Strategic Logic of Unilateral Climate Intervention

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Abstract

Climate change and unabated greenhouse gas emissions are increasing the possibility that the world will turn to climate intervention to curb ever-increasing global temperatures. To date, most work on this topic has imagined that an international organization like the United Nations or an international coalition of states will synchronize their efforts to deploy climate intervention at ideal latitudes to maximize global effect. Nearly all climate model simulations run-to-date have assumed this. Thus, our understanding of the science of climate intervention is largely based on an ideal of perfect geopolitical coordination. However, geopolitical uncertainties make this scenario unlikely and the costs of climate intervention are sufficiently low that many states could comfortably finance a climate intervention program that could have global consequences. This paper uses game theory to elucidate the conditions that might make a state more or less likely to begin unilateral climate intervention (UCI). We solve this game for several specific scientific, economic, and climatological conditions that change the likelihood of a government starting its own climate intervention program without the participation of the broader international community. Specifically, we demonstrate that the plausibility of UCI is linked to our scientific understanding of three key elements: (1) the effectiveness of climate intervention strategies, (2) the sensitivity of specific governments to punishment by other states, and (3) satisfaction with climate and weather in the present. We conclude by discussing how this formal game theory model informs the design of future earth system model simulations of UCI, international agreements related to climate intervention, and the development of solar climate intervention technologies.
Introduction

Climate change is unfolding in the present as humanity continues unabated greenhouse gas emissions globally (Masson-Delmotte et al. 2021). Extreme heat and precipitation events, disastrous flooding, and sea level rise are realities in the present and increasingly provide a window into the future of environmental disasters (Davenport et al. 2021). Despite this, policy commitments are consistent with a world that will likely warm by a global mean of at least 2 degrees Celsius globally (Diffenbaugh and Barnes 2023, SEI et al. 2021). Moreover, those policy commitments are falling far short of what is needed to minimize temperature increases and avoid potentially dangerous earth system change (Armstrong McKay et al. 2022).

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If temperatures become intolerable, there may be interest in other methods for avoiding the most dangerous impacts of climate change. One such method could be solar climate intervention (SCI) (Burns et al. 2016). Broadly speaking, solar climate intervention refers to the process of deliberately reflecting more of the sun’s energy back to space (Keith 2020). The most widely researched approach to global SCI is stratospheric aerosol injection (SAI), which involves the dispersal of aerosols in the earth’s stratosphere (NASEM 2021). While there is currently no widespread, active program of SAI, increased attention on SAI suggests a need for wide-ranging scenarios that explore numerous possibilities of both the rationale of how SAI may be pursued, and the associated details of how this may unfold.

Climate model scenarios simulated-to-date have largely focused on the scientific plausibility of SAI. These scenarios of SAI include both detailed sensitivity analyses of various levels of deployment (MacMartin et al. 2022) and archetypical scenarios for various types of SAI (Lockley et al. 2022). The goal of scientific plausibility has incentivized running scenarios where SAI can be deployed at ideal locations on the Earth to maximize its effects on climate, with little attention to geopolitical plausibility of coordinated deployment across the world’s surface. As a result, the community has gained an improved understanding of the physical science and impacts of SAI, but this knowledge rests on assumptions about international relations that are inconsistent with contemporary geopolitical realities. Specifically, geopolitical uncertainties make a coordinated strategy unlikely and the costs of climate intervention are such that an individual state could act alone (Eliason 2021). This is the so-called “free-driver” problem, whereby a single actor (or limited set of actors) could affect the entire earth system (Heyen et al. 2019). Likewise, detailed, technical analysis of the costs and logistics associated with a continuous program of SAI deployment are now available (Smith and Wagner 2018). A primary conclusion of this work is that, relative to global costs of decarbonization, maintaining a globally-effective SAI program is notably inexpensive So, while climate simulations have favored coordinated,
global deployment of SAI, it is plausible that SAI could be pursued unilaterally, without any international coalition (Rabitz 2016). As such, there is an urgent need to develop tools with which we can rigorously explore the potential for unilateral climate intervention (UCI).

