COMMENTARY

Paths to climate cooperation

Thomas Dietz[a,1] **and Jinhua Zhao**[b]

[a]*Department of Sociology, Environmental Science and Policy Program, and Animal Studies Program, and* [b]*Environmental Science and Policy Program and Departments of Economics and Agricultural, Food and Resource Economics, Michigan State University, East Lansing, MI 48864*

Climate change is the largest commons governance problem that humanity has ever faced. Emissions of greenhouse gases anywhere in the world contribute to radiative forcing everywhere. The impacts of climate change vary greatly from place to place, and the vulnerability to those impacts differs across human groups and across other species, even in a single location. The five nations with the largest CO_2 emissions in 2008 were responsible for less than 60% of total global CO_2 emissions (1). Although the action of a moderate number of the largest emitters could have some effect, substantial reductions in climate risk will depend on cooperative action across many nations. However, the costs of reductions are borne by each nation individually, whereas risk reduction is shared by all nations. Getting self-interested and often distrustful nations to cooperate is a major obstacle to addressing the climate problem. So far, international agreements have not had much impact on the trajectory of emissions or the concentration of greenhouse gases in the atmosphere. In the midst of this impasse, Heitzig et al. (2) offer an analysis that may show a way out, and they certainly suggest important avenues for additional analysis. Their work (2) falls clearly in what Stokes (3) labeled "Pasteur's Quadrant"—like the work of Louis Pasteur, it contributes to fundamental knowledge and is clearly useful.

The Game of Climate Policy

Game theory is one of our most powerful tools for making sense of commons problems like climate change. The games of game theory are situations in which the outcomes that result from my decisions depend on what you decide to do. To find the best strategy, I must take account of what your strategy will be. Unfortunately, as Nash (4) showed, each of us projecting what the other may do can lead to outcomes neither of us would prefer. In the case of the atmosphere as a commons, if my nation bears the costs of reducing greenhouse gas emissions but other nations do not act, the reductions in risk from climate change will not be very substantial—no single nation can have much effect. Additionally, if other nations do not cooperate, my nation will have borne all of the costs of emissions reductions but will not see less risk from climate change. Conversely, if other nations reduce emissions but my nation does not, we receive the benefits of reduced risk without the costs of emissions reductions. The result could be the classic tragedy of the commons in which each nation has incentive to free ride and undertake little or no reduction in emission, and thus, all nations bear substantial risks as the climate warms.

However, game theory is richer than that simple and grim conclusion. Since its first elaboration by Von Neumann and Morgenstern (5), it has revealed that there are situations in which cooperation can emerge. Indeed, the literature on commons shows that, although sometimes it has been impossible to secure cooperation with the result that commons collapse, it is also possible for commons to be managed quite successfully over long periods of time without serious degradation of a resource (6, 7). Game theory provides useful theoretical insights into how commons governance might be designed to encourage cooperation and discourage the kind of behavior that leads to resource degradation (8, 9). Game theory applied to the design of international environmental agreements can help to find strategies that promotes participation and abatement by most, if not all, emitters (10, 11).

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If we assume that each nation will act rationally in its own self-interest, then the path to reducing climate risk is to design a set of rules for emissions to which countries will agree, because they find it beneficial. Punishments for not meeting greenhouse gas emissions targets are an important part of such designs. However, such punishments can be costly in several ways. First, nations may choose not to participate if they feel that they will be punished. The substantial uncertainty about some aspects of climate change may make nations leery of committing to binding targets for emissions and punishments for missing those targets. Our estimates of the amount of climate change that will occur in response to any particular level of greenhouse gas emissions are somewhat uncertain. There is considerable uncertainty about the exact amount of damages that may occur and who will suffer those damages as well as about how easy it will be to meet targets. Second, most punishments impose costs on both the punished and the punisher. For example, trade sanctions certainly hurt the nation being sanctioned. However, the reduction of trade can also harm the nations who impose the sanctions. Third, for both of these reasons, nations imposing the substantial punishments as well as those nations facing them may attempt to renegotiate the terms of the agreements. Therefore, punishments, although essential for generating compliance, can also lead to pressure to not participate or change an agreement and thus, obviate its benefits.

A Path to Cooperation

Heitzig et al. (2) offer a mechanism, linear compensation (LinC), that gets past many of these problems. Under LinC, if a nation does not meet its reduction target, it does indeed face a punishment—a penalty in the form of an increased target for next year. However, unlike the Kyoto Protocol where the punishment is a fixed multiplier of 1.3 times the shortfall, the LinC punishment is adjusted relative to the performance of other nations. If most other nations also failed to meet their targets (that is, if the average of underperformance is substantially greater than zero), the punishment for each nation is less. In fact, it is proportional to how much below average performance a nation falls. Nations are punished most for being far from the norm of how other nations performed rather than being judged on an absolute basis.

