. Kagel, A. E. Roth, Eds. (Princeton Univ. Press, Princeton, NJ, 1995), pp. 111-194.
- S2.** Scott Barrett theoretically examines what happens if these (and other) conditions do not apply. For preliminary results (accessed December 19, 2010), see <http://cbey.research.yale.edu/uploads/Environmental%20Economics%20Seminar>
- S3.** M. Milinski, R. D. Sommerfeld, H.-J. Krambeck, F. A. Reed, J. Marotzke, The collective-risk social dilemma and the prevention of simulated dangerous climate change. *Proc. Natl. Acad. Sci. U.S.A.* **105** 2291-2294 (2008).
- S4.** U. Fischbacher, Z-tree: Zurich toolbox for ready-made economic experiments, *Exp. Econ.* **10**, 171-178 (2007).
- S5.** For information about the EU ETS, the European Commission official website can be found at [http://ec.europa.eu/environment/climat/emission/index\\_en.htm](http://ec.europa.eu/environment/climat/emission/index_en.htm).
- S6.** [http://www.zew.de/en/topthemen/meldung\\_show.php?LFDNR=1517&KATEGORIE=2](http://www.zew.de/en/topthemen/meldung_show.php?LFDNR=1517&KATEGORIE=2)
- S7.** For emission certificate prices visit <http://www.eex.com/en>. We thank UniCredit Bank AG, Germany for assistance in the certificate purchase.
- S8.** E. Fehr, K. Schmidt, A Theory Of Fairness, Competition, And Cooperation. *Q. J.Econ.* **114**, 817-868 (1999).
- S9.** R. Kümmerli, *et al.*, Human cooperation in social dilemmas: comparing the Snowdrift game with the Prisoner’s Dilemma, *Proc. R. Soc. B* **274**, 2965-2970 (2007).
- S10.** Note that, while the all fair-sharer equilibrium is present in all three matrices (top-left cells), the one where all players choose the selfish act in each of the ten rounds (bottom-right cell in the first matrix) is not preserved in either of the games introduced here. Put differently, due to the introduction of the computerized rounds, the €0 contribution is no longer attainable in the remaining two matrices.

**S11.** B. Skyrms, The stag hunt. Presidential address of the pacific division of the american philosophical association. *Proc. Addresses A.P.A.* **75**, 31-41.