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CLIMATE CHANGE AND SECURITY

The Scientific Case for Climate Liability and Loss and Damage Claims

By **Justin S. Mankin**, **Christopher W. Callahan** Monday, November 14, 2022, 8:16 AM

Who is responsible for the damage caused by global warming? This question and its implications for redress are at the center of international climate negotiations at the 27th Conference of the Parties (COP27), currently proceeding in Sharm el-Sheikh, Egypt. Historically, the COP has been an annual occasion to remind everyone of the deep intransigence among the world's climate polluters not just on mitigation, but on substantive questions of compensation for the harms brought by global warming. One reason for the lack of meaningful compromise has been the veil of plausible deniability that major emitting countries have hid behind when it comes to emissions and damage. All countries contribute to the climate problem—and so, the logic goes, no one country can be blamed.

On the one hand, the chain of causality is clear. Human well-being relies on combusting fossil fuels. Combustion's by-product, carbon dioxide, warms the planet. A warmer planet intensifies climate extremes, like droughts, floods, and heat waves. Intensified climate extremes harm our well-being and make our economies sluggish.

On the other hand, the chain of causality linking any one emitter to any one harmed party is less clear: All the countries of the world have been emitting carbon dioxide, and all the countries of the world have suffered the impacts of warming. Yet some are emitting more than others, and some are suffering more than others—and, in general, these are not the same people. There is an embedded inequity in the causes and consequences of global warming, and for countries seeking redress for their climate-driven losses, it's not clear who they can point the finger to.

The inability to show whether *specific* emissions from one party were the cause of *specific* harms endured by another has been among the major sticking points for questions of climate liability —the idea that emitters need to be held liable for the damage they have caused—and for questions of loss and damage—the idea that wealthy emitters should provide compensation to nations suffering the most acute climate impacts. Such questions strike at the heart of how to rectify and redress the lived reality of global warming and the damage it has and will continue to cause, particularly to the most vulnerable people.

Enter our new analysis, published this summer in the journal Climatic Change, which helps lift the veil of plausible deniability that major emitters have hid behind—showing that there is, in fact, a scientific basis for liability claims. We overcome the prevailing evidentiary hurdle by providing the first quantification of the economic impacts individual countries have caused to other countries through their contributions to global warming. Our work uses an integrated framework that allows us to quantify whose emissions have caused damage to whom, and how much. Moreover, we serve the data underpinning the analysis publicly, allowing users to evaluate the losses and benefits attributable to individual emitters. Such science is one part of the wider effort to overcome the stalemate on climate injustice and advance legal discussions about how courts might apportion liability among the world's emitters.

The Challenge of Constructing Climate Liability

Absent a rigorous chain of evidence that makes the case that *specific* emissions caused *specific* harms, this year's COP was likely to look and sound the same—pomp and circumstance resulting in little promise. Much of this question of whether damaged countries have the standing to make liability claims is legal and political and will be hashed out in backroom negotiations at this and future COPs and in courts around the world. But a key part of this question of standing resides with whether it is even scientifically possible to link individual emitters to the downstream impacts of warming. There are physical uncertainties in how particular emissions translate to warming, as well as how warming translates to harm, and so it is not clear whether an individual country's emissions can be shown to be the cause of another country's suffering. The complexity of the carbon cycle, natural variations in climate, and differing choices about how best to simulate the physics of the climate system—these "scientific uncertainties"—have been important threads in that veil of plausible deniability that major carbon emitters have relied on to skirt individual damage claims.

When considering the causal chain from emissions to harm, the question arises immediately of how best to measure each link. There are the emissions themselves, the accounting of which is ultimately a political question. For example, perhaps we want to consider all emissions since the dawn of the Industrial Revolution, say, somewhere around 1850. That would, on the one hand, increase the liability burden of major early-industrializing economies in the Global North. But the marginal impact of each gigaton of carbon dioxide on any country's growth would be less. This counterintuitive effect arises for two reasons: First, the warming problem is one of accumulating carbon, meaning a gigaton of carbon today causes more damage than an equivalent gigaton did in 1850. And second, today's economies are much larger than they were in 1850, and so there's just more stuff to damage. One can argue that we collectively didn't know the global consequences of industrialization in 1850, so perhaps, instead, we want an accounting that considers only the period since the 1990s after

there was a consensus around climate pollution. This raises the contributions of rapidly industrializing economies like China, Brazil, and India, which have rightfully been working to secure well-being for their people but have also had detectable economic impacts on other countries, raising challenging questions about the legacy of emissions and what constitutes the time scale of culpability.

