Stabilizing the Earth's climate is not a losing game: Supporting evidence from public goods experiments

Manfred Milinski*†, Dirk Semmann*, Hans-Jürgen Krambeck*, and Jochem Marotzke†‡

*Department of Evolutionary Ecology, Max Planck Institute of Limnology, 24306 Plön, Germany, and ‡The Ocean in the Earth System, Max Planck Institute for Meteorology, 20146 Hamburg, Germany

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Maintaining the Earth's climate within habitable boundaries is probably the greatest "public goods game" played by humans. However, with >6 billion "players" taking part, the game seems to rule out individual altruistic behavior. Thus, climate protection is a problem of sustaining a public resource that everybody is free to overuse, a "tragedy of the commons" problem that emerges in many social dilemmas. We perform a previously undescribed type of public goods experiment with human subjects contributing to a public pool. In contrast to the standard protocol, here the common pool is not divided among the participants; instead, it is promised that the pool will be invested to encourage people to reduce their fossil fuel use. Our extensive experiments demonstrate that players can behave altruistically to maintain the Earth's climate given the right set of circumstances. We find a nonzero basic level of altruistic behavior, which is enhanced if the players are provided with expert information describing the state of knowledge in climate research. Furthermore, personal investments in climate protection increase substantially if players can invest publicly, thus gaining social reputation. This increase occurs because subjects reward other subjects' contributions to sustaining the climate, thus reinforcing their altruism. Therefore, altruism may convert to net personal benefit and to relaxing the dilemma if the gain in reputation is large enough. Our finding that people reward contributions to sustaining the climate of others is a surprising result. There are obvious ways these unexpected findings can be applied on a large scale.

climate change | public goods game | reputation | tragedy of the commons

There is widespread consensus in the climate research community that human activities are changing the climate through the release of greenhouse gases, particularly CO_2, into the atmosphere (1–3). This release will lead to adverse effects on many societies, especially if it involves threshold crossing and abrupt climate change (1–8). To avoid major long-term climate change, average per capita greenhouse gas emissions must be reduced to a small fraction of the present levels of developed countries on the time scale of a century (1, 9). Can this goal be achieved? Stabilizing the global climate has been identified as a "tragedy of the commons" problem (10), which Hardin introduced as a metaphor for our inability to sustain a public resource that everybody is free to overuse (11, 12). Several studies have modeled the international negotiation or bargaining game with nations or governments as players and have tried to characterize its equilibria (13–15). For a first approach, this scenario may be regarded as being independent of the game that comprises all individual players, on which we concentrate here. The potential interaction between these two layers will require further analysis.

Many attempts have been undertaken to find conditions that allow for cooperative solutions to the tragedy of the commons problem with individuals as players (16, 17). Public goods experiments, which are used to study this type of problem, usually confirm that the collective benefit will not be produced (18). In a standard experiment, four students each given an endowment of \$10 are told that they can each choose to invest between \$0 and \$10 in a group resource by putting the money privately in an envelope. The experimenter will collect the contributions, total them up, double the amount, and then divide this money evenly among the players. The economic-theory prediction is that no one will ever contribute anything because each \$1 contributed yields only \$0.50 to its contributor, no matter what the others do. However, the group would be best off if all would contribute \$10 (taking home \$20 each). Individual self-interest is at odds with group interest. Therefore, initial cooperation usually declines quickly (19). A rise in the level of contribution to the public good can be achieved both by the opportunity for direct punishment of noncooperators (20) and the interaction with a second game that promises reward for those with a good reputation (21–23). Because the reputation effect is expected to be rather robust (23), we test here whether a similar effect in combination with reliable information on prospects of the global climate can be an incentive for humans to invest private money in sustaining the climate.