This approach has great intuitive appeal. One the one hand, if technological advances make it relatively easy to reach

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[1]To whom correspondence should be addressed. E-mail: tdietz@msu.edu.

targets and most nations do hit their targets or come close, then the penalties for nations that underperform are relatively large. On the other hand, if it turns out that it is harder to reduce emissions than was anticipated and most nations fall short, then the penalties are relatively smaller. Therefore, LinC is an effective way of dealing with our uncertainty about how difficult it will be to reduce emissions. Furthermore, it is well-established in social psychology that descriptive norms—information about how you are doing relative to others in your peer group—are an exceptionally powerful influence on behavior (12). LinC bases expected performance on a kind of descriptive norm—how well a nation is doing compared with others. While some kinds of norms clearly play a role in international affairs, we do not know if the idea of descriptive norms applies in the same way to the behavior of nations, but it is an intriguing idea.

Heitzig et al. (2) do more than simply offer an intuitively appealing way of structuring an international agreement to reduce greenhouse gas emissions. They go on to show that the LinC approach produces agreements to which rational actors will adhere: the net benefits of cooperating will always outweigh the net benefits of defecting, and the LinC strategies are subgame perfect so that they are robust to empty threats. Furthermore, along the equilibrium path, the outcomes can be made Pareto-efficient if the agreement stipulates first best abatement levels. Of course, some might consider the assumptions that nations are rational actors or that they have perfect information unrealistic (13). Indeed, Heitzig et al. (2) identify several interesting paths for relaxing the assumptions and developing experiments to elaborate our understanding of how LinC performs.

There are additional research challenges ahead. Because participation in international environmental agreements is voluntary, a self-enforcing agreement requires that a nation has leverage: my decision to undertake abatement, through the mechanism of the agreement, can influence the abatement decisions of other nations (14). In the LinC approach, leverage is achieved by the punishment mechanism: if I abate less in period t, other nations will abate less in period $t + 1$. It is, thus, conceivable that, along certain off-equilibrium paths, all nations will engage in too little or no abatement. However, given the obvious gains from cooperation, renegotiation may be warranted. Although Heitzig et al. (2) establish that the LinC strategies are renegotiation-proof along the equilibrium path (i.e. when nations abate at the agreed levels), more research is needed to find strategies that are renegotiation-proof in all subgames, including those games off the equilibrium path. Although assuming nations are the primary actors is a useful starting place for analysis, climate policy involves a complex, polycentric network of state, substate, and nonstate actors, many of whom may not be well-described by rational actor assumptions (even if nations can be) but all of whom are engaged in social learning (15, 16). This complexity need exploration both theoretically and empirically.

Domestic climate policy debates often focus on concerns that other nations will free ride. LinC offers an approach to discussing this issue that might move us past the current political impasse. Of course, as Heitzig et al. (2) acknowledge, LinC does not speak to how initial reduction targets are set. However, as it becomes increasingly clear that the world is almost certainly moving past the 2 °C target that is usually seen demarking dangerous interference in the climate system (17), even modest agreements that show the viability of international cooperation are warranted. LinC may aid us in moving in that direction; at a minimum, it points to new paths to explore.

1. United Nations Statistics Division (2011) *Carbon Dioxide Emissions (CO2), Thousand Metric Tons of CO2 (CDIAC)* (United Nations, New York).
2. Heitzig J, Lessman K, Zou Y (2011) Self-enforcing strategies to deter free-riding in the climate change mitigation game and other repeated public good games. *Proc Natl Acad Sci USA* 108:15739–15744.
3. Stokes DE (1997) *Pasteur's Quadrant: Basic Science and Technological Innovation* (Brookings Institution, Washington, DC).
4. Nash JF (1950) Equilibrium points in N-person games. *Proc Natl Acad Sci USA* 36:48–49.
5. Von Neumann J, Morgenstern O (1944) *The Theory of Games and Economic Behavior* (Princeton University Press, Princeton).
6. Ostrom E, et al. (2002) *The Drama of the Commons* (National Academy Press, Washington, DC).
7. Dietz T, Ostrom E, Stern PC (2003) The struggle to govern the commons. *Science* 302:1907–1912.
8. Fehr E, Gintis H (2007) Human motivation and social cooperation: Experimental and analytical foundations. *Annu Rev Sociol* 33:43–64.
9. Ostrom E, Gardner R, Walker J (1994) *Rules, Games and Common-Pool Resources* (University of Michigan Press, Ann Arbor, MI).
10. Finus M (2008) Game theoretic research on the design of international environmental agreements: Insights, critical remarks, and future challenges. *Int Rev Environ Resource Econ* 2:29–67.
11. Barrett S (2003) *Environment and Statecraft* (Oxford University Press, Oxford).
12. Schultz PW, Nolan JM, Cialdini RB, Goldstein NJ, Griskevicius V (2007) The constructive, destructive, and reconstructive power of social norms. *Psychol Sci* 18:429–434.
13. Young OR, Schroeder H, King LA, eds (2008) *Institutions and Environmental Change: Principal Findings, Applications, and Research Frontiers* (MIT Press, Cambridge, MA).
14. Karp L, Zhao J (2010) International environmental agreements emissions trade, safety valves and escape clauses. *Revue Economique* 61:153–182.
15. Henry AD (2009) The challenge of learning for sustainability: A prolegomenon to theory. *Hum Ecol Rev* 16:131–140.
16. Ostrom E (2010) Polycentric systems for coping with collective action and global environmental change. *Glob Environ Change* 20:550–557.
17. Clarke L, et al. (2009) International climate policy architectures: Overview of the EMF 22 International Scenarios. *Energy Economics* 31(Suppl 2):S64–S81.