Strategic Logic of Unilateral Climate Intervention

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All authors devised the research plan. C.M.B. undertook the development of the formal model. All authors contributed to the writing of the manuscript.

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None.

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The formal model is completely described in the text and supplementary material.

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).

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 after 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.

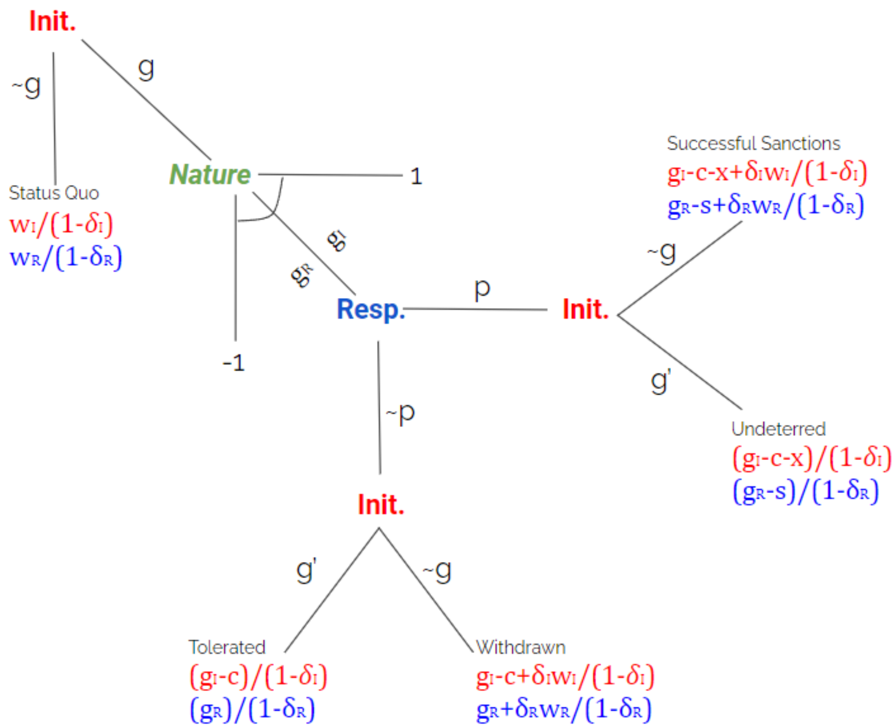

Figure 1: The Unilateral Climate Intervention (UCI) Game in the extensive form. Red colors correspond to the Initiator, and Blue colors correspond to the Respondent.

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 $\frac{w_I}{(1-\delta_I)}$ and $\frac{w_R}{(1-\delta_R)}$, 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 δ 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 δ place more value in the future, while states with a lower δ 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. Afterall, 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 Withdrawn* $(g, \sim p, \sim g)$ 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 Tolerated* $(g, \sim p, g')$.

***Lemma 1: R* will <u>never</u> 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^H 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* $(g, p, {\sim}g)$.

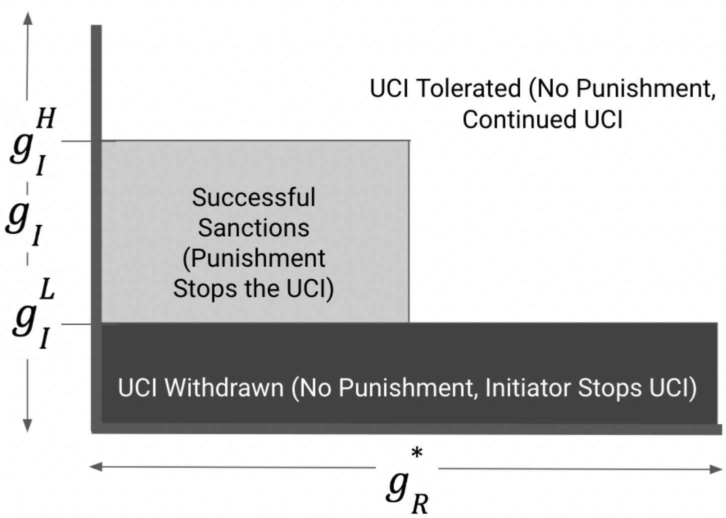

Figure 2: Possible Outcomes Following Nature's Reveal of g_I and g_R.

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 $\boldsymbol{\Theta}_I$ and $\boldsymbol{\Theta}_R$, respectively.

