

Policy Brief

Recommendations for Improving the Treatment of Risk and Uncertainty in Economic Estimates of Climate Impacts in the Sixth Intergovernmental Panel on Climate Change Assessment Report

Thomas Stoerk*, Gernot Wagner[†], and Robert E. T. Ward[‡]

Introduction: An Opportunity to Improve Economic Estimates of Climate Impacts

Preparations are under way for the Sixth Assessment Report (AR6) by the Intergovernmental Panel on Climate Change (IPCC), due to be released between 2021 and 2022. This Policy Brief argues that it is vitally important for AR6 to confront a major discrepancy between scientific and economic estimates of the impacts of unmanaged future climate change. In particular, we review mounting evidence that current economic models of the aggregate global impacts of climate change are inadequate in their treatment of uncertainty and grossly underestimate potential future risks.

Inconsistent Assessment of Risks in the IPCC Fifth Assessment Report (AR5)

The IPCC's AR5 included a volume on impacts, adaptation, and vulnerability. This volume was produced by IPCC Working Group II (WGII) and included a chapter on "Emergent Risks and Key Vulnerabilities" (Oppenheimer et al. 2014). Counterintuitively, among five categories of concern, Oppenheimer et al. (2014) found that the risks associated with global aggregate impacts are the slowest to develop.¹ These risks were estimated to be only moderate up to about 3.0°C of warming, although the other four categories show high risks. A major reason

*Environmental Defense Fund, Office of the Chief Economist; e-mail: tstoerk@edf.org

[†]Harvard University Center for the Environment; e-mail: gwagner@fas.harvard.edu

[‡]ESRC Centre for Climate Change Economics and Policy, and Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science; e-mail: r.e.ward@lse.ac.uk

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for the difference in risks discussed in [Oppenheimer et al. \(2014\)](#) is the inclusion of the results of a survey reported in a different AR5 WGII chapter ([Arent et al. 2014](#)), which appeared to show that economic impacts would be only “a small fraction of gross world product up until at least 2.5°C of warming above preindustrial” levels ([Oppenheimer et al. 2014](#), p. 1078). However, [Oppenheimer et al. \(2014\)](#) also noted that published estimates of global economic impacts were “highly uncertain” and “omit a number of factors.” Many of these estimates were generated by climate–economy integrated assessment models (IAMs), which are also used to calculate the values of the social cost of carbon dioxide (SC-CO₂) and the optimal CO₂ price.² There is now a growing awareness of the limitations of the existing generation of IAMs (e.g., [National Academies of Sciences, Engineering, and Medicine 2017](#)), including an understanding that they inadequately account for the potential damages from climate change, especially at moderate to high levels of warming (i.e., >2°C). These levels of warming have become increasingly likely ([World Bank Group 2014](#)).

Although considerable econometric improvements have been made in estimating economic damages, including nonlinear effects (e.g., [Burke, Hsiang, and Miguel 2015](#); [Hsiang et al. 2017](#)), these estimates largely ignore the potential for “tipping points” beyond which impacts accelerate, become unstoppable, or become irreversible (e.g., [Lenton 2013](#); [Kopp et al. 2016](#)). Thus, in the remainder of this Policy Brief, we will argue that AR6 needs to go well beyond simply updating the damage functions in existing IAMs using the latest climate econometric evidence yet leaving the underlying IAM structure and decision framework unchanged.

More specifically, we recommend that the IPCC embrace better approaches to the management of uncertainty inherent in climate policy decisions by (1) strengthening its focus on decision making under uncertainty and outright ambiguity, exploring options beyond the standard expected utility framework (e.g., [Millner, Dietz, and Heal 2013](#); [Heal and Millner 2014](#)) and (2) estimating how the uncertainty itself affects its economic and financial cost estimates of climate damage and, ultimately, the optimal price for each ton of CO₂ and other greenhouse gases released (e.g., [Stern 2016](#)).