Contrary to the usual conditions of this game, the contents of the public pool were not redistributed among all players but transferred to a "climate account," after the players, i.e., undergraduate students, had made their contributions and the total amount had been doubled. This condition is unusual because it increases the public goods group size to all humans that profit from a potential improvement of the climate. The students were assured that the money from the climate account would be used to publish a press advertisement, the size being determined by the final climate account, in a widely distributed daily newspaper, to be published simultaneously with the present work. The advertisement would contain expert information from the Max Planck Institute for Meteorology about the state and expected development of the global climate and a list of simple but effective rules on how everybody could help reduce CO_2 emissions (see *Methods*). After this press release, sponsorship for international advertisement campaigns would be sought. To test whether improved knowledge of climate change influenced behavior, every second group, designated as "well-informed" in the following (compared with "little-informed"), received additional expert information about the state of the global climate (see *Methods*).

To allow for reputation being taken into account in climate public goods games, this game was alternated with a two-player game ("indirect reciprocity game"; see *Methods*). In indirect reciprocity situations (24–26), individuals who have helped others are given support (here, money), that is, the supporters improve their reputation and are rewarded in turn: "give and you shall receive" (27–30). Because players would risk their reputation if they did not cooperate in a public goods game, that was alternated with the indirect reciprocity game; alternating rounds

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†To whom correspondence may be addressed. E-mail: milinski@mpil-ploen.mpg.de or marotzke@dkrz.de.

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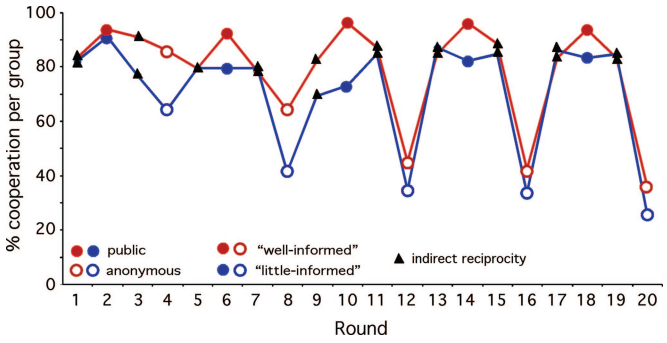

Fig. 1. Percentage of cooperation (yes) per group of six subjects in each round of the climate public goods game (circles) and each round of the indirect reciprocity game (triangles). Rounds of the climate public goods game were either anonymous (open circles) or nonanonymous (filled circles). In one treatment (well-informed), the groups received additional expert information about the state of the global climate (red symbols); in the other treatment (little-informed), the groups received no additional information (blue symbols).

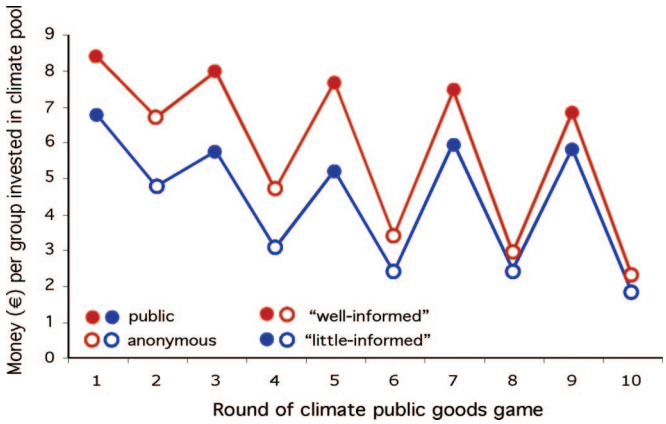

Fig. 2. Money (€) per group of six subjects invested in climate pool in each round of the nonanonymous (filled) and anonymous (open) climate public goods game. In one treatment (well-informed), the groups received additional expert information about the state of the global climate (red); in the other treatment (little-informed), the groups received no additional information (blue).

of these two games may induce cooperation in the public goods game (21–23).