Game theory is a useful tool for formally describing and modeling how a certain set of assumptions about state actions, beliefs, and available strategies could lead to a decision like unilateral climate intervention (Urpelainen 2012, Heyen et al 2019). Unlike individual narrative explanations for UCI, creating and solving a simplified UCI game allows us to identify conditions that might make different UCI outcomes—including, for example, sanctions, continued UCI, or a decision to start and stop UCI—more or less likely. Such an analysis would provide new theoretical insight, both into the types of actors that might pursue UCI, as well as the types of strategic interactions that could unfold following the initiation of UCI. Importantly, it could also point to specific international actions that could make lone states much less likely to experiment with UCI in the future.

Formal models are not predictions of the future and they cannot represent the complexity of climatological and political systems. They can, however, reduce strategic decisions to their base elements and then leverage logical implications to understand what might affect the decision to pursue UCI, including beliefs about the future, vulnerability to punishment from other states, and satisfaction with weather in the status quo, might alter climate intervention decisions in some counterintuitive ways. The next section introduces a novel two-player UCI game and is followed by solutions to the game. The paper concludes with a discussion of the limitations of the analysis and specific implications for climate intervention and international environmental governance.

**Formal Model**

This section sets up the game, and the solution is provided in the following section. Imagine a simplified model of the world in which one state, an *Initiator*, possesses the ability to begin unilateral climate intervention (UCI) and another state, the *Respondent*, must then choose to either stand by or punish the *Initiator*, perhaps through economic or military sanctions. We can model the conditions that might compel the *Initiator* to use UCI with a three-move game, which is depicted in the extensive form in Figure 1.
The game begins when the Initiator decides to start UCI ($g$) or not ($\sim g$). If the Initiator does not use UCI, the game is over and both states receive the climate in the status quo path indefinitely. The payoffs for this outcome are represented mathematically by the terms \(\frac{w_I}{(1-\delta)}\) and \(\frac{w_R}{(1-\delta)}\), with the desirability of each state’s climate unaltered by UCI ($w_I$ and $w_R$) ranging from 0 to 1. Future payoffs are calculated by dividing by the term $1 - \delta$, where $\delta$ ranges from 0 to 1 and represents the extent to which each state discounts payoffs in the future vis-à-vis the present. States with a higher $\delta$ place more value in the future, while states with a lower $\delta$ are primarily concerned with the present and care relatively less about long-term costs or benefits. This is the standard notation for representing future payoffs in game theoretic modeling (Gibbons 1992).

Should the Initiator begin UCI, it suffers the cost of $c$. This cost can represent any combination of financial and non-pecuniary penalties that the Initiator must endure should it choose UCI ($g$). UCI also creates altered climate conditions for the Initiator and the Respondent, represented by $g_I$ and $g_R$. These outcomes could be better or worse than climate in the status quo ($w_I$ and $w_R$), so let each of these terms range independently from each other between -1 and 1. The Initiator’s payoff for UCI in a single period,
independent from the reactions of other states, is therefore $g_i - c$. The Respondent does not pay the costs of UCI, so it receives $g_R$. Due to the complexity of the global climate, the exact values of $g_i$ and $g_R$ are unknown until UCI is attempted at scale. To model this revelation of new information, we follow the game theoretic literature (Gibbons 1992) by allowing an entity called Nature to randomly define and reveal the heretofore unknown values of $g_i$ and $g_R$ after and only if the Initiator decides to use UCI. This reveal effectively divides the game into two parts. After Nature reveals the true effects of UCI, the Initiator and Respondent act with complete information about UCI. Before Nature’s reveal, the Initiator must decide whether it will initiate with beliefs about UCI, but crucially, no concrete knowledge of the outcomes of its decision to initiate UCI.

After Nature reveals $g_i$ and $g_R$, each state has one decision left to make. First, allow the Respondent to experience the effects of UCI and then decide whether to punish ($p$) or not punish ($\sim p$) the Initiator. Punishment—used interchangeably with “sanctions” below—imposes costs equal to $x$ on the Initiator, but the act is not costless for the punisher. The Respondent suffers costs equal to $s$ when it applies sanctions. After all, the implementation of sanctions entails costs on countries that must now mobilize their militaries or suffer from decreased or less efficient international trade (Martin 1993). If the Respondent applies sanctions, the Initiator’s payoff for using UCI at a given time decreases to $g_i - c - x$. Meanwhile, the Respondent receives a payoff of $g_R$ for that time period if it does not apply sanctions or $g_R - s$ for that time period if it does. Whether these payoffs are indefinite into the future, and thus divided by $1 - \delta$, depends on what the Initiator chooses to do in the game’s final move.

