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Coordinating to Protect the Global Climate: Experimental Evidence on the Role of Inequality and Commitment

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Non-technical summary

In the aftermath of the climate conference in Copenhagen in December 2009 (15th Conference of the Parties of the United Nations), two issues appear to have played a determinant role in the negotiation discourse in protecting the global climate. First, different views on fairness considerations in sharing the burden of the greenhouse gas mitigation costs: Developed countries are historically the main contributors to climate change, while in some newly industrializing economies, notably China, emissions grow at an unprecedented rate. What is a fair way to share the responsibilities among developing and developed countries in the containment of global emissions? In international climate policy, different notions of equity have been proposed supported by different countries. The lack of consensus on equity principles has informed much of the exchanges between the United States and China. These two largest emitters worldwide have managed to stay clear of binding commitments to date. Second, coordination difficulties are displayed by the many participants to the climate negotiations: The Copenhagen Accord has introduced a nonbinding "pledge and review" mechanism where individual countries define voluntary emission reduction targets to reduce greenhouse gas emissions before 2020. Can this emergent institution prove successful as a first stage to achieve the required global coordination?

Against this background, this paper is concerned with the drivers of cooperation among groups of unrelated individuals faced with a coordination game requiring multilateral effort in order to reach a target and avoid losses to all members. Free riding and coordination difficulties are held to be the primary causes of cooperation breakdown among nonrelatives. These thwarting effects are particularly severe in the absence of effective monitoring institutions capable of sanctioning deviant behavior. A growing literature however stresses the importance of non-economic factors in explaining human behavior; therefore, instruments that go beyond the traditional incentives might prove effective in facilitating the task.

Given the empirical nature of the problem, we address it by means of a controlled laboratory experiment. To this end, we extend an experiment regarding a framed threshold public goods game with distinctive elements such as inequality and commitment as salient features of the ongoing debate over how best to share the "common but differentiated responsibilities" of climate change. We have built upon the game proposed by Milinski et al. (2008) to explore these further aspects that were not captured by the original design, and that we deem important both at the theoretical and policy level. The experimental results show that the real-world features introduced in the game have deep consequences on the cooperation level. Both claims that the inequality disrupts and the commitments help coordination are supported by the data. Thereby the experiment clearly shows the conditions under which subjects effectively coordinate their efforts to avoid the climate catastrophe: All successful groups agreed on a common equity notion and eliminated inequality while failing groups often disagreed about the reduction of inequality. In that context, the announcement of unbinding targets is particularly helpful to solve the coordination problem.

Das Wichtigste in Kürze

In der letzten Klimakonferenz in Kopenhagen im Dezember 2009 (15. Conference of Parties of the United Nations) haben zwei Dinge eine entscheidende Rolle für den Verhandlungsverlauf gespielt: Erstens, unterschiedliche Ansichten über die Anwendung von Fairnessprinzipien zur Verteilung der Lasten des Klimaschutzes: Die Industrieländer sind hauptverantwortlich für die historischen Treibhausgasemissionen. In den rasant wachsenden Schwellenländern wie China steigen die Emissionen jedoch in einem nie da gewesenen Tempo. Was wäre angesichts dieser Entwicklungen eine faire Verteilung der Lasten? In den Klimaverhandlungen haben unterschiedliche Länder sehr unterschiedliche Vorstellungen über die faire Verteilung. Dieser fehlende Konsens spiegelt sich sehr deutlich in den Position der beiden größten Emittenten, die Vereinigten Staaten und China, wider, die sich beide bislang geweigert haben, einem verbindlichen internationalen Abkommen beizutreten. Zweitens, im Nachgang von Kopenhagen haben viele Länder konkrete Reduktionsziele verkündet, welche jedoch unverbindlich sind. Hier stellt sich die Frage, ob diese unverbindlichen Ankündigungen die Koordination der nationalen Anstrengungen zur Lösung des globalen Klimaproblems verbessern können.

Vor diesem Hintergrund beschäftigt sich die vorliegende Arbeit mit den Determinanten von Kooperation in einer Situation, in der sich eine Gruppe von Individuen auf ein Ziel koordinieren muss, um einen Verlust für alle Mitglieder zu vermeiden. Freifahreranreize und Koordinierungsprobleme werden als die Hauptursache für das Scheitern internationaler Kooperation angesehen, vor allem wenn keine glaubwürdigen Bestrafungsmechanismen bei abweichendem Verhalten zur Verfügung stehen. Die verhaltensökonomische Literatur hat jedoch auch gezeigt, dass Menschen sich nicht immer gemäß der Standardtheorie verhalten und dass auch nicht-ökonomische Anreize einen Effekt auf Koordination und Kooperation haben können.

Da es sich hierbei vor allem um empirische Fragen handelt, nutzen wir für die Analyse ein ökonomisches Laborexperiment. Dieses baut auf einem Öffentlichen-Gut-Spiel mit Zielschwellenwert von Milinski et al. (2008) auf und erweitert es um zwei Aspekte, die in der Klimapolitik eine zentrale Rolle spielen: Erstens unterscheiden sich die Akteure hinsichtlich ihres Vermögens und ihrer Verantwortung hinsichtlich ihrer historischen Emissionen. Zweitens haben die Akteure die Möglichkeit unverbindliche Reduktionsziele zu verkünden. Das Experiment bestätigt die theoretischen Hypothesen: Die Ankündigung von Reduktionszielen fördert und die Ungleichheit erschwert die Koordinations- und Kooperationsfähigkeit. Die Ergebnisse zeigen dabei deutlich die Bedingungen, die für effektive Koordination erfüllt sein müssen: Alle Gruppen, die sich erfolgreich auf das vorgegebene Ziel koordiniert haben, einigten sich auf ein gemeinsames Fairnessprinzip und lösten die vorhandene Ungleichheit komplett auf. Gescheiterte Gruppen dagegen konnten sich oftmals nicht einigen, in welchem Maß die vorhandene Ungleichheit vermindert werden sollte. In diesem Kontext war die Möglichkeit, Reduktionsziele anzukündigen, sehr erfolgreich bei der Lösung des Koordinierungsproblems.

Coordinating to protect the global climate: experimental evidence on the role of inequality and commitment*

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Abstract

Free riding and coordination difficulties are held to be the primary causes of cooperation breakdown among nonrelatives. These thwarting effects are particularly severe in the absence of effective monitoring institutions capable of sanctioning deviant behavior. Unfortunately, solutions to global environmental dilemmas, like climate change, cannot depend on coercion mechanisms, given the transnational effects of emissions. A further complication is that it yields "common but differentiated responsibilities". Such asymmetries in wealth and carbon responsibilities among the actors, and the ensuing issues of equity, might further impede cooperation. Yet, a growing literature stresses the importance of non-economic factors in explaining human behavior; therefore, instruments that go beyond the traditional incentives might prove effective in facilitating the task. Given the empirical nature of the problem, we address it by means of a controlled laboratory experiment: a framed threshold public goods game is used to investigate the degree of cooperation and coordination achieved by groups of six participants in combating simulated catastrophic climate change. While necessarily simple for the sake of tractability, the game is designed to incorporate key real-world issues, such as inequity and the impact of emergent institutions based on nonbinding "pledge and review" mechanisms.