Evidence of Discrepancies Between Scientific and Economic Assessments of Climate Impacts

IAMs typically combine a deterministic economic growth model with a simplified model of the carbon cycle ([National Academies of Sciences, Engineering, and Medicine 2017](#)). The links between the physical and the economic building blocks go both ways: (1) economic output generates emissions that feed into the carbon cycle and (2) the climate model generates temperature changes that affect the economic outcome via an economic damage function.

¹The other four categories are threats to endangered species and unique systems, damages from extreme climate events, effects that fall most heavily on developing countries and the poor within countries, and large-scale high-impact events ([Oppenheimer et al. 2014](#)).

²The “social cost of carbon”—or more accurately the SC-CO₂—is the marginal damage caused by the emission of one ton of CO₂ given present emissions trajectories. This is distinct from the optimal CO₂ price, which depicts the price along an optimal trajectory.

Although there is a large amount of literature documenting the many problems with the use of IAMs to estimate the costs of future climate change impacts (e.g., [Stern 2016](#)), we empathize with the architects of these IAMs. Estimating economic damage is a daunting task that requires an array of normative judgments. The authors of some IAMs are forthcoming about their models' limitations. [Nordhaus \(1992\)](#), for example, concludes his first article about the Dynamic Integrated Climate–Economy (DICE) model by pointing to “a number of important qualifications,” among them uncertainty and risk aversion. Meanwhile, many of the significant recent climate econometric advances (e.g., [Burke, Hsiang, and Miguel 2015](#); [Hsiang et al. 2017](#)) have yet to find their way into the IAMs used to calculate the optimal CO₂ price or SC-CO₂ ([National Academies of Sciences, Engineering, and Medicine 2017](#)). Moreover, the discrepancy between physical impact studies and economic estimates diverge sharply with greater amounts of warming ([Lenton and Ciscar 2013](#)). DICE, for example, projects a loss of less than 10 percent of global economic output as a result of raising the global mean surface temperature by 6°C ([Wagner and Weitzman 2015](#)). These discrepancies between the physical and the economic impact estimates are large, and they matter. However, physical impacts are often not translated into monetary terms and they have largely been ignored by climate economists ([Hanemann 2016](#)).³

Recommendations for the IPCC AR6

We urge the authors of AR6 to explore—and help guide the policy community toward—an explicit recognition of the risks, uncertainties, and ambiguities involved in the long climate–economic chain—from greenhouse gas emissions to concentrations, from concentrations to global average temperatures, from temperatures to climate damages, and from damages to how society can be expected to react. At the same time, AR6 could and should seek to advance the science and practice of IAMs themselves, in particular, how these models incorporate risks and uncertainties into calculations of the optimal CO₂ price. More specifically, we recommend that the IPCC:

1. Strengthen its focus on decision making under uncertainty and outright ambiguity

The simplicity of the expected utility framework, which weighs expected outcomes by the probability of occurrence, fails to capture a crucial characteristic of the climate policy decision problem; that is, it does not allow decision makers to express their subjective confidence in different sources of information contained in the model ([Millner and Heal 2017](#)). However, important probabilities in climate science are subjective or missing, which means information is lost if an expected utility model is used. Thus we recommend that AR6 examine how this loss of subjective confidence in different data affects optimal climate policy.

Alternative frameworks for examining decision making under ambiguity exist. Instead of the technical expert calculus that is currently used, decisions concerning optimal climate policy should ideally move to public debates about the ethical choices that underlie different decision frameworks ([Baldwin 2016](#)). Thus taking uncertainty seriously implies that AR6

³For additional references, see the online [supplementary materials](#).

needs to include a debate about the correct model of rational decision making for climate policy, a recommendation supported by [Brock and Hansen \(2017\)](#), among others.⁴ [Arrow et al. \(1996\)](#) could serve as a template for how such a debate might play out in the IPCC context.

