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Experimental Insights: Testing Climate Change Cooperation in the Lab

THE SERIOUSNESS OF CLIMATE CHANGE HAS BEEN WELL ESTABLISHED BY the physical and biological sciences. There were also early attempts to recognize the importance of social science in climate change research, such as research on climate-related hazards established at the US National Center for Atmospheric Research in the 1970s (Jamieson 2014), as well as the 1983 edited volume *Social Science Research and Climate Change: An Interdisciplinary Appraisal* (Chen et al. 1983). However, the majority of climate change research remained focused on the natural sciences (Oreskes and Conway 2014).

At the same time, political action to mitigate climate change has been limited—and in the United States, one of the world's largest greenhouse gas emitters, ascribing "limited" to federal political action would be putting it generously. In part, to try to understand the human dimensions behind opposition to climate policy, there have been calls for increased research efforts in the social sciences. Dale Jamieson, philosopher of climate change and author of *Reason in a Dark Time*, said that after the publication of the 2007 Intergovernmental Panel on Climate Change (IPCC) report intergovernmental research should have turned its focus to social questions (pers. comm.).

In the last decade, many social science fields, such as sociology (e.g., Dunlap and McCright 2008), history of science (e.g., Oreskes and Conway 2011), and communication research (e.g., Boykoff and Boykoff 2004), have made large strides in addressing climate change inaction, and some recent work has attempted to synthesize our understanding of the ideological divide over climate change opinion in the United States (e.g., Jacquet et al. 2014).

The field of psychology was one of the first social science disciplines to make gestures toward studying climate-related decision-making (Stern 1992), but it was not until more recently that some psychology research programs became exclusively dedicated to exploring environmental problems like climate change (including the Center for Research on Environmental Decisions at Columbia University, founded in 2004). In 2009, the task force of the American Psychological Association issued a report about the role of psychology in addressing and understanding climate change, and summarized many climate-related experiments (Swim et al. 2011). To date, climate-related experiments in the field of psychology focus on how individuals respond to, for instance, priming (belief in climate change increases with warmer temperatures [Zaval et al. 2014]), framing (Republicans are more likely to support an additional fee if it is labeled a "carbon offset" rather than a "carbon tax" [Hardisty et al. 2010]), and questions about moral intuitions (almost half of US undergraduates believe climate change represents a moral issue [Markowitz 2012]). These methodologies provide valuable insights into certain aspects of decision making, but they are not designed to capture the social dilemma that climate change presents.

Experiments built around cooperation, also referred to as game theory experiments, are able to highlight the social tensions related to climate change decisions. The field of game theory began with von Neumann and Morgenstern (1944), and eventually expanded to include resource-related cooperation dilemmas. Hardin's (1968) qualitative model of the common pasture showed that because benefits of defection are individualized while costs of defection are shared, the result is "the tragedy of the commons." The work on natural resources quickly moved from qualitative and quantitative models into the realm of game theoretical lab experiments.

The prisoner's dilemma is one of the oldest game theoretical experiments. In this setup, two players have the individual incentive to defect rather than cooperate, as defection leads to higher individual payoffs. However, the positive payoffs of defection are contingent on the partner player cooperating, and because the partner player has the exact same starting payoffs, the outcome of mutual defection often occurs and leads to lower payoffs for both players than had they each cooperated. Public goods experiments are mathematical equivalents of *n*-player prisoner dilemmas. Individuals within a group of *n* participants are each given an endowment and told that they can invest part or all of their money in a common pool. They are aware that the experimenter will multiply the contributions to the common pool by some factor (often two) and then divide contributions evenly among all participants, regardless of whether each contributed. The structure of the experiment is nonrivalrous, in that one player's benefits from the public good do not compete with another's benefits, and the payoffs are nonexcludable, in that all players benefit from the public good. The optimal, egalitarian outcome is for everyone to contribute the maximum amount, but a tension arises because an individual can maximize his or her earnings by withholding cooperative investments and free riding off the benefits produced by other members of the group (yet if everyone strategizes this way, there will be no public good provision). This generates a conflict of interest between an individual's performance and the performance of the group, which is the signature of social dilemmas (Dawes, 1980).

Public goods experiments (and other games of this sort) are a cross-disciplinary tool for examining cooperation, and are assumed to uncover actual behavior (rather than, for instance, stated preferences), since participants' earnings depend on their decisions in the experiments. A search in November 2014 of the ISI Web of Science reveals that the field of economics now accounts for almost half of the 1,864 records with the key phrase "public goods experiment," although environmental studies and environmental science together account for 13 percent, and political science accounts for 5 percent of records. The prevailing assumption is that the findings from this body of work, such as the fact that if players can discuss the experiment they also cooperate more, can be generalized to all cooperative decision-making, including decisions related to climate change (Brekke and Johansson-Stenman 2008; Gowdy 2008; Raihani and Aitken 2011). Some researchers have even gone so far as to discuss the findings from their general cooperation experiments from the viewpoint of climate-related decisionmaking (Barrett and Dannenberg 2012, 2014). However, in the last decade scientists have begun modify cooperative experiments to specifically study cooperation in the lab framed by climate scenarios (table 1).