JEL Classification: C72, C92, Q54 Keywords: experimental economics, threshold public goods game, climate change, inequality, pledge

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1 Introduction

In the aftermath of the 15th Conference of the Parties of the United Nations (COP 15), which took place in Copenhagen in December 2009, two issues appear to have played a determinant role in the negotiation discourse in protecting the global climate.

First, different views on fairness considerations in sharing the burden of the greenhouse gas (GHG) mitigation costs: Developed countries are historically the main contributors to climate change, while in some newly industrializing economies, notably China, GHG emissions grow at an unprecedented rate. What is a fair way to share the responsibilities among developing and developed countries in the containment of global GHG emissions? In international climate policy, different notions of equity have been proposed: For example, the egalitarian rule incorporates the principle of equal per capita emissions, the sovereignty rule postulates the principle of equal percentage reduction of current emissions, the polluter-pays rule incorporates the principle of equal ratio between abatement costs and emissions, and the ability-to-pay rule stipulates the principle of equal ratio between abatement costs and GDP. The lack of consensus on equity principles has informed much of the United States-China exchanges on who is to be the first mover in the emission reduction game. Advocating the other country was to take the lead in terms of timing and magnitude of GHG reductions on the grounds of reciprocity considerations, the two largest emitters worldwide (each accounts for roughly one fifth of energy related global CO2 emissions) have managed to stay clear of binding commitments to date.

Second, different proposals to achieve the global cooperation required by the global warming problem given the strategic nature of the interactions between sovereign countries that need to coordinate to resolve it. These coordination difficulties are displayed by the many participants to the climate negotiations. The Copenhagen Accord has introduced a nonbinding "pledge and review" mechanism where individual countries define voluntary emission reduction targets to reduce GHG emissions (or a correlated measure such as the carbon intensity of output) before 2020. Can this emergent institution prove successful as a first stage to achieve the required global cooperation? Some 100 countries have already associated themselves with the Accord, of which 75 have also issued domestic goals for mitigation actions by 2020.

Against this background, this paper is concerned with the drivers of cooperation among groups of unrelated individuals faced with a coordination game requiring multilateral effort in order to reach a target and avoid losses to all members. Free riding and coordination difficulties are held to be the primary causes of cooperation breakdown among nonrelatives. These thwarting effects are particularly severe in the absence of effective monitoring institutions capable of sanctioning deviant behavior. Unfortunately, solutions to global environmental dilemmas, like climate change, cannot depend on coercion mechanisms, given the transnational effects of emissions. A further complication is that addressing climate change requires large scale cooperation, due to the ineffectiveness of unilateral action in the face of the global nature of the problem. A growing literature however stresses the importance of non-economic factors in explaining human behavior; therefore, instruments that go beyond the traditional incentives might prove effective in facilitating the task.

Given the empirical nature of the problem, we address it by means of a controlled laboratory experiment. To this end, we extend an experiment regarding a framed threshold public goods game with distinctive features such as the climate change game in order to take into account inequality and commitment as salient features of the ongoing debate over how best to share the "common but differentiated responsibilities" of climate change. We have built upon the game proposed by Milinski et al. (2008) to explore these further aspects that were not captured by the original design, and that we deem important both at the theoretical and policy level.[1] The original game introduced two salient and distinguishing characteristics of the individuals' attitude towards risk and time. On the risk–aversion side, it sets itself apart from commonly studied public goods games, as it involves investing in a public good (climate protection) in order to avoid a loss (hazardous climate change), rather than realizing a gain. Concerning the time dimension, a relevant trait of the climate problem is the tension between avoiding incurring immediate mitigation costs by not contributing to the public good today, and the long-term preference for a sound environment.

Our focus here is on two further aspects that are, to our knowledge, absent in the experimental literature: *First*, we explicitly consider how the game is perceived in the presence of an asymmetric geometry for sharing the burdens of mitigation; that is, differences in the endowments originating from contributions (or lack of thereof) in the initial rounds of play are introduced in two treatments to convey the idea of differential wealth and responsibilities to players. Such asymmetries in wealth and carbon responsibilities among the actors, and the ensuing issues of equity referred to in the Framework Convention on Climate Change – "parties should act to protect the climate system" "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities" (UNFCCC, Article 3.1), might further impede coordination. *Second*, we empower players with the ability to make nonbinding pledges before the actions are chosen. This is reminiscent of the current climate negotiations where individual nations can make pledges in an uncoordinated manner. While these announcements do not carry any enforceable commitments with them, we postulate that they may facilitate the coordination among players.[2]

The experimental results show that the real-world features introduced in the game have deep consequences on the coordination level. Both claims that the inequality disrupts and the pledges help coordination are supported by the data. 70% of the groups provided the public good in the symmetric treatment with pledges, relative to 50% in the corresponding treatment without pledges; 60% successful cooperation is obtained in the asymmetric treatment with pledges, while only 20% is obtained in the corresponding treatment without pledges.

The paper is structured as follows: Section 2 provides a brief discussion of related literature along with the design of the present experiment, while Section 3is concerned with its theoretical underpinnings, followed by a section displaying the main results. Section 5 draws some concluding remarks.

[1] Refer to Section 2 for details about the original game and the one proposed here.

[2] See Bernasconi et al. (2010) for an experimental investigation of the role of expressive obligations in public good provision.

2 Experimental Design

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 (see e.g. Ledyard, 1995). 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, in order to create a setting which incorporates realistic issues faced by climate change negotiators. 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 (€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 the groups taking part in the game have consequences that are not deterministic. If they collectively fail to reach the target required to provide the climate protection public good, 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 their contributions.[3]

The probability of the climate catastrophe was chosen in the light of the results of the experiment by Milinski et al. (2008), which shares with us the above departures from standard public good games, 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, Milinski and his co-authors implemented the above setup, with individuals deciding on 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 probability 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, cooperation was highest and half of the participating groups where successful in collecting at least €120, while only one group out of ten succeeded in the 50% treatment and no in the one where failing groups had only a small 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

[3] Scott Barrett theoretically examines what happens if these (and other) conditions do not apply. For preliminary results see http://cbey.research.yale.edu/uploads/Environmental%20Economics%20Seminar/Yale%20seminar%20paper.pdf (access date July 12, 2010).