2. Focus on estimating how the uncertainty itself affects economic and financial cost estimates of climate damage

A second problem with the expected utility framework is that it does not consider ambiguity aversion, a widely held preference to avoid uncertainty ([Ellsberg 1961](#)). How can the effect of uncertainty on estimates of climate damage estimates be computed within the expected utility framework? As a starting point for answering this question, [Weitzman \(2012\)](#) proposes a steeper damage function that relies on input from an expert panel that explicitly considered physical tipping points. This damage function leads to a loss of global output of around 50 percent for a temperature increase of 6°C. In contrast, to this day, DICE continues to rely on a 1994 expert survey that focused on the likelihood of a 25 percent “Great Depression”-size loss ([Nordhaus and Sztorc 2013](#)). [Wouter Botzen and van den Bergh \(2012\)](#) show that when physical tipping points are incorporated into DICE, the optimal carbon price rises to \$350 by the end of the 21st century. Finally, [Millner, Dietz, and Heal \(2013\)](#) find that incorporating ambiguity aversion directly into the DICE model leads to more stringent optimal abatement. Thus climate policy recommendations based on the current framework seriously underestimate the economic value of climate damages.

Another strategy for addressing uncertainty is to add probabilistic tipping points to the climate sector in an IAM. [Lemoine and Traeger \(2016\)](#) study the effect of ambiguous tipping points on the optimal carbon price and find that specific tipping points increase the optimal carbon price, but only by a small amount. In contrast, [Lemoine \(2017\)](#) finds that uncertainty concerning both climate science and economics increases the optimal CO₂ price by 60 percent. In addition, in a study of the channels by which uncertainty affects the optimal carbon price, [Lemoine and Rudik \(2017\)](#) show that future economic adjustment costs are likely to be the dominant source of additional damage. Similarly, [Daniel, Litterman, and Wagner \(2016\)](#) find that when a climate–economy model is calibrated to reflect financial risk attitudes, the uncertainty in climate impacts increases the optimal CO₂ price.

Conclusions: Toward a Revamping of Climate Damage Estimates in AR6

Two distinct conclusions emerge from our review of the state of climate economics. First, the expected utility framework fails to capture important dimensions of the climate decision problem. Second, when uncertainty is explicitly considered within the expected utility framework, estimates of the economic damages from climate change generally increase, often by as much as an order of magnitude.

⁴[Weitzman’s \(2009, 2011\)](#) “Dismal Theorem” and argument concerning the climate sensitivity distribution’s “heavy” or outright “fat” tails potentially dwarfing expected-value arguments holds particular sway in this regard ([Wagner and Weitzman 2015](#)).

Once again, this suggests that AR6 will be able to provide policymakers with a more robust and rigorous way of assessing the potential future risks of economic damage from climate change by (1) strengthening its focus on decision making under uncertainty and outright ambiguity and (2) estimating how the uncertainty itself affects its economic and financial cost estimates of climate damage.

Our hope is that AR6 can act as a broad forum that brings together scientists and economists with a goal of quantifying the impacts of climate change. Such a forum should follow the modular approach to building IAMs proposed by the [National Academies of Sciences, Engineering, and Medicine \(2017\)](#). In this way, AR6 can carry out the daunting task of helping to revamp both existing climate damage estimates and their use for climate policy decision making and further its mission to “provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts” ([Intergovernmental Panel on Climate Change 2018](#)).

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Abstract

Large discrepancies persist between projections of the physical impacts of climate change and economic damage estimates. These discrepancies increase with increasing global average temperature projections. Based on this observation, we recommend that in its Sixth Assessment Report (AR6), the Intergovernmental Panel on Climate Change (IPCC) improve its approach to the management of the uncertainties inherent in climate policy decisions. In particular, we suggest that the IPCC (1) strengthen its focus on applications of decision making under risk, uncertainty, and outright ambiguity and (2) estimate how the uncertainty itself affects its economic and financial cost estimates of climate damage and, ultimately, the optimal price for each ton of carbon dioxide released. Our hope is that by adopting these recommendations, AR6 will be able to resolve some of the documented inconsistencies in estimates of the physical and economic impacts of climate change and more effectively fulfill the IPCC's mission to provide policy-makers with a robust and rigorous approach for assessing the potential future risks of climate change. (*JEL*: Q54, D81)