The groups started with a round of the indirect reciprocity game, followed by a round of a climate public goods game, etc., until a total of 20 rounds had been played. Every second round of the climate public goods game was completely anonymous. In each round of the indirect reciprocity game, each potential receiver's history of giving both in the indirect reciprocity and the nonanonymous (pseudonym shown) climate public goods game was displayed simultaneously for all players. The potential donor decided whether to support this person with 1.50 euros (€1.50), doubled by the experimenter for the receiver's account. In each climate public goods round, all six players were asked whether they wanted to invest €0, €1, or €2 in sustaining the climate, doubled by the experimenter for the climate account. Every second group (well-informed) received additional information about the state of the global climate (see *Treatments*).

Results and Discussion

All subjects contributed money to sustain the global climate in climate public goods rounds. The level of cooperation, i.e., investing either €1 or €2, was highest in nonanonymous climate rounds in well-informed groups both on average (94.4 ± 1.8%; mean ± SEM) and during all five rounds (filled red circles in Fig. 1). This level was even higher than that in indirect reciprocity rounds (triangles in Fig. 1) on average (84.1 ± 3.4%; $P = 0.001$; $n = 13$ groups; $t = -4.516$; using a two-tailed paired t test with arcsine transformed data; our null hypothesis is always no difference between treatments), in which the students could earn money to receive cash after the session. In anonymous climate rounds (open circles in Fig. 1), the students were much less willing to contribute to the climate account than in nonanonymous rounds (filled circles) in both information treatments [both $P < 0.0001$; $n = 13$; $t = 10.110$ (well-informed); $t = 10.897$ (little-informed); two-tailed paired t tests with arcsine transformed data].

Because climate public goods rounds alternated with indirect reciprocity rounds, subjects were probably more cooperative in nonanonymous than in anonymous rounds to build a high reputation for the next indirect reciprocity round. The mean level of cooperation in rounds of indirect reciprocity was both similar in well-informed (84.1 ± 3.4%) and little-informed (81.4 ± 4.2%) groups and comparable with values found in previous studies (21, 22). Subjects might have foreseen the potential reputation effect because they were highly cooperative already in their first nonanonymous climate round (Fig. 1) after the first indirect reciprocity round. We can test whether the few defectors in a nonanonymous climate round were "punished" by not receiving money in the following indirect reciprocity round. We can compare such potential consequences in indirect reciprocity rounds between preceding nonanonymous and anonymous climate rounds, taking all individual decisions into account. From 93 cases of refusing to give in a nonanonymous round, 30.7% were punished in the next indirect reciprocity round, whereas of 304 cases of refusing to contribute in an anonymous round, only 19.8% were not supported thereafter ($\chi^2 = 4.6054$; df = 1; $P = 0.03$). This result shows that investments in sustaining the global climate are socially rewarded, and the refusal to do so is socially punished. If players are paid for being altruistic, it is no longer pure altruism. However, the finding that subjects reward other subjects' contributions to sustaining the climate, thus reinforcing their altruism, is surprising because such reinforcements reduce the supporter's income but may pay off in later indirect reciprocity rounds.

The benefit of investing to the climate pool, a stabilized climate, potentially lies in the distant future, so the investment might be viewed as being equivalent to a donation to charity. Among several hypotheses for the motives behind giving to charities, prestige has been proposed (31, 32) and confirmed (33). In the present experiment, donors are players in the climate public goods game and thus share potential future benefits, in contrast to donations to charity. However, in both cases, the motivation to contribute can be boosted by an expected gain in reputation. Reputation is a currency that can be used in various social contexts (22, 26).