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 the design of Milinski et al. (2008) 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 being presented with the probability of savings' loss of 50%. 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 Milinski et al. (2008), 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 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 €4/round contribution, while the remaining three players could only select a €0/round contribution. 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 begin 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-Fair*" and we expect that this setup conveys a sense of responsibility to the relatively wealthy players, as their position is due to past free-riding. This situation is reminiscent of that of global CO2 emissions, with developed countries owing much of their prosperity to past carbon-intensive industrialization, relative to developing countries with historically 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 go through three inactive rounds where they all have 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 3.2.

Finally, 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-Fair*" 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 1 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 using the ORSEE software (Greiner 2004). Each subject was seated at linked computer terminals that were used to transmit all decision and payoff information. We used the Z-tree software (Fischbacher 2007) for programming. Once the individuals were seated and logged into the terminals, a set of written instructions were handed out. Experimental instructions (see the Appendix) 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 €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, as well as the general opinion about climate change policy (see Section 5). 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)[4]. 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 increase the participants' motivation. The experimental instructions contained a short explanation of the EU ETS and the above mentioned rules (see 5). We announced furthermore that the purchase and the suspension of certificates would be certified by a notary and that the

[4]For information about the EU ETS visit the European Commission official website (http://ec.europa.eu/environment/climat/emission/index_en.htm)

Treatment	Asymmetric players	Pledge stages	Probability of climate change	No. of subjects
Base	no	no	50%	60
Pledge	no	yes	50%	60
Base-Fair	yes	no	50%	60
Pledge-Fair	yes	yes	50%	60

Table 1: Summary of experimental design

overall amount of certificates and the notarial acknowledgment could be found on a specific website. Overall, we spent €3,248 for emission certificates which corresponds to 212 tons of CO_2 given a price of 15.3 €/ton.[5]

3 Discussion of equilibria

As noted in Milinski et al. (2008), 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. Given the choice of the 50% probability of loss, conditional on the group failure to collect €120, the intermediate contribution of €2/round provides the same take home expectation than no contribution, namely €20. This implies that any average round contribution above €2 is irrational, in the sense of welfare diminishing relative to not contributing anything. In fact, borrowing the wording from Milinski et al. (2008), "each course of the game that leads to exactly reaching the target sum of €120, irrespective of who[m] contributes how much as long as each player invests" at most €20, is a Nash equilibrium. Of course, depending on the round and the path that has led to it, a high round contribution of €4 bringing the individual sum above €20 may still be optimal if successful in guaranteeing that past investments were not wasted.

Before commenting on the impact of the three computerized rounds in §3.2, we briefly discuss the tradeoffs inherent in the game.

3.1 Game tradeoffs

For illustrative purposes, we provide an hypothetical scenario in Table [tab:End-payoffs matrix snow drift]. 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:

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

[5] For emission certificate prices visit http://www.eex.com/en. We thank UniCredit Bank AG, Germany for assistance in the certificate purchase.

	€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 2: 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.

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 deer 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).[6]

Inequity aversion may be determinant in guiding the decision based on Table 2-type of scenarios. If for example a player is risk-averse but strongly resists disadvantageous inequity (has a high \alpha parameter, in Fehr and Schmidt, 1999 terminology), 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 2). 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. [7]

However, if risk aversion is dominated by inequity aversion, the column player may choose

[6] See the discussion on group level patterns in Section 4.

[7] Kümmerli et al. (2007) argue for the omnipresence of these situations in human working life, with the following example: "two scientists accomplishing a research project would each benefit if the other invests more time than oneself in the writing of the paper reporting the collaborative work. But if one of the collaborators does not contribute at all, the best option probably remains to do all the work on one's own." We believe that these tradeoffs, which also apply to the sharing of the global climate bill, are captured by the game analyzed here.

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.

3.2 Impact of the computerized rounds

As discussed in Section 2, 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.

Let us consider the case of symmetric contributions constrained to the intermediate round contribution of €2. Of the two symmetric Nash equilibria from the setup in Milinski (2008), corresponding to all players contributing either €2 or €0 per round, the latter is no longer available. This difference may promote coordination, as the unrecoverable individual contribution of €6 early in the game could in principle steer away individuals from no contribution towards the intermediate contribution. [8]

For what concerns the remaining two asymmetric treatments, both symmetric Nash equilibria disappear, as not only the all selfish equilibrium is ruled out by the first three rounds (although now three players do have the option to avoid any contribution), but also the one where all players contribute €2/round. This happens since half of the group begins round four with a sunk investment of €12, while the remaining players are unbound. The difference with respect to the symmetric case is stark, as it arguably introduces profound differences in the motivations of the two subgroups to provide the public good. Those who had no choice but to contribute 30% of their endowment early on, may be more committed to going the extra step to reach the target of €20 per person. The empirical question is: will the remaining players be sufficiently committed?

Before turning to it, at the risk of oversimplifying the complexity of the 6-person, 10-round game, we present payoff matrices in Table [tab:A-coordination-game], with the aim to highlight some key characteristics of the game in Milinski et al. (2008) 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 3 players can only choose between either free-riding in all active rounds (no contributions), or always contributing the intermediate

[8] In the experiment by Milinski et al. (2008), participants of the 50% treatment, which weren't bound to the fair amount in rounds one to three, contributed on average > €1.5/round. This suggests that the selfish Nash equilibrium was not popular even in the absence of the discussed mechanism.

	Fair	Selfish
Fair	20, 20 (120)	10*, 20* (60)
Selfish	20*, 10* (60)	20*, 20* (0)

	Fair	Selfish
Fair	20, 20 (120)	10*, 17* (78)
Selfish	17*, 10* (78)	17*, 17* (36)

	Fair	Selfish
Fair	14, 26 (120)	7*, 20* (78)
Selfish	14*, 13* (78)	14*, 20* (36)

Table 3: 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.

amount of €2/round. This simplification allows analyzing the game as if it was a one shot game, where people simultaneously reason on the outcome from 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).[9]

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 one simplifying the game in Milinski et al. (2008), 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 3 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 cooperation to succeed. [10]

[9]It is important to stress again 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. In other words, due to the introduction of the computerized rounds, the €0 contribution is no longer attainable in the remaining two matrices.

[10]Skyrms (2001), has the following interpretation of the game: "In the Stag Hunt, what is rational for one player to choose depends on his beliefs about what the other will choose. Both stag hunting and hare hunting are equilibria. [....] A player who chooses to hunt stag takes a risk that the other will choose not to cooperate in the Stag Hunt. A player who chooses to hunt hare runs no such risk, since his payoff does not depend on the choice of action of the other player, but he foregoes the potential payoff of a successful stag hunt. Here rational players are pulled in one direction by considerations of mutual benefit and in the other by considerations of personal risk". The game analyzed here adds a further layer of complexity, as the option that doesn't require cooperation to succeed, namely the always defect strategy labelled Selfish in Table 3, is not entirely safe due to the associated probabilistic payoff; Fair, on the other hand, is risky in terms of reliance on coordination, but safe with respect to the ensuing payoff.