LAB EXPERIMENTS ON COOPERATION AND CLIMATE CHANGE

Milinski et al. (2006) conducted the first game theoretic experiment framed around climate change by modifying a public goods experiment. Participants were given a €12 endowment and could invest €0, €1, or €2 over the course of 20 rounds (although students were not aware of the end point of the experiment). Rather than being doubled and redistributed evenly to all players, any investments in the public good were invested in a newspaper advertisement to increase awareness about the scientific predictions of climate change. The size of the advertisement was determined by the overall contributions, which participants knew. Although all players were given a pseudonym, rounds alternated between displaying the decisions of each player under his/her pseudonym, and rounds in which decisions were completely anonymous. The rounds in which decisions were made public were followed by a two-player indirect reciprocity game, in which players rotated as "donors" of a potential sum of money to other players, whose previous decisions in the public goods experiment were visible. In addition, Milinski et al. (2006) added two treatments: one in which participants were given additional expert information about the state of global climate, and one in which they were not. Cooperation was enhanced in the treatment in which participants were well informed about climate, and it was also enhanced

Table 1: Summary of Climate-Framed Cooperation Experiments to Date

Article	Focal issue	Set-up	Sample characteristics
Milinski et al. 2006	Expert information about climate as well as opportunity to build a reputation	Groups of 6 players participated in a public goods experiment (donations were invested in climate awareness) that alternated between public and anonymous rounds (public rounds were followed by an indirect reciprocity game); half the groups were provided with expert information about climate change.	156 undergraduates from Hamburg University, Germany
Milinski et al. 2008	Perceptions of risk	Groups of 6 players participated in a threshold public goods game with, depending on the, treatment a 10, 50, or 90 percent chance of losing their capital if they did not reach the threshold.	180 undergraduates from University of Cologne and the University of Bonn, Germany
Hasson et al. 2010	Investment in adaptation vs. mitigation	There were two treatments, low-vulnerability and high-vulnerability; groups of 4 participants played a one-shot game in which they could choose to invest in mitigation (the public good) or adaptation (the private good).	64 students from the University of Cape Town, South Africa
Tavoni et al. 2011	Inequality and communication	Groups of 6 players participated in a threshold public goods game with a 50 percent chance of losing their capital if they did not reach the threshold; in some treatments, participants were allowed to communicate their intended contributions.	240 students from University of Magdeburg, Germany
Milinski et al. 2011	Inequality and intermediate targets	Groups of 6 players were randomly assigned as “all rich,” “all poor,” or “3 poor and 3 rich” in a threshold public goods game; there were two treatments, one with intermediate climate targets and one without.	342 students from the Universities of Hamburg, Kiel, and Münster, Germany
Jacquet et al. 2013	Intragenerational and intergenerational time discounting	Groups of 6 players participated in a threshold public goods game that offered an additional endowment if they reached the threshold. That endowment was offered, depending on the treatment, one day later, seven weeks later, or was used to plant oak trees that would sequester carbon.	192 students from Hamburg University, Germany

in the "public rounds" in which participants built a reputation and experienced the costs or benefits of that reputation in the indirect reciprocity game.

The public goods experiment, however, is limited as a metaphor for climate change because in the traditional set-up, if there are any donations to the public pool, every participant gains money no matter what. The problem climate change presents can be even better represented by a threshold public goods game, in which the public good is not attained or distributed unless some minimum contribution is obtained. Milinski et al. (2008) therefore added a threshold to a climate public goods experiment and then tested perceptions of risk. Each participant in a group of six students was give €40 and could donate €0, €2, or €4 over the course of 10 rounds (they were aware of the number of rounds) to a climate fund. If they reached €120 by the end of 10 rounds, they would receive what they had not invested with 100 percent certainty. If the group failed to reach the goal, each participant would lose his/her endowment with a 90, 50, or 10 percent chance, depending on the treatment. Only 5 of 10 groups successfully achieved the target in the treatment with a 90 percent chance of losing everything. In the 50 percent probability treatment, one group succeeded, while no groups succeeded in achieving the climate target in the treatment with a 10 percent risk of losing the endowment. These results confirmed the difficulty of collectively dealing with even high levels (that is, 90 percent) of risk.

Another challenge climate change presents is that the costs and benefits are not evenly distributed: many rich countries accrue the benefits of fossil fuel use while citizens of poor countries are more likely to suffer the costs associated with climate change (Füssel, 2010). However, rich countries also have more to lose. Two experiments to date have tested the inequity's role in cooperative decisions related to climate change.