The subjects invested money (€1 or €2) in the climate pool to a large extent but differently in nonanonymous and anonymous rounds (Fig. 2). Well-informed groups gave €76.8 ± 3.1 in five nonanonymous and only €40.2 ± 3.7 in five anonymous rounds ($P < 0.0001$; $n = 13$; $t = 17.92$; two-tailed paired t test), little-informed groups gave €59.2 ± 4.8 in five nonanonymous and €29.1 ± 4.1 in five anonymous rounds ($P < 0.0001$; $n = 13$; $t = 9.80$; two-tailed paired t test). The latter sum of money can be regarded as basically altruistic investment, significantly different from zero ($P < 0.0001$; $n = 13$; $t = -7.094$). The altruism in anonymous rounds is remarkable because it seems to be different from the cooperative beginning of conventional public goods experiments with the players directly benefiting from their

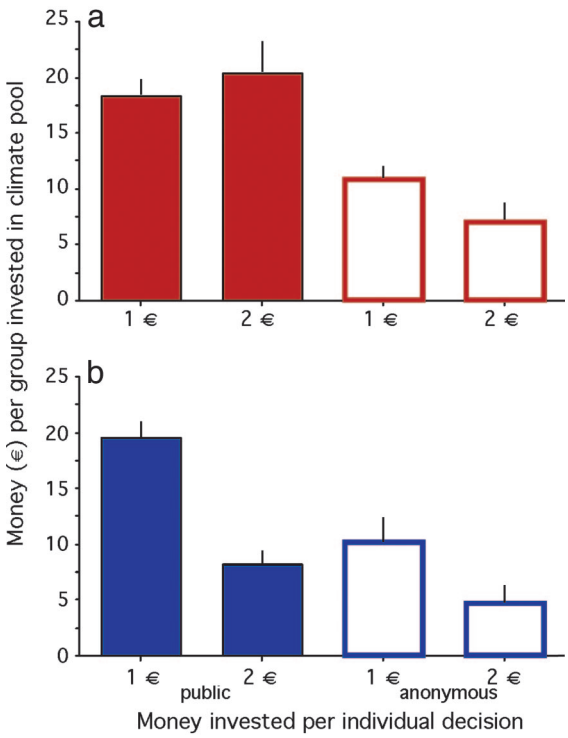

Fig. 3. Money (€) per group of six subjects invested in the climate pool. The mean (±SEM) sum of money invested in €1 and €2 contributions both in nonanonymous (filled) and anonymous (open) climate public goods rounds is shown. (*a*) Well-informed groups. (*b*) Little-informed groups.

coplayers' investments, where conditional cooperators (19) such as "tit-for-tat" players (34) can be persuaded to invest further. Here, self never profits directly from any other player's investment in the public goods game. Groups that invested more money in nonanonymous rounds also invested more money in anonymous rounds both when well-informed ($P < 0.0004$; $n = 13$; $r = 0.84$; $t = 5.03$; two-tailed test) and with little information ($P < 0.005$; $n = 13$; $r = 0.74$; $t = 3.60$; two-tailed test).

Does expert information about the expected change of the global climate enhance the motivation to invest in this public resource? The average cooperation level in nonanonymous climate rounds was higher in well-informed groups (94.4 ± 1.8%) than in little-informed groups (Fig. 1) (81.8 ± 5.5%; $P = 0.009$; $n_1 = n_2 = 13$ groups; $t = 2.879$; two-tailed unpaired t test with arcsine transformed data). Also, in anonymous climate rounds well-informed students were more cooperative (54.6 ± 4.1%) than little-informed groups (39.7 ± 5.0%; $P = 0.03$; $n_1 = n_2 = 13$; $t = 2.309$; two-tailed unpaired t test with arcsine transformed data). Because giving money in anonymous rounds is a purely altruistic behavior, this result shows that pure altruism can be boosted by more detailed information about the global climate.