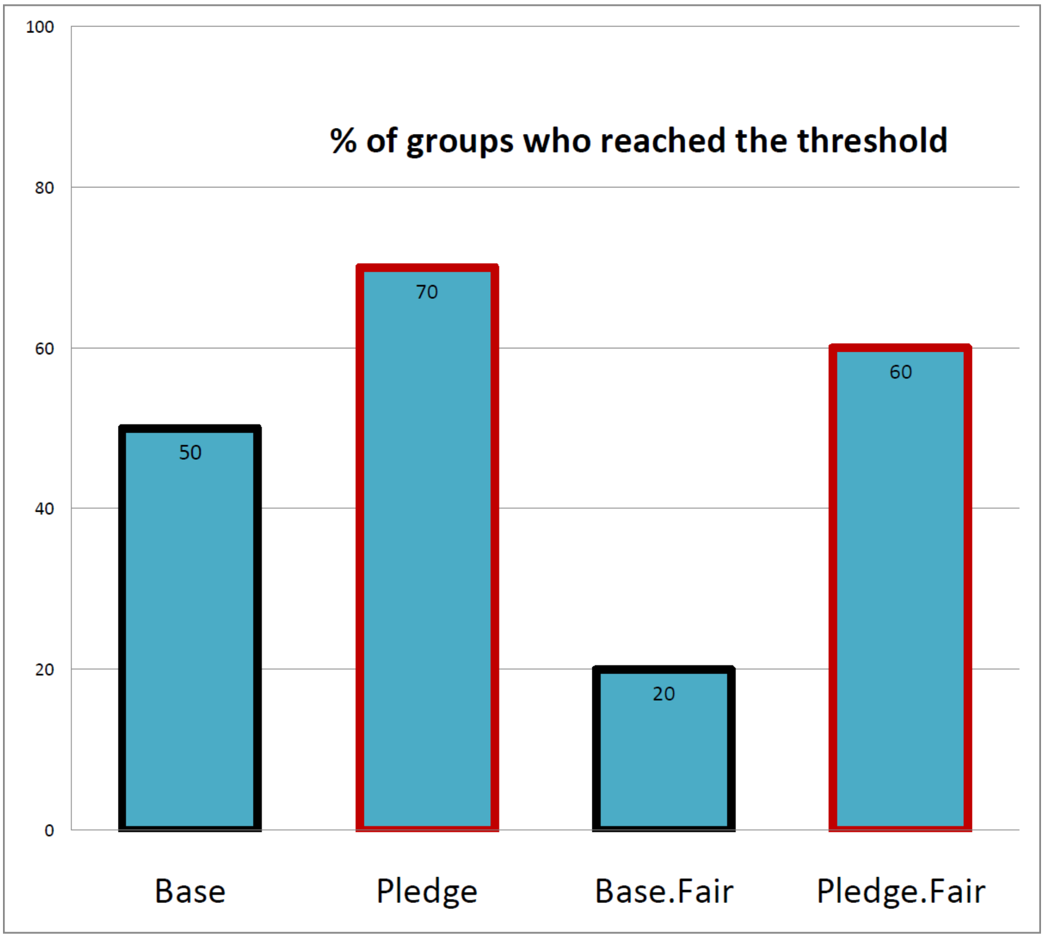


Figure 1: Success rate by treatment

4 Results

The bird's eye view on the cooperation level across treatments is provided in Figure 1, which reports the success rate in providing the public good of climate protection. That is, for each treatment, it shows the percentage of groups who contributed at least €120 to the climate account. Inspection of Figure 1 suggests:

a) the pledges are effective tools to ease coordination among group members;

b) inequality disrupts cooperation, and more severely so in the absence of the pledges.

In the following three sections, we take a closer look at between and within treatment differences, and find supporting evidence for the above claims, as well offering explanations based on the underlying patterns.

4.1 Trajectories

Much of this section's analysis is based on Figure 2. In it, the contribution trajectories resulting from averaging those of the participants of the four treatments are contrasted with the symmetric

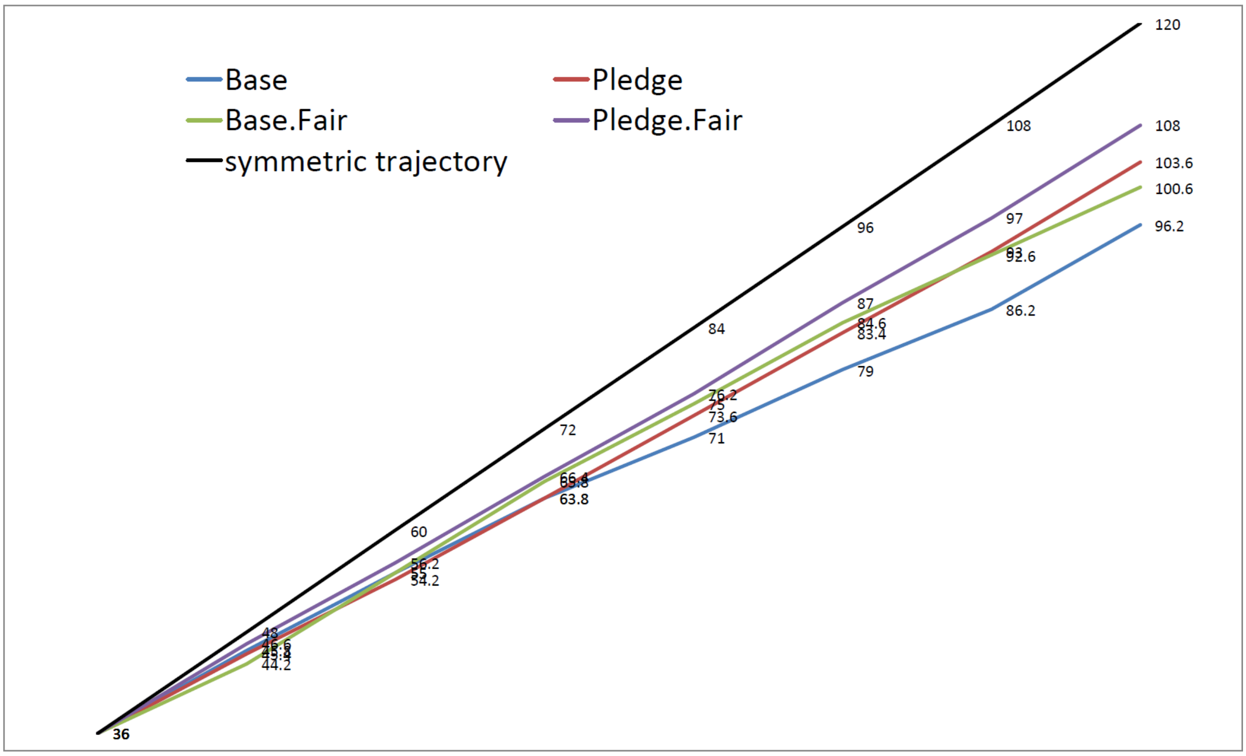


Figure 2: The contribution patterns in each treatment, starting with round 3

trajectory that would arise if all subjects chose the intermediate €2 strategy, therefore collecting €12 per round. Note that each curve concerns eight rounds, the first of which represents the group contribution in round three, set by default at €36 for all treatments (see Section 2 for the experimental design), after which each subject has the freedom to choose the round contribution between €0, €2 and €4.