The game ends when the Initiator decides what it will do after observing the true outcome of UCI and the Respondent’s willingness to punish. Having made these observations, the Initiator can decide to cease UCI ($\sim g$) or continue it indefinitely into the future ($g'$). When UCI is continued into the future, the payoffs described above are divided by $1 - \delta_i$ for the Initiator and $1 - \delta_R$ for the Respondent. However, when UCI is stopped, states receive the payoffs for UCI only once and then return to the status quo payoffs of $\frac{w_i}{(1-\delta_i)}$ and $\frac{w_R}{(1-\delta_R)}$.

Solutions

We solve the game for subgame perfect Nash equilibria through backwards induction by starting with the final decision and determining what each player would do, assuming earlier decisions were to deliver a player to that decision node. By doing so, we can identify the sets of conditions that allow each of the
outcomes listed above to occur, given each state’s payoffs and beliefs at each stage of the game (Gibbons 1992). A complete technical solution is provided in the supplementary appendix, while the main text outlines the basic logic of the game and summarizes the principal implications. Most importantly, we identify important thresholds linked to the efficacy of UCI both for the Initiator ($g_I$) and the Respondent ($g_R$).

Beginning first with the Initiator, we identify two thresholds, which we shall label $g_I^L$ and $g_I^H$ and define as follows:

**Definition 1:** Let $g_I^H \geq w_I + c + x$ represent the range of $g_I$ at which $I$ strictly prefers $g'$ to $\sim g$, regardless of $R$’s decision in the previous move.

**Definition 2:** Let $g_I^L \leq w_I + c$ represent the range of $g_I$ at which $I$ strictly prefers $\sim g$ to $g'$, regardless of $R$’s decision in the previous move.

When Nature reveals that $g_I$ is low enough to satisfy $g_I^L$, then the Initiator will stop UCI in the second period regardless of whether it is punished. Knowing that this is a strict preference and also wanting to avoid the unnecessary costs of implementing sanctions, the Respondent would never apply costly sanctions needlessly. Therefore, $UCI \text{ Withdrawn (} g, \sim p, \sim g \text{)}$ is the only outcome that is in equilibrium once Nature has revealed a poor UCI outcome in the range of $g_I^L$. A similar threshold exists if $g_I$ is sufficiently high. If $g_I$ is so favorable as to satisfy $g_I^H$, then the Initiator would continue to use UCI even if that meant it would surely suffer punishment from the Respondent. But once again, punishment is costly to the punisher and the Respondent would never suffer costs with no hope of the punishment being effective. Thus, the only outcome that can occur in equilibrium when $g_I$ falls above the threshold $g_I^H$ is $UCI \text{ Tolerated (} g, \sim p, g' \text{)}$.

**Lemma 1:** $R$ will **never** punish if Nature reveals that $g_I$ is in the ranges described by $g_I^L$ or $g_I^H$.

Between these thresholds ($g_I^L \leq g_I \leq g_I^H$), the Initiator is satisfied with UCI outcomes enough to continue, but not so satisfied that it would continue UCI if that meant it would suffer punishment from the Respondent. We define the outcomes of UCI between these thresholds as $g_I^M$.

**Definition 3:** Let $w_I + c \leq g_I^M \leq w_I + c + x$ represent the range of $g_I$ at which $I$ will choose $\sim g$ if $R$ punishes, but $g'$ if $R$ does not punish in the previous move.
Here, the Respondent controls the outcome of the game and this decision is dependent upon how it is being affected by UCI, which is labeled $g_R$. Call the threshold at which the Respondent would apply sanctions $g_R^*$:

**Definition 4:** Let $g_R^* = w_R - \frac{s(1-\delta_R)}{\delta_R}$ represent the threshold at which $R$ is indifferent between punishing and not punishing $I$, given the condition $g_I^M$ (see Definition 3). Let $g_R^M$ represent the values of $g_R$ in $g_R \geq g_R^*$ and let $g_R^L$ represent the values of $g_R$ in $g_R \leq g_R^*$.

Above this threshold, the effects of UCI on the Respondent are good enough that the Respondent would rather tolerate UCI than apply sanctions, meaning the only equilibrium is **UCI Tolerated** ($g, \sim p, g'$). Below this threshold, continued UCI would trigger sanctions and the only equilibrium is **Successful Sanctions** ($g, p, \sim g$).