Tavoni et al. (2011) used a set-up similar to Milinski et al. (2008) but limited their analysis to the 50 percent probability of disaster (that is, for groups that failed to invest a total of €120, individuals lost all remaining money with 50 percent probability). All decisions were anonymous, and the game occurred over 10 rounds. However, the first three rounds involved contributions predetermined by the software so that there was always €36 in the climate account after three rounds. For some groups, the software determined that each player had given €6 in the first three rounds. For other groups, three participants were assigned by the computer €12 donations over the first three rounds and therefore started the game with €48, while the other three participants were assigned €0 in donations over the first three rounds, and therefore entered the fourth round with €40 in capital. After these three fixed rounds, seven active rounds followed, in which all participants made decisions to invest or not. In some treatments, players were given the option to communicate (after round 3 and round 7) whether they planned to contribute during the game. Inequality in the experiment made success more difficult, and when players could communicate, success increased.

Milinski et al. (2011) elaborated on inequality. Asymmetries were not only present in the capital that participants received (as in Tavoni et al. 2011), but also in the potential gains from investment. This threshold public goods experiment promised an additional endowment if participants succeeded in reaching the €120 goal by the end of 10 rounds, in addition to whatever each participant had not spent from his or her operating fund. If the group failed to reach the target, participants lost their endowment with 90 percent probability (and received only what was left in his or her operating fund). There were three different set-ups: a treatment with 6 "rich" participants, who were each given a €40 operating fund and €60 possible endowment; a treatment with 6 "poor" participants were given €20 operating fund and €30 endowment; and a treatment that included 3 "rich" and 3 "poor" participants (with their respective funds and endowments). Each of these three types of treatments was examined in light of two further treatments designed to test two different forms of climate targets. In one, €120 had to be collected by the end of the tenth round (participants knew the number of rounds in both treatments).

In the other, there was an intermediate climate target, where €60 had to be collected by round 5 to avoid a "climate event" occurring with a 20 percent probability in the following five rounds and causing all capital to be lost. Without intermediate targets, all of the rich, 60 percent of the mixed, and none of the poor succeeded in reaching the target. With the intermediate targets, all of the rich, almost all of the mixed, and 60 percent of the poor succeeded in reaching the target, showing the value of near-term goals in assisting cooperation.

In another experiment, Hasson et al. (2010) used a one-shot game to test participants' investments in mitigation, which is a public good (for example, reducing greenhouse gas emissions), versus adaptation, which they considered a private good (for example, building a sea wall in response to sea level rise), in treatments with high and low vulnerability to a simulated catastrophic event. Students were randomly placed into anonymous groups of four and could contribute some amount of their endowment toward either mitigation or adaption. Depending on how many other players made their same choice, the probability of disaster declined. Everyone was at less risk of disaster if all four players chose mitigation, but if anyone chose adaptation, everyone was at higher risk than if they had each chosen adaptation. On average, only 26.5 percent of the participants chose mitigation (the difference between low and high vulnerability was not significant). The differences between adaptation and mitigation can also be considered in light of time discounting, since the benefits of adaptation are often realized more quickly than the benefits of mitigation.

The discounting component of climate change presents another powerful challenge, insofar as many of the sacrifices required today will not yield benefits for many decades to come, sometimes far beyond one generation in the future (Schelling 1995). All climate change cooperation experiments had offered the rewards of cooperating in the climate game immediately after the game. Jacquet et al. (2013) modified a climate change experiment so that the rewards of defection were immediate, but the rewards of cooperation were delayed by one day, delayed by seven weeks, or delayed by decades because donations were invested in planting oak trees that would sequester carbon. Each participant in a group of six received €40 each to invest, and if participants cooperated and pooled together €120, each participant received an additional €45 paid out on these three different time horizons (in the third, the endowment was invested in tree planting). Time discounting led to a marked decrease in cooperation. The majority of groups cooperated when the benefits were paid out the next day; a minority of groups when the benefits were paid out seven weeks later; and none of the 11 groups cooperated in the third "intergenerational" condition, where the benefits of cooperation were used to plant trees and thereby sequester carbon to the benefit of future generations.

DISCUSSION

Cowling (2014) wrote that "conservationists . . . need to get serious about human behavior by following the cue of behavioral economists." The handful of game theory experiments (one tool of behavioral economists) framed specifically around climate change demonstrates this advice is being heeded, albeit at a small scale. Still, some things have been learned that can be generalized to policy.