The experimental subjects displayed a significant amount of variation, with some groups contributing little to the public good (the group that came closest to the no contribution equilibrium collectively contributed only €12 in the seven active rounds), and others surpassing the threshold (the maximum was €126). Nevertheless, each treatment was characterized by substantial differences in terms of success rate in simulated climate catastrophe avoidance. Five of the ten groups participating in *Base* were successful, contributing on average €122.4, while the remaining five fell short by contributing €70. The ten groups as a whole contributed €96.2 $\pm$ 32.5 (mean $\pm$ error), as shown in Figure 2.As expected, the *Pledge* treatment proved effective in facilitating coordination, even if based on nonbinding commitments; successful coordination on the target increases to 70%, with all groups contributing €103.6 $\pm$ 29.6, stemming from the €121.1 set aside by the seven groups who reached the target and €62.7 by the remaining three.

The effect of introducing asymmetric endowments to the *Base* treatment is negative: compared to it, the participants of *Base-Fair* where 30% less successful (see Fig. 2). Interestingly, adding the possibility to make pledges again proved to be an extremely powerful tool to facilitate coordination on the threshold: *Pledge-Fair* groups had a success rate of 60%, which is remarkably higher than the 20% achieved by groups in the *Base-Fair* treatment (and 10% higher than that of groups participating in *Base*, the symmetric treatment without pledges). In terms of average giving, as evident from Figure 2, participants of *Base-Fair* provided €100.6 ± 21.8, which is below the provision level in both pledge treatments (the highest across treatments was achieved in *Pledge-Fair*, with 108 ± 21.8), reflecting the positive impact of the pledges discussed above. Notably, this impact is higher when considering the asymmetric treatments (+40% success rate from *Base-Fair* to *Pledge-Fair*), with respect to the symmetric ones (+20% success rate from *Base* to *Pledge*).

What is not captured in these treatment-wise comparisons (Fig. 1 and Fig. 2) is the differences 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-Fair* and *Pledge-Fair* contributed a remarkable €95.5 and €88, despite the lower success rate in the latter two (-30% in *Base-Fair* w.r.t. *Base*, and -10% in *Pledge-Fair* w.r.t. *Pledge*, see Fig. 1). This evidence, together with questionnaire analysis, suggests that the role of the asymmetric endowments is twofold: it disrupts cooperation by rendering more complex coordination, but 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 combat simulated climate change damage, but not their motivation, which is actually higher than in symmetric treatments (cf. green vs. blue and purple vs. red lines in Fig. 2).

4.2 Contribution dynamics

Taking a closer look at *Base-Fair*, an analysis of the dynamics of contributions provides a perspective on the patterns behind the high number of failures that characterized this treatment. Figure 3 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-Fair* 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, 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-Fair*, owe much of it to the different dynamics, since contributions in round four where similar across

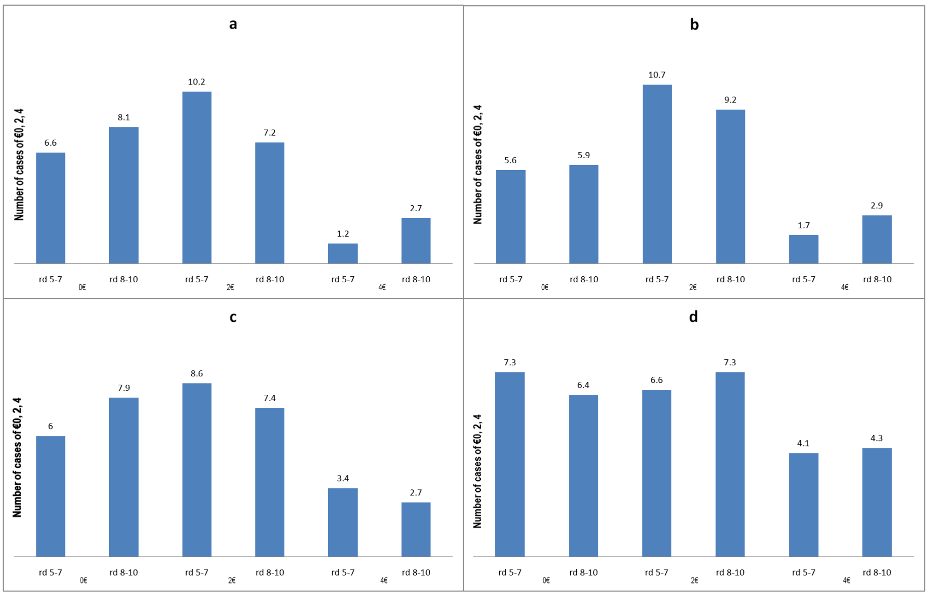


Figure 3: Contributions in early and late rounds. Amounts invested in rounds 5-7 and 8-10 to protect climate in: (a) Base; (b) Pledge; (c) Base-Fair; (d) Pledge-Fair

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 know take a closer look at the dynamics in *Pledge-Fair* and *Base-Fair*, since both are subject to three unequalizing rounds at the beginning. Although the number of no contributions in *Pledge-Fair* is higher in rounds five to seven relative to *Base-Fair*, 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-Fair* participants chose this contribution level close to 14 times, while the *Base-Fair* 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 cooperation" 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 4.4). It should be noted that the subjects took seriously the opportunity to express their planned contributions. In *Pledge-Fair*, 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.

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: 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 over one altruistic act 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. Such insight is of relevance for the current climate negotiations, and reinforces the importance of following up declarations with tangible action, especially among developed nations with higher responsibilities.