Beyond the time scale of emissions, there's also the question of whose emissions belong to whom. Perhaps instead of considering territorial emissions, a court wants to consider emissions that adjust for international trade in goods and services: Consumers in the U.S., for example, import the emissions embodied in China's goods and services, and so the question arises whether those emissions should be assigned to the United States. Such an accounting would increase U.S. culpability and reduce China's culpability. Again, these questions are the province of legal and policy minds, not scientific ones.

Then there are the climate consequences of such emissions to consider. For example, examining a region's average temperature change may be an obvious way to capture the climate consequences of some given emissions. But climate change is more than average temperatures. It is droughts and floods and more intense storms and wildfires and sea-level rise and ecosystem losses, and so on. So while average temperature change is a useful aggregate measure of climate impact in that it proxies many other changes in the climate system, it is still imperfect, missing nonlinear changes in harmful extremes, like heat waves. How different kinds of climate extremes generate different harms is an active area of continued scientific research. Recent work has identified the contribution of warming to flood losses, and our recent work has identified losses arising from extreme heat. These more precise impact measures suggest that the cost of warming, and thus the liability associated with emissions, is far higher than estimates based on average temperatures alone.

Harm, like emissions or the changes to climate such emissions cause, could also be quantified in myriad ways. Perhaps one could use insured losses, or estimates of sectoral impacts like those on agriculture to assess damage. But these would likely undercount the true magnitude of losses, as we now know that global warming influences an economy's underlying ability to grow. Even so, such economic measures, while useful for providing a dollar-based accounting, arguably do not capture the full scope of human loss from climate change. What of the things not easily monetized? The loss of culture, the mass displacement of people, a greater propensity for violent conflict, not to mention the direct health and mortality burden from warming, the more favorable environment for zoonotic diseases, and the untold losses of ecosystem services. None of these is captured effectively in an aggregate measure of an economy like gross domestic product (GDP) alone.

These choices will ultimately be the subject of legal and political debates. But to move the discussion forward, choices must be made, particularly if we're interested in identifying whether it is even scientifically possible to attribute specific harms suffered from specific emissions.

Bridging the Gap

Our approach relies on a broad framework referred to as "climate attribution," which has been used successfully to quantify human contributions to warming (winning the authors of the Fourth Assessment of the Intergovernmental Panel on Climate Change a Nobel Prize), and has recently been extended to assess how warming has influenced observed extreme weather events. In our attribution, we use statistical and climate models to compare the economic growth each country experienced in the real world relative to the growth they would have experienced in a counterfactual world where one country did not cause warming with its greenhouse gas emissions. The idea here is to isolate how the temperature change from one country's emissions influenced another country's economic growth, absent all other factors.