First, the chance to acquire a reputation, both in climate change experiments (Milinski et al. 2006) and other cooperation experiments, has made individuals more cooperative. It is also important to note that the effects of reputation scale to the group level (for example, countries or corporations; [Jacquet 2015]), which means that the tool of reputation should be of great interest to policymakers. The reputation of the information about climate change also matters to cooperation (Milinski et al. 2006), which is why it is important to establish the trustworthiness of the science of climate change, which the IPCC has also encouraged, and important that trustworthy global leaders (for example, Pope Francis) engage with the topic.

Research shows that members of the public consistently misinterpret the verbal IPCC descriptions of uncertainty as underestimates

(Budescu et al. 2012; 2014), and Milinski et al. (2008) highlighted why this matters in cooperation dilemmas. The likelihood of cooperation is higher when people believe the probability of losing their funds is higher, but even with high rates of certainty—a 90 percent change of loss—only 50 percent of groups cooperated to meet the "climate target." This means that we must be cognizant of our poor dealings with the interpretation and avoidance of collective risk, and work not only to give the public a more accurate perception of collective risk, but also a richer education in decisionmaking that involves a high probability of loss.

Another problem posed by climate change is that the costs of many proposed policies (for example, a carbon tax or cap-and-trade) are felt immediately, while our grandchildren will be the ones to experience many of the benefits of those actions (Jacquet et al. 2013). A policy perspective that tries to incorporate actions with both immediate and long-term benefits is likely to be more acceptable than a policy that results in only long-term gains. This might also mean that adaptation to climate change could be more attractive than mitigation—not only because the benefits are more privatized, but also because the benefits of adaptation often occur sooner.

We have learned as well from this work about how to tweak the features of cooperative experiments to best model the climate change scenario. The threshold public goods experiment appears to be a better model for climate change than just a public goods experiment because some minimum contribution must be attained for the public good to be provided. In addition, the target donation lies at the end of several rounds and allows participants to make up for less cooperative participants, but no single player is capable of ensuring the group's success, and often the majority of defectors guarantees that the threshold cannot be met. The element of risk is also a valuable addition to the set-up given the important role of risk perception to the problem of climate change (although, individuals, at least in the United States, tend to believe that the costs of climate change will occur later in the future than scientists expect; [Swim et al. 2011]). It is also possible to analyze decision making in participants with asymmetrically allocated resources. Delaying the benefits of cooperation is also an option in experimental set-ups to model the issue of time discounting.

We can expect to see more game theoretical work in the future, and perhaps some experiments will address some of the major factors the field of psychology has identified as barriers to climate action (Swim et al. 2011), including uncertainty about the severity of climate change, mistrust of information, and feelings of personal insignificance, which seem important and distinct from the experimental arrangements to date, where participants form a group of six and every player is given a significant role in the dilemma. Jamieson (2014) identified some of main difficulties of conceptualizing the issue of climate change as a moral problem, including the challenges of understanding who (or what) is most responsible for the harm, whether the harm is intentional, and how closely the action and the harm are related in space and time. All of these questions—about responsibility, intentionality, and the relation of action and harm—are testable and findings would provide valuable insights. There are also questions that have been asked repeatedly with similar results, such as public goods experiments that show communication enhances cooperation (including one of the first public goods experiments, Dawes 1977) and these questions should not continue to be asked at the expense of more novel ones.

Lab experiments can provide insights to human behavior (Falk and Heckman 2009), but there are also obvious limitations. In general, social scientists have been critical that participants are WEIRD—that is, that they come from Western, Educated, Industrialized, Rich, and Democratic cultures (Henrich et al. 2010). In the climate cooperation experiments to date, participants are even WEIRDer: with the exception of one study done with South African students, all have used German students (table 1), which might lead to greater cooperation than if participants had been drawn from the United States, especially given the ideological divide and high rates of denial and skepticism in the United States over climate change (Jacquet et al. 2014). Given that the United States and China together account for

40 percent of global greenhouse gas emissions, it seems important that these two cultures be represented and even a targeted sample in social science experiments.

Even if cultures from the United States and China were better represented in lab experiments, questions would remain about how well results from lab experiments generalize at scale. In the real world, the climate problem is not being addressed by six participants, but by hundreds of countries, corporations, and other institutions, which all come to climate negotiations with different sets of resources and political power and influence. Just 90 corporations (some of them state-owned) are responsible for supplying nearly two-thirds of historic carbon dioxide and methane emissions (Heede 2013). Cities around the world account for 50 percent of the population but are responsible for 80 percent of greenhouse gas emissions and are addressing climate change to different degrees. What makes some cities more prone to action over inaction, or mitigation over adaptation? Do findings from game theory experiments generalize to the city level?

The limitations of lab experiments speak to the importance and need for all forms of social science to address questions about the politics of climate change. In this century, the most important questions related to climate will be social ones. Game theory experiments will be just one of many modest tools used to address one of humanity's most immodest problems.

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