4.3 Group level patterns

Before moving on to Section 5, we will inspect behaviour in certain groups that either displayed a recurring pattern or one which is worth of notice. The first one considered in Fig. 4belongs to the latter category. While the group, which took part in the *Base-Fair* treatment, got off on a good start, mimicking the symmetric trajectory in rounds four and five by providing €12 in each, and continuing to oscillate around this contribution level until round nine (where they were actually ahead by €2 with respect to the symmetric trajectory), a meagre €6 was contributed in the last round and the threshold missed by €4. This extremely irrational behavior, in terms of departure from payoff maximization, seems to be the consequence of an unwillingness to further invest in the climate account by those who contributed much in earlier rounds. The three players with low initial endowment due to high contributions in the first three rounds, for example, had already contributed €22 each on average by round nine, corresponding to almost €2.5/round. Their reaction was to contribute €2 collectively in the last round, presumably expecting the remaining three players to provide most of the missing €10. However, the latter did not take on the entire burden, providing only €4 collectively. This qualitative pattern took place in four of the forty groups in the sample, providing €116 or €118 by the last round. All these instances took place in treatments with endowment inequality, providing experimental evidence supporting the hypothesis advanced in Section 3, on the important role of inequity aversion in certain situations characterized by unequal burden sharing. We will come back to this issue in Section 4.4.

A somewhat diametrically opposite scenario is the one depicted in Figure 4b, where a group in the *Base* treatment was able to catch up, after lagging behind the symmetric trajectory in previous rounds often by €8 or even €10. Thanks to a remarkable effort in the ninth round, where all subjects contributed €4 with the exception of one who contributed €2, the group surpassed the threshold in the final round with a total contribution of €122. This qualitative pattern took place in two more groups, which successfully rebounded back from either €102 or €104 in the penultimate round.

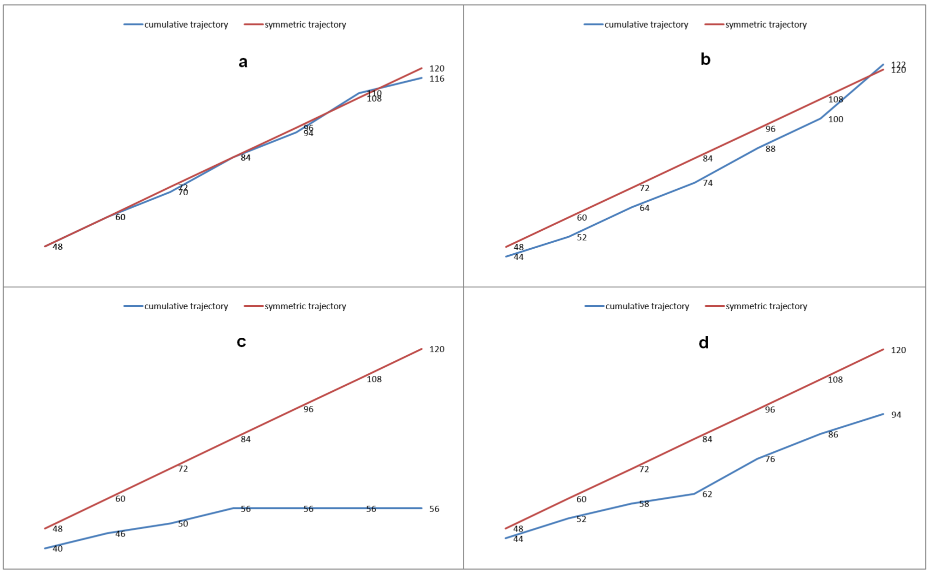


Figure 4: Selected examples of: (a) late miscoordination; (b) catching up in last round; (c) retreating early in the game; (d) still trying up to the end, but failing

The last two illustrations (see Fig. 4c and d), respectively taken from *Pledge* and *Pledge-Fair*, represent two failed attempts of different nature. In the first, after round seven all players abandoned hopes to provide the public good, due to the pervasiveness of free-riding (15 no contribution instances in rounds four to seven), stopping at an aggregate €56. This class of group behavior was the most frequent: 12/40 groups 'abandoned the ship' no later than in round seven, meaning that most subjects in these groups did not make any contribution in the last three rounds, collectively providing at most €12. Notably, 67% of these instances took place in either *Base* or *Base-Fair*, indicating that the pledges promoted a sense of unity among the participants, since only 4/20 groups abandoned the ship in these treatments. The second case differs in that the non-provision of the public good does not appear to follow from an intentional decision to stop investment in the climate account. Three players, the initially poor ones, invested €20 or more, while the remaining three rich ones still contributed almost €11 on average (or almost €1.1/round), which is closer to the intermediate contribution than to the free-rider one of €0/round. This is remarkable since, as of round nine, having the group provided only €86, it was impossible to reach the €120 target even if all had gone for the high €4 contribution. This suggests high motivation to protect the climate by some members, as also found in Milinski et al. (2008). In fact, in five groups at least one subject continued to submit positive contributions until the last round, even if the target was beyond reach. Again, these groups were not evenly distributed across treatments: 80% of them took part in one of the two pledge treatments, suggesting a positive effect of the pledging ability on motivation to protect the climate.

In addition to the cases discussed above, and depicted in Figure 4, a last one deserves attention, due to its frequent appearance (9/40 groups) and theoretical relevance, the group level Nash equilibrium. By it we mean that the group as a whole successfully coordinated on a provision of precisely €120, whether or not the burden was symmetrical shared among the members.[11] In fact, only in two instances did each member contribute €20 overall (one in *Base* and one in *Pledge*), and in one of these they all played the symmetric strategy of always contributing €2. Braking down these instances by treatment sheds further light on the positive role of the pledges as a coordination mechanism: 6/9 Nash equilibria were achieved in pledge treatments.

4.4 Inequality

We have seen that inequality impede coordination among the players. Now we will analyze in more detail how the groups in the asymmetric treatments *Base-Fair* and *Pledge-Fair* handle 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. Both the rich players and the poor players contributed on average precisely €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. We will come back to this point later on when we discuss the questionnaire data. Interestingly, the successful groups managed to eliminate inequality independently of whether they had the opportunity to announce pledges. However, the pledges appeared to be of great help since in the *Pledge-Fair* treatment 75% of the groups managed to eliminate inequality and reach the target while in the *Base-Fair* treatment only 33% of the groups managed to do so.

4.5 Questionnaire analysis

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 the Appendix). Overall, the subjects appear to take climate change seriously. About 5% of the subjects think that climate protection is currently the greatest challenge in Germany. Out of 15 possible challenges for the German policy, climate protection ranks sixth. However, the magnitude of the problem is seen very differently: about 21% think that the problem of global climate change is being rather overestimated, 35% think that it is being correctly estimated, 37% think that it is being underestimated, and 7% do not know. The subjects also differently evaluate the equity principles that may guide international climate agreements: 23% support the polluter-pays principle, 22%

[11] This is a loose interpretation of the definition of Nash equilibrium given in Section 3, which requires symmetric behavior.

support the ability-to-pay principle, 17% favor the egalitarian principle, 22% prefer the sovereignty principle, and 16% support another principle.