If the *Initiator* believes UCI will be worth the costs regardless of any punishment, ($\boldsymbol{\theta}_I \geq g_I^H$), 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 $g_I^L \leq \boldsymbol{\theta}_I \leq g_I^H$, it may still use UCI if it believes that g_R will be good enough for the *Initiator* to escape any punishment ($\boldsymbol{\theta}_R \geq g_R^*$). 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 ($\boldsymbol{\theta}_I \leq g_I^L$), then it will never initiate. Even cautious optimism about its own outcome will not incentivize UCI if this cautious optimism ($g_I^L \leq \boldsymbol{\theta}_I \leq g_I^H$) is paired with pessimism for the *Respondent* ($\boldsymbol{\theta}_R \leq g_R^*$). 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 ($\boldsymbol{\theta}_I \geq g_I^H$) or when it is only cautiously optimistic for itself, but also optimistic for the *Respondent* ($\boldsymbol{\theta}_R \geq g_R^*$ and $g_I^L \leq \boldsymbol{\theta}_I \leq g_I^H$). Next, we turn to the factors that determine these thresholds, and therefore, the likelihood of unilateral climate intervention,

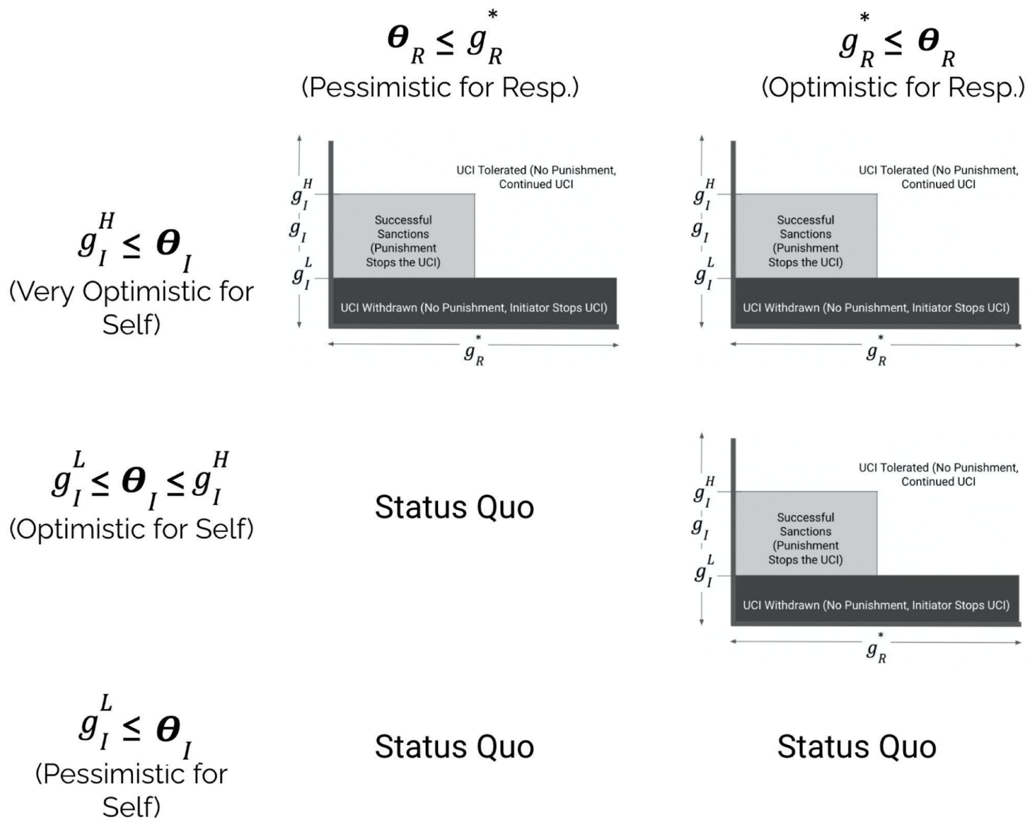

Figure 3: The Initiator's Beliefs ($\boldsymbol{\theta}_I$, $\boldsymbol{\theta}_R$) and UCI Outcomes (g_I , g_R).

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 $\boldsymbol{\theta}_I$, $\boldsymbol{\theta}_R$): 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 δ_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 (δ_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 high cost of deterring UCI. This could embolden the Initiator. Would a Respondent jeopardize its own economy for a marginally negative change in the climate? Savvy initiators may bet that one would not.

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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