In nonanonymous rounds, well-informed groups invested significantly more money in the climate account than little-informed groups (Figs. 2 and 3) ($P < 0.005$; $n_1, n_2 = 13$; $t = 3.09$; two-tailed unpaired t test); in anonymous groups, there was only a trend for this difference between well-informed and little-informed groups ($P = 0.06$; $n_1, n_2 = 13$; $t = 2.00$; two-tailed unpaired t test). Compared with little-informed subjects, well-informed subjects invested €2 about three times as often in nonanonymous climate rounds (Fig. 3; $P = 0.01$; $n_1 = n_2 = 13$; $t = 2.72$; two-tailed unpaired t test). Thus, well-informed subjects not only contributed more often, but also higher amounts of money than little-informed students. Even though we used scientific language to transmit expert information about climate change, this information might have reminded people of pictures they probably could not avoid seeing in the news reports of television programs. Therefore, an altruistic framing effect resulting from such memory may be an unavoidable part of the mechanism, which enhances altruistic motivation. This phenomenon also will certainly occur when our findings might be applied. Furthermore, the students might have contributed less if they had been required to invest out of their own pockets instead from an endowment that they had received for taking home if not invested. This potential overestimate of the treatment effect should be contrasted with one potential underestimate. Presumably, people would be more willing to contribute if they were certain that it would be effective in solving the problem.

The altruistic motivation of humans both to invest in stabilizing the climate and to reinforce such investments of other people, which we have found in students, seems promising. Presumably, implementing efficient policies for climate protection is difficult in part because climate prediction is inherently uncertain. The whole picture appears confusing. However, there are many certainties regarding climate change as well. The scientific community and policy makers need to make these certainties explicit while acknowledging that there is more work to be done. Therefore, our finding that expert information about the state of the global climate enhanced human altruistic motivation points to a gap in the publishing policy of the scientific community and policy makers, which can readily be filled.

Our findings show a much greater personal support for stabilizing the climate when the subjects were allowed to make their contributions in public as compared with anonymous investments. Even though previous studies (21–23, 35) showed that recognizable identities allow for reputation building, which as a consequence can increase cooperation in the public goods game, there was no guarantee that this mechanism would work when the money in the common pool is not divided among the players but instead is used to encourage other people outside the present group of six players to reduce their fossil energy use. This result shows that the applicability of our previous findings is not restricted to the conventional public goods boundaries. To test for the external validity of our findings, further studies should address the potentially large heterogeneity across different actors with respect to wealth, vulnerability to climate change, and culture. People also may differ in trading off costs and benefits of climate change abatement. It would be interesting to compare the behavior of undergraduates with, for example, executives in European and U.S. businesses.

The reputation effect that we found in the present study was surprisingly strong (Fig. 2). This finding has huge implications, given that the size of the group of people who will profit from the effect of these investments is enormous. However, the potential profits will not be shared, i.e., divided by all members of the human society. Any gain would be for the benefit of everybody, undivided. Nevertheless, sustaining the global climate is a tragedy of the commons (11, 12), because those who do not invest have a larger net benefit as they rely on others' altruism. If everybody adopts this most profitable strategy, the "commons" will collapse, as Hardin envisaged. However, altruistic behavior may convert to net personal benefit if the gain in reputation is large enough. Designing strategies to improve the social reputation of people investing in climate protection thus ought to figure prominently in climate policy makers' priorities.

Methods

We tested with 156 undergraduates from Hamburg University, who participated in 26 groups of 6 subjects each in a computerized experiment, to see whether they would contribute their own money to sustain the global climate in a public goods game.

The six subjects of each group could see a public screen on which instructions and the actual game was projected. They were told the following: (*i*) that each person had a starting account of €12 and could gain or lose dependent on his/her, and the other participants', decisions; (*ii*) that each player would be assigned a pseudonym, a new identity, for the whole game; and (*iii*) that they would play in two situations, a group game (public goods game) and a two-player game (indirect reciprocity game).

Players were anonymous; each subject was assigned a pseudonym by the computer for the whole session of 20 rounds (the players did not know this number) so that at any time, players could make their decisions contingent on the history of the game up to that time with one exception: in five anonymous climate public goods rounds (see below), pseudonyms were not shown. Each player knew his/her name but did not know who had been assigned the other names; the subjects were separated by opaque partitions and communicated their decisions with silent (piezo) switches; they knew that they would obtain their money after the game in a way that did not disclose their anonymity.