The summary statistics of the players' motivation for their contribution decisions during the game are more 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-Fair* and *Pledge-Fair* 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 particularly important because they reflect the application of the different equity principles. In our game, the egalitarian rule, the polluter-pays rule and the ability-to-pay rule are equivalent: According to these principles the rich (and responsible) players should compensate for the inactive rounds where they gained their wealth without contributing to climate protection. 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. As opposed, the sovereignty rule does not consider the players' wealth or responsibility but rather requires the same contribution during the active rounds, i.e. €2 per round for the rich as well as for the poor players. In fact, a couple of rich subjects argued that the assignment of roles was just bad luck or good luck and that the €2 contribution per (active) round and player was a fair burden sharing. Hence, our game as much as the real climate negotiations allow for different notions of fairness. The players tend to pick the notion that is in their best interest ("self-serving bias") meaning that the implementation of that notion would generate least costs for them. This self-serving bias in the perception of fairness has been also observed in the real climate negotiations (Lange et al. 2010) and it obviously deteriorates the chances for effective coordination.

5 Conclusions

In this paper we have experimentally explored the relevance of equity and commitment issues in affecting the subjects' willingness to contribute to a public good framed in terms of avoidance of catastrophic climate change. We have built upon the game proposed by Milinski et al. (2008) to explore some further aspects that were not captured by the original design, and that we deem important both at the theoretical and policy level. In particular we have focused on: (i) introducing asymmetries among players by means of a novel unequalizing mechanism in the first three rounds; (ii) allowing players to make unbinding pledges concerning future contributions. The extended climate game empirically tested here captures trade-offs that are particularly salient for the issue of climate change mitigation. It is a promising tool for analysing such tensions notwithstanding its simplicity, as it provides insights into many aspects that are crucial to climate change and coordination at large. Given the lack of scientific consensus on who should bear the burden of mitigation costs, providing empirical evidence on the driving forces behind coordination in a setting designed to mimic inequalities and bargaining possibilities faced by actors involved with climate change, should be fruitful also from a policy perspective.

The main purpose of the paper was to address the question: Will the most responsible actors contribute more to combat climate change damage in a public goods game experiment where players differ in wealth (and responsibilities) and are allowed to make nonbinding pledges? The empirical answer to this question is generally "no": initially wealthier subjects were often unwilling to compensate for past, "inherited", actions which had benefited them at the expense of the common good. Such resistance, much to the frustration of the remaining subjects who expected initiative on the part of the wealthy, accounted for the frequent coordination failures in the asymmetric treatments. In all twelve instances (out of twenty participating groups) where the target sum was not provided, there was an unfavourable contribution imbalance for those who had been bound to the altruistic act in the first three rounds, who ended up on average paying 60% of the bill. Not surprisingly, the burden was shared evenly in the remaining eight successful groups, with both subgroups contributing 50% of the sum.

While neither one of the new features introduced in the climate game alters the game structure in terms of the group trajectory required to reach the threshold for climate protection, they both have a significant impact on the groups' success rate. Asymmetries undermined coordination, especially in the treatment where subjects had no signalling mechanism beyond contributions, in which 80% of the groups failed to reach the target sum. Pledges, on the other hand, proved to be an effective lubricant of coordination, halving the percentage of failures in the treatment with endowment inequalities. Both in the baseline and across all treatments, the rate of success was 50%, a remarkably high level considering the instability of the fair share Nash equilibrium and the previous findings of 10% cooperation by Milinski et al. (2008). With respect to the latter, the higher coordination may stem from design and subject pool differences (see Section 2 and the Appendix for details on the design and for the complete instructions translated from German). As for the former, we argue, in accordance to much of the experimental literature, that human behavior is guided by a rich set of heuristics that may interfere with expected payoff computations, steering decisions away from the rationality prescriptions. In Section 3 we have discussed two such heuristics, risk aversion and inequity aversion; data and questionnaire analysis suggest that both play an important role in explaining the observed departures from best-response behavior.

The asymmetric geometry of global emissions introduces the possibility to argue in essentially opposite directions on the grounds of fairness motives. Developing countries may insist on the importance of past emissions to justify their unwillingness to take action, while developed countries can appeal to the relevance of current emissions, generally higher in transitioning economies, to refute to take lead in mitigation actions. These positions can be backed with different notions of equity: The egalitarian rule, for example, incorporates the principle of equal per capita emissions, which would demand drastic emission cuts in industrialized countries. On the other hand, the sovereignty rule, which postulates the principle of equal percentage reduction of current emissions, shifts more of the abatement burden to developing countries. Such asymmetries may lead to "political lock-ins" that are detrimental to the establishment of a global agreement to curb emissions (Halsnæs et al., 2007). However, equity criteria might be also used by countries to influence the negotiations process in their own material self-interest. Lange et al (2010) provide evidence that the perceived support of different equity rules by countries is self-serving, i.e. purely tactical, and can be explained by the ranking of their economic costs. The game introduced here allows capturing relevant aspects concerning both the tension between collective good and free riding on the efforts of others (e.g. benefitting from polluting activities without internalizing the externality), as well as the potentially disruptive role of uneven wealth and responsibilities arising from past activities. As to future research, the extended climate game would be well suited to also shed light on the role of the self-serving use of equity in climate negotiations.

The implications of our results for the ongoing policy discussions may be important. Inequality further impedes coordination. An alignment of wealth and carbon responsibilities might, on the other hand, facilitate coordination in addressing climate change. This strategy, however, is seen as dangerous as it risks unconstraint growth in emissions which might prove difficult to curb substantially in the future. Our analyses concerning the faculty to make nonbinding pledges on future contributions to the public good, however, showed that this institution promotes coordination and mitigates the problems arising from the above mentioned inequalities. Future research might investigate the potential role of the "pledge and review" mechanism in the economic catch up process in developing countries. That is, one could experimentally investigate the successfulness of a bottom-up approach based on delayed action by parties that commit to a mechanism that ensures future emission reductions.

Although necessarily simple for the sake of tractability, the game presented here is designed to incorporate key real-world issues, such as equity and the impact of emergent institutions based on nonbinding "pledge and review" mechanisms. One further salient aspect which is not captured by this game is that of uncertainty over the magnitude of the threshold: future research is needed along these lines. Moreover, different games emphasizing mitigation cooperation over catastrophe avoidance coordination would complement the present analysis.