![Figure 2: Possible Outcomes Following Nature’s Reveal of $g_I$ and $g_R$.](image)

At this point we understand what will happen once Nature reveals the results of UCI and this is illustrated in Figure 2. However, the players can only arrive at this point in the game if the Initiator’s beliefs are such that it will give Nature an opportunity to reveal $g_I$ and $g_R$ in the first place. This decision depends upon the Initiator’s ex ante beliefs about how UCI might unfold. Let these beliefs about $g_I$ and $g_R$ be represented by $\Theta_I$ and $\Theta_R$, respectively.
If the Initiator believes UCI will be worth the costs regardless of any punishment, \((\Theta_I \geq g_I^H)\), then I will always choose to initiate UCI and the outcome of the game will depend on the revealed values of \(g_I\) and \(g_R\). Even if I is cautiously optimistic about how UCI will affect its own climate \(g_I^l \leq \Theta_I \leq g_I^H\), it may still use UCI if it believes that \(g_R\) will be good enough for the Initiator to escape any punishment \((\Theta_R \geq g_R^*)\). Here again, these beliefs will cause the Initiator to test UCI and the ultimate outcome of the game will depend on Nature’s determination of \(g_I\) and \(g_R\).

Likewise, if the Initiator is pessimistic about the outcome of UCI \((\Theta_I \leq g_I^l)\), then it will never initiate. Even cautious optimism about its own outcome will not incentivize UCI if this cautious optimism \((g_I^l \leq \Theta_I \leq g_I^H)\) is paired with pessimism for the Respondent \((\Theta_R \leq g_R^*)\). This is because this combination of beliefs will cause the Initiator to anticipate punishment that it is not willing to tolerate. With beliefs in these ranges, the only outcome in equilibrium is the Status Quo \((-g)\).

When we layer the beliefs that entice the Initiator to intervene in the climate alongside the effects of intervention as revealed by Nature, many equilibria emerge. These are illustrated in Figure 3. We see that the Initiator will experiment with UCI only when its beliefs about the outcome are very optimistic \((\Theta_I \geq g_I^H)\) or when it is only cautiously optimistic for itself, but also optimistic for the Respondent \((\Theta_R \geq g_R^*)\) and \(g_I^l \leq \Theta_I \leq g_I^H\). Next, we turn to the factors that determine these thresholds, and therefore, the likelihood of unilateral climate intervention,
Figure 3: The Initiator’s Beliefs ($\theta_I$, $\theta_R$) and UCI Outcomes ($g_I$, $g_R$).

### Formal model implications

This formal model elucidates several conditions under which unilateral climate intervention may become more plausible, even when accounting for the possibility of punishment from another state. This section discusses further implications of the model and points to predictors of future unilateral climate intervention and several avenues for future research. Specifically, several conditions might increase the likelihood that a state pursues a strategy of unilateral climate intervention:

**Worse conditions in the present (low $w_I$):** When states are less satisfied with their climates in the status quo, our game theory solution suggests that UCI is more likely to be seen as worth any costs, punishments, and risks of failure. This is because deep dissatisfaction with the status quo causes potential initiators to become more acceptant of even mildly successful interventions. Worse conditions in the present “lower the bar” for what constitutes a worthwhile climate intervention, meaning that governments facing graver conditions in the present should be much more likely to turn to UCI in the near-term, all else being equal.
More confidence in UCI outcomes (high $\theta_1, \theta_R$): Even if we assume that all states will have similar access to scientific information about the global effects of UCI, climatological factors will cause some states to be more confident of their own local outcomes than others. For example, some forms of UCI, such as stratospheric aerosol injection, may be associated with more predictable consequences at certain latitudes (Labe et al. 2023, Hueholt et al. 2023). Thus, a country’s location on the surface of the Earth may be a key determinant of beliefs in climate intervention effects.