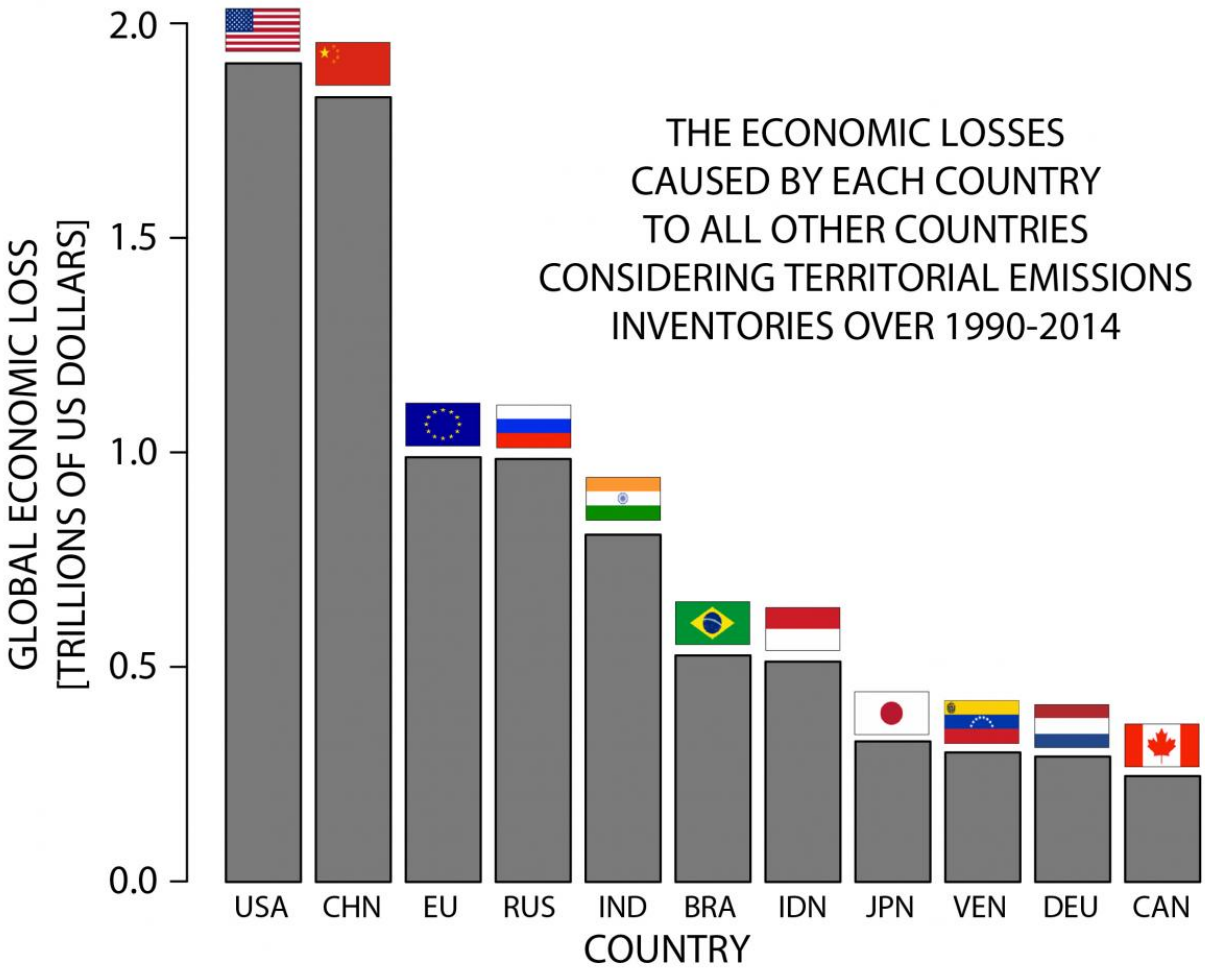
We do this in three main steps. We first create the counterfactual climate by using a simple computer model of the climate system to simulate what the global average temperature would have been if a single country—the United States, for example—had not emitted greenhouse gases under three different emissions accounting schemes. The difference in global temperature between the real and counterfactual worlds is a quantification of one country's contribution to global warming via its emissions. We then want to know how this warming from one country's emissions affected the temperatures in every other country. To calculate this, we use pattern scaling, a well-vetted statistical approach that allows us to predict country-level temperatures based on global temperatures. Because one country's temperature can be warmer or cooler in a given year just due to randomness in the climate (what we call "internal variability"), we need a really good quantification of that country-level climate variability to see if it masks our ability to detect temperature changes caused by that one emitter. This technique allows us to assess if an emitter is responsible for temperature changes in another country, not just in the global average, while also deconvolving it from internal variability. Finally, we assess how the temperature change a country experienced because of an emitter (as determined in the preceding steps) influenced that country's economic growth. To do this, we use the observed relationship between temperature and economic growth as measured by year-to-year changes in GDP. Together, these steps allow us to calculate how an individual country's emissions have affected economic growth in every other country and put a dollar amount to that effect.

At each step, we quantify the key scientific uncertainties in the global carbon cycle, the relationship between global warming and country-level warming, and the relationship between country-level warming and economic output. This holistic and integrated modeling framework

allows us to fully consider these uncertainties (and allow them to appropriately compound) at each step in the chain of causality. Quantifying these uncertainties is a massive computational investment, from running climate simulations, to leveraging large repositories of climate and economic data. Our approach yields some 2 million estimates of the economic change each country experienced in a given year due to another country's emissions. This is an incredibly well-sampled distribution of outcomes, and it allows us to assess robustly —given uncertain factors—whether an emitting country influenced the economy of another via its contributions to warming. This enables us to answer the call of climate liability claims: whether *specific* harms endured in one country were due to *specific* emissions from another.

It's important to emphasize that quantifying the uncertainty in the relationship between the warming from a single emitter and the damage suffered by a single claimant is the whole point of our attribution framework. It tells us whether there is, in fact, a scientific case for liability claims. That's because it is precisely this uncertainty that major carbon-emitting countries have used to deflect any claims of individual wrongdoing and slow the pace on climate negotiations for loss and damage or climate liability. Our work rigorously quantifies this uncertainty to statistically test whether the veil of plausible deniability of wrongdoing holds for a particular emitter, or whether it is, in fact, threadbare.

In terms of the hard numbers (for example, "how much is the U.S. on the hook for?"), the precise dollar values are going to be a function of legal and political questions about the best measures to use at each link in the causal chain. The causal chain can be built, as we have shown. And it is extendable to different scales and entities. All we need is a measure of emissions, climate, and harm. While the answers to the question of which measures one uses are ultimately political and influence the dollar value of liability that gets assigned to any one country, it does not, far as we can tell, alter who is culpable in the first place. The main perpetrators at the country-scale remain largely the same. The United States, Russia, Japan, the European Union, and Canada, alongside rapidly developing countries like China, India, Brazil, Indonesia, and Venezuela all emerge as the countries most culpable for depressing economic growth around the world from the global warming they have caused since 1990 (Figure). Courts and negotiators will determine the precise liability burden, and for the reasons we discuss above about temperature being an imperfect measure of climate change and GDP being an imperfect measure of harm, we think our estimates provide a lower bound.