Appendix

Experimental instructions for the treatments Base-Pledge and Pledge-Fair

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 (CO2). CO2 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. CO2 is a global pollutant, i.e. each quantity unit of CO2 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?*"

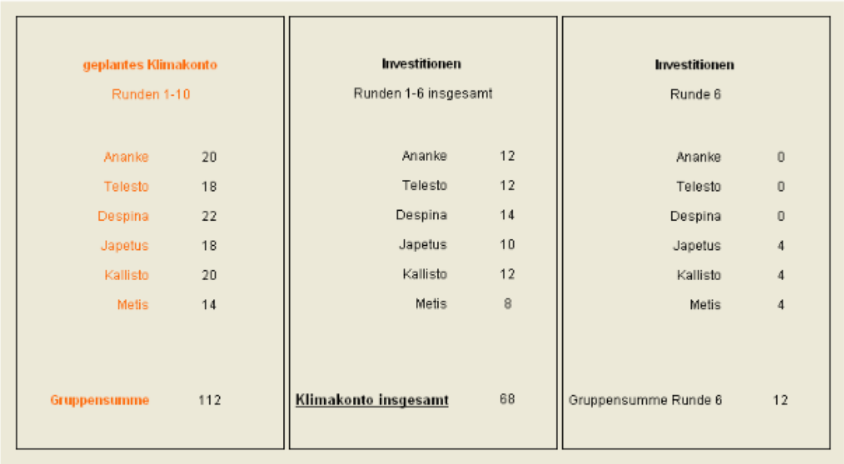
Possible answers are EUR 0, 2 or 4. Only when each player has made his choice, all decisions will be displayed simultaneously. After that the computer will credit all invested amounts to an account for climate protection ("climate account"). At the end of the game (after exactly 10 rounds) the computer 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 (round 6).

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



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

account, whereas players Japetus, 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, Japetus 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 CO2 emitted, the company has to give a certificate to the state. The certificates can be traded between companies.

For each quantity unit of CO2 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 CO2emissions 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 CO2 (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)? O EUR 12 O EUR 20 O EUR 40 O 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)? O in 3 rounds O in 5 rounds O in 7 rounds O 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)? O EUR 12 O EUR 52 O EUR 68 O 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)? O EUR 2 O EUR 12 O EUR 14 O EUR 20

h. Are the declarations of intent binding for the investment decisions in the following rounds (please tick the according box)? O Yes O 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)? O the invested amounts of the first three rounds O the planned investments for the last seven rounds O 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 3 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)? O Yes O 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)? O 10% O 30% O 50% O 70% O 90% O 100%

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

Questionnaire

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	3	1.25
		4	0	0.00
(3) Please try to remember the decisions made by your fellow players during the game. In your opinion, which players have been motivated by following reasons? Please write one or more names next to each motive. Do you think there were any other motives for your fellow players besides the given? Possible motives are - Monetary self-interest - Fairness consideration - Advancement of the common coordination process - Other motives (please specify and state name)				
(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.				
		$\sum$	240	100.00

Notes: Question 1 was asked in the asymmetric treatments Base-Fair and Pledge-Fair 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 3-6.

Table 4: Questionnaire and responses – Part I

Question	Answer	No.	%
(7) Please imagine the following situation: You have EUR 40. With a probability of 50 % you will lose all EUR 40. You could abide 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
(8) Did you ever donate money of goods to a charity organisation?	Often	14	5.83
	Sometimes	77	32.08
	Rarely	102	42.50
	Never	47	19.58
(9) Do you agree with this statement? "I think social differences should be levelled out more in Germany."	Agree	110	45.83
	Disagree	47	19.58
	Neither	83	34.58
(10) Do you think the problem of global climate change is being estimated correctly or not? In my opinion, the Problem is being	Rather overestimated	51	21.25
	Rather correctly estimated	83	34.58
	Rather underestimated	89	37.08
	I don't know	17	7.08
(11) In your opinion which challenges in Germany are currently the greatest? Please state the three greatest challenges in a descending order of importance.	Old age provisions	18	7.50
	Unemployment	48	20.00
	Poverty	6	2.50
	Educational policy	66	27.50
	Energy supply	3	1.25
	Health care	3	1.25
	Climate protection	13	5.42
	Crime	1	0.42
	Social security	4	1.67
	Fiscal policy	6	2.50
	Terrorism	0	0.00
	Environmental protection	3	1.25
	Economic upturn	40	16.67
	Immigration/Integration	7	2.92
	Other (please state below)	22	9.17
(12) Which of the following guiding principles describes your understanding of fairness best in the context of international climate negotiations?	Countries with high emissions in the past should reduce more emissions.	56	23.33
	Countries with high economic performance should reduce more emissions.	53	22.08
	Countries should reduce their emissions in such a way that emissions per capita are the same for all countries.	41	17.08
	Countries should reduce their emissions in such a way that the emissions percentage is the same for all countries.	53	22.08
	Other principle (please specify)	37	15.37
(13) What are the reasons for your answer in the previous question? Please state the three most important reasons in a descending order of importance.			
	∑	240	100.00

Notes: The responses to question 11 refer to the first of the three greatest challenges. No responses are provided for the open question 13.

Table 5: Questionnaire and responses – Part II

References

Bernasconi, M. et al., 2010. "Expressive" Obligations in Public Good Games: Crowding-in and Crowding-out Effects. Working Paper

Buckley, E., Croson, R.,2006. Income and wealth heterogeneity in the voluntary provision of linear public goods. Journal of Public Econ

Chan, K. et al., 1996. The voluntary provision of public goods under varying income distributions. Canadian Journal of Economics

Croson, R., Marks, M., 2001. The effect of recommended contributions in the voluntary provision of public goods. Economic Inquiry 39(2): 238-249.

Fehr, E., Schmidt, K., 1999. A Theory Of Fairness, Competition, And Cooperation. The Quarterly Journal of Economics 114(3): 817-868.

Fischbacher, U., 2007. Z-Tree: Zurich Toolbox for Ready-made Economic Experiments, Experimental Economics 10: 171-178.

Greiner, B., 2003. An Online Recruitment System for Economic Experiments. In: Kurt Kremer, Volker Macho (Eds.): Forschung und wissenschaftliches Rechnen. GWDG Bericht 63, Göttingen.

Halsnæs, K., Olhoff, A., 2005. International markets for greenhouse gas emission reduction policies–possibilities for integrating developing countries. Energy Policy 33(18)

Lange, A., Löschel, A., Vogt, C., Ziegler, A. (2010), On the Self-Interested Use of Equity in International Climate Negotiations, European Economic Review 54 (3), 359-375

Ledyard, J. (1995). Public goods: a survey of experimental research, in J. Kagel and A. E. Roth (eds) Handbook of Experimental Economics, Princeton, NJ.

Maurice, J. et al., 2010. Income Redistribution and Public Good Provision: an Experiment. Working paper

Milinski, M. et al., 2008. The collective-risk social dilemma and the prevention of simulated dangerous climate change. Proceedings of the National Academy of Sciences, 105(7), 2291-2294.

Skyrms, B., 2001. The Stag Hunt. Presidential Address of the Pacific Division of the American Philosophical Association, in Proceedings and Addresses of the APA. 75: 31-41