Lower—or less sensitivity to—UCI costs (low $c$): Some states are going to be more sensitive to the financial and political costs of initiating UCI than others. Recent research on stratospheric aerosol injection (SAI) suggests a globally effective program could be financed for less than $5$ billion per year (Smith and Wagner 2018), and this is well within reach of many of the world’s largest economies. These costs will vary by region. Recent scientific research also suggests that the efficiency of UCI methods like SAI vary greatly based on where on the planet these methods are used. Dai et al. 2018, for example, found that SAI at mid-latitudes may have greater effect than SAI deployed in the southern hemisphere or near the equator. Non-financial costs, including political “audience costs” imposed by unsupportive voters, could also deter governments from taking action (De Mesquita et al. 2005). Countries experiencing more political stability and greater insulation from political opinion (non-democratic states and illiberal democracies) could therefore be more accepting of the risks inherent in experimental UCI, relative to budget-constrained governments that must soon face voters (Allen 2008). Together, this suggests the states facing the lowest costs for experimenting with UCI could be wealthy, northern, mid-latitude states that face limited political competition.

Less sensitivity to punishment from other states (low $x$): Countries with substantial exposure to punishment from other states may be less likely to deploy UCI. This is because the more impactful a punishment is expected to be, the greater the results of UCI must be for a government to consider it worthwhile. Examples of countries that are more vulnerable to punishment, and therefore less likely to pursue UCI, include those that are highly dependent upon foreign imports of critical goods (Tostensen and Bull 2002), or, in the case of UCI methods like SAI, those that could be severely affected by restrictions on their use of neighboring states’ airspace. Many types of climate intervention rely upon specific chemical compounds and/or advanced capabilities to build and launch high-altitude aircraft. Self-sufficient or autarkic countries with domestic resources and capabilities are substantially less vulnerable to targeted sanctions. These vulnerabilities give potential respondents incredible leverage, and they therefore substantially influence an initiator’s cost-benefit comparison (Bapat et al. 2013). Countries that are less vulnerable to international airspace closures, such as coastal countries, or countries that export
goods on which others are very dependent, such as energy products, are among the least sensitive to post-UCI punishment from other states. This may make them the most likely initiators.

Lower probability of punishment (high $s$ and low $\delta_R$): From the perspective of a prospective respondent, some potential initiators are more costly to effectively punish than others (Tostensen and Bull 2002, Pape 1997). Punishment is least costly to implement when the target of the punishment is relatively powerless and unable to retaliate. Conversely, large and powerful states have significant leverage in the international political economy and they can be both difficult and costly to coerce. The cost of effective punishment against these states can become too expensive to bear, even if another state’s implementation of UCI degrades its climate. Some economists and international relations experts point to the high costs of effective sanctions to claim that sanctions are often ineffective if used (Pape 1997). As our game theory model shows, fears that sanctions will not be effective can dissuade potential respondents from punishing other states in the first place (Smith 1995).

Our analysis also suggests that some states may be more willing to punish than others based on how much they discount the future ($\delta_R$). UCI should be more likely when countries with the greatest leverage to punish a UCI initiator—major trading partners or geographic neighbors, perhaps—have significant problems in the present and therefore lack the luxury of prioritizing longer-term goals like climate actions. Governments facing pressing political problems are less likely to trade the short-term costs of imposing punishment for the long-term gains that punishment might produce (McLean and Whang 2014). In these cases, the short-term harm of sanctions enforcement may not be worth longer-term marginal changes in climate conditions. On the other hand, countries with trading partners and neighbors with more social stability and economic well-being may be more likely to place higher value on non-pressing longer-term policy goals, making them much more likely to implement costly punishment in the present so that they might realize longer-term benefits.

Implications and Limitations

Proponents of economic globalization and multilateral global governance typically assume that the interdependence created by globalization and governance decreases the likelihood of one state pursuing selfish interests at the cost of its political and economic partners (Keohane and Nye 2011). The model presented above casts some doubt on this generalization. If interdependence increases a potential initiator’s exposure to punishment, but also makes punishment more costly for the respondent, then these changes could offset each other or even make UCI more likely. As the costs of punishment increase for a respondent, UCI must do more damage before the high cost of imposing punishment becomes worth the
Belief and knowledge about how the climate system may respond to UCI is an important component of our game theory model. Because of this, scientific research into climate intervention could impact the likelihood of UCI in multiple ways within our formal model. We discuss some of these pathways here. First, further improvements in scientific understanding of the consequences of SAI could affect the cost efficiency of UCI efforts. Second, research into the regional climate responses to UCI could affect the beliefs, as well as ultimate accuracy, of UCI efficacy. However, we note that a recent, systematic intercomparison of three earth system models simulating SAI deployment found that model differences (e.g., representation of atmospheric circulation, aerosol microphysics) led to notable differences in the earth system response to the same SAI forcing across climate models (Visioni et al 2022, Bednarz et al 2023). Thus, there is no guarantee that more scientific research will automatically lead to decreased uncertainty of the earth system consequences of SAI. Third, if new research reveals that SAI benefits some parts of the globe at the expense of others, then this increases the chances that states would likely avoid altering the climate out of fear of punishment from an adversely affected respondent. This sort of asymmetric consequence of SAI might also create incentives for states in regions likely to be adversely affected by SAI to advocate for new international laws that strictly control UCI. This could then trigger more widespread and expensive penalties for any states that would otherwise initiate UCI for their own benefit. Multilateral sanctions of this kind simultaneously increase the costs to the initiator while sharing the costs for the punisher.