(Figure) The Economic Losses Caused By Each Country To All Other Countries Considering Territorial Emissions Inventories Over 1990-2014. World flags courtesy of Wikimedia Commons.

Implications

Some broader implications of this work are worth discussing. First is that the responsibility for the economic damages from warming rests primarily with a handful of major emitters, and this warming has resulted in a wealth transfer from the poorest to the wealthiest countries in the world. The countries suffering the most are the least responsible. The tendency of warming to enhance existing patterns of inequality has created a perverse set of circumstances: The Global South is in a footrace to develop in a global economy that strategically disadvantages them in order to be resilient to climate impacts, while also generating more warming from that development. A considerable amount of discussion has focused on how to accelerate the clean energy transition in the low-income world. From a climate mitigation standpoint, such conversations and any policies and monies emerging from them are essential. But such efforts are prospective, addressing future warming and impacts, not retrospective, compensating harms endured already. And so, such questions of financing the clean energy transition are distinct from those of redress from past harms. In practice at the negotiating table at COP27, they're intertwined, but it is clear that their moral underpinnings are not the same.

The second insight from our work is the upending of the notion that no one benefits from a country forgoing future emissions unless all countries do; if one country's emissions can cause detectable harm, one country forgoing emissions can generate measurable economic benefits. Such an insight complicates the reductive idea that global climate change is simply a tragedy of the commons and, by extension, that climate mitigation is simply a public good from which no individual country benefits. Our work suggests that a rigorous assessment of each country's liability burden could raise the costs of historical emissions, potentially making countries consider their future contributions differently. A last implication of our analysis is its transparency and extendability: We can use it to quantitatively assess corporate responsibility for warming-induced damages, such as from fossil fuel companies themselves.

How can and will this information be used? To date, scientific uncertainty has been a key determinant of legal uncertainty about whether tort law can be applied to questions of climate liability. Theories about climate liability and loss and damage have relied on broad ethical arguments, treaty-based compensation, or other approaches like parametric insurance, largely because assigning responsibility has been so elusive, leaving courts to dismiss liability claims as nonjusticiable. But the linkages we uncover are explicitly casual: There is a culpable entity who committed the act, and there is a party who suffered calculable damages because of that act. And so, our analysis is—quite literally—a dollar accounting of who is responsible for climate damages, and to whom, along with the level of confidence we have in that assignment. It is a calculation of fault with a probability attached. Such an assignment of responsibility has obvious implications for the viability of tort-based claims and may help move legal discussions away from considering the liability burden as being prospective, to more appropriately being retrospective for harms endured.

A controlling question will be the scale at which policymakers or litigants make an argument for responsibility; our work examines country-level emissions and country-level harms, which may not be the optimal scale for tort-based liability claims. But to the extent that scientific and legal uncertainty have been intertwined, the clarity our results provide may make tort claims a more viable path than previously thought, particularly since the framework we use is extendable to more tort-friendly scales, such as corporate entities such as fossil fuel companies. Our findings upend the informational asymmetry and plausible deniability that have plagued climate negotiations by rigorously, transparently, and reproducibly estimating the costs of emissions.

Our results also present aid to backroom negotiations. It is part of a wide portfolio of work that is informing the International Court of Justice's expert opinion on loss and damage from climate change for the United Nations, and we hope it will be central to informing these discussions at COP27. Recent reporting out of COP27 suggests some high-income countries are taking loss and damage finance more seriously, but the magnitudes of losses we identify (on the order of $1.9 trillion in losses caused by the U.S. alone, for example) dwarf the monies being pledged to these funds (on the order of tens of millions).

There are tragic inequities embedded in the causes and consequences of historical warming; this reality motivates our work to understand how climate change will affect people, and to provide science to help better manage climate risks. The lack of scientific evidence linking individual emitters to the downstream impacts of warming has been a principal evidentiary gap in climate litigation. Such a gap disadvantages the most vulnerable as they seek to make rightful claims for restitution. Our work takes an important step in closing that evidentiary gap, reconciling large scientific uncertainties to provide data essential to more effective climate policies.

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Justin Mankin is a climate scientist appointed as an assistant professor in the Department of Geography at Dartmouth College, where he directs Dartmouth's Climate Modeling & Impacts Group.

jsmankin

Christopher Callahan is a PhD student at Dartmouth College in the Climate Modeling and Impacts Group. His research examines the human impacts of climate change, with a particular focus on the economic effects of extreme climate events.

cwcallahan45