Indirect Reciprocity Game. For this game each person was assigned repeatedly as either a potential donor or a potential receiver. For example, a potential donor, say, Telesto, was asked on the public screen whether he/she would give to Galatea. Telesto would lose €1.50 from her/his account, and Galatea would gain €3 to his/her account if Telesto decided "yes." Telesto's decision (yes or no) was displayed for 2 s on the public screen. Everybody knew about the contributions of all players, for example, whether Galatea had given both in previous rounds when she/he had been playing as a potential donor and in previous nonanonymous climate public goods rounds (see below). The subjects also knew that there would be no direct reciprocity; if A has been the potential donor of B, B would never be the potential donor of A. In each round of the indirect reciprocity game, each of the six players was once a potential donor and once a potential receiver; i.e., there are six "subrounds" for each round of this game.

Climate Public Goods Game. For this game all six players were asked simultaneously whether they would contribute €0, €1, or €2 to the climate pool, the content of which then would be doubled and moved to the climate account. The students knew that the total sum in this account, accumulated from all groups, would be used to publish a press advertisement, the size being determined by the final climate account, in a widely distributed daily German newspaper ("Hamburger Abendblatt"), to be published simultaneously with the present paper. All players were shown the following text: "Professor Jochem Marotzke, Managing Director of the Max Planck Institute for Meteorology in Hamburg, Germany, will briefly summarize the current knowledge of climate change for the text of the advert, and will issue the following recommendations: Some future climatic consequences of human-induced CO_2 emissions, for example some warming and sea level rise, cannot be prevented, and human societies will have to adapt to these changes. Other consequences can perhaps be prevented by reducing CO_2 emissions. Everyday measures can contribute to climate protection. Household energy consumption can be reduced, for example by a slight reduction of room temperature in winter, or in transportation, by enhanced use of public transportation instead of private cars. The increased use of renewable energies likewise contributes to a reduction of CO_2 emissions." (The original German wording is provided in *Supporting Text*, which is published as supporting information on the PNAS web site).

After all players had decided in each round, each player's decision (yes or no) and his/her contribution (€0, €1, or €2) were displayed below his/her pseudonym for 20 s in the nonanonymous climate public goods rounds. In the anonymous climate public goods rounds, the decision and contribution of each of the six players was displayed as before but without any pseudonym. Furthermore, the players knew (*i*) that the position at which a player's decision was displayed would be assigned randomly for each round anew and (*ii*) that any decision made in an anonymous round would never be displayed anywhere; it would be used only by the computer program to transfer €0, €1, or €2 from the player's account to the climate account.

Treatments. Every second group (well-informed compared with little-informed) received written additional expert information about the state of the global climate as follows: "Professor Jochem Marotzke, Managing Director of the Max Planck Institute for Meteorology in Hamburg, Germany, provides the following expert opinion on the state of the climate: Human activities have already demonstrably changed global climate, and further, much greater changes must be expected throughout this century. The emissions of CO_2 and other greenhouse gases will further accelerate global warming. As a consequence, we will have to face more frequent extremes in climate and weather. Heat waves such as 2003 in Europe, with >15,000 deaths in France alone, will occur more often. The water cycle in the atmosphere will increase in strength: arid areas will be drier, humid areas more moist. Droughts, extreme precipitation, and floods will occur more frequently. Sea level will rise, and hence the risk of extreme storm surges. In addition to these risks, there is the danger of abrupt climate change, if climate crosses certain thresholds and undergoes fast, irreversible transitions. For example, the deep circulation in the Atlantic Ocean could collapse, switching off the 'heat conveyor' of Europe. In an extreme case, temperature in northwestern Europe could fall by 3 to 5° centigrade, in 10–20 years. Such a scenario is featured in Roland Emmerich's film 'The Day After Tomorrow,' which has just been released. The climatic consequences shown there are hugely exaggerated and unrealistic, but the underlying cause of an abrupt climate change is not." (The original German text of this message is provided as *Supporting Text*.)

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