Formal models simplify complicated natural and political dynamics in an attempt to uncover the core drivers of strategic decision-making. They necessarily make simplifying assumptions about complex processes to gain analytical leverage. A useful model identifies key drivers of decisions, even if the mathematical representation of climatological outcomes and political decision-making neglect important nuances.

Crucially, this model assumes that states will be sensitive to the punishments imposed by others. The empirical evidence for this is mixed, though this deductive logic is a foundation for much of international relations theory on topics like coercion and deterrence. Writing long before the recent rounds of sanctions against Russia for its transgressions against its neighbors, Robert Pape argued, “nationalism often makes states and societies willing to endure considerable punishment rather than abandon their national interests. States involved in coercive disputes often accept high costs, including civilian suffering, to achieve their
objectives. Even in the weakest and most fractured states, external pressure is more likely to enhance the
nationalist legitimacy of rulers than to undermine it” (1997, pp. 106-107). Sanctions driven by rivals’ UCI
programs could be especially ineffective, given the difficulty that states will have drawing a direct line
between specific-weather phenomena and solar climate intervention occurring outside of one’s own
national airspace.

This model also assumes that states will both understand and agree about the outcomes of unilateral
climate intervention, when in fact any post-UCI outcomes are very likely to be politicized. Voters are
very likely to misperceive local effects of a major climate intervention, and anomalous events like major
storms are very likely to steer public opinion and political action, even if these events deviate from clear
general climate trends (Diffenbaugh et al 2023). This disconnect between the true and perceived effects of
climate intervention introduces substantial uncertainty around potential reactions (Keys et al 2022). This
means that initiators must consider that international punishment could occur, even if the scientific
consensus is that unilateral climate intervention caused no harm. In the archetypal formal models,
“Nature” reveals outcomes that are as clear to all players as a poker dealer’s draw. UCI outcomes are not
so easily observed, and this means that reactions to UCI are likely to be much noisier and uncertain than
they are represented to be in a model.

Finally, this is a model of UCI initiation, but it is not a model of indefinite continuation, suspension, or
international governance. In a multilateral world, reactions to UCI could include sanctions imposed by
communities of respondents that can share the cost of punishment (NASEM 2021). Coalitions of states
could join the initiator and effectively divide the world into blocks or climate intervention supporters and
opponents. Successful climate intervention could create incentives for unabated carbon emissions, which
could then transform the global economy and create insurmountable economic and political pressures to
maintain climate intervention efforts. The possibilities are endless, but they are also so speculative that
they are unlikely to affect a state’s initial decision to begin unilateral climate intervention in a predictable
way. This makes these topics critical for the future of climate intervention science and governance, but
unimportant for modeling the drivers of a state’s decision to initiate.

Conclusions

We explore how unilateral climate intervention (UCI) might unfold in the face of unrelenting climate
change. Ultimately, the fundamental solution to addressing ongoing and future climate change is to
reduce anthropogenic carbon emissions to net zero, or further (IPCC 2022). However, given the pace,
scale, and stakes of global climate change, it is incumbent on the research community to understand the
broader range of how society, united or otherwise, may respond. Using game theory, we show how a decision to engage in UCI is conditional on a chain of reciprocal interactions and perceptions. We anticipate future work could leverage our findings to shed light on how contemporary countries may play the game with one another. This could provide needed insight into the potential countries most likely to pursue UCI, and thus anticipatory capacity for international solar climate intervention governance.

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