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The Intergovernmental Panel on Climate Change: Challenges and Opportunities

Mark Vardy,[1] Michael Oppenheimer,[2,3] Navroz K. Dubash,[4] Jessica O'Reilly,[5] and Dale Jamieson[6]

[1]Princeton Environmental Institute, Princeton University, Princeton, New Jersey 08544; email: mvardy@princeton.edu

[2]Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, New Jersey 08540; email: omichael@princeton.edu

[3]Department of Geosciences, Princeton University, Princeton, New Jersey 08544

[4]Centre for Policy Research, New Delhi 110021, India; email: ndubash@gmail.com

[5]Department of International Studies, Indiana University, Bloomington, Indiana 47405; email: jloreill@indiana.edu

[6]Department of Environmental Studies, New York University, New York, NY 10003; email: dale.jamieson@nyu.edu

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Abstract

The Intergovernmental Panel on Climate Change (IPCC) conducts policy-relevant but not policy-prescriptive assessments of climate science. In this review, we engage with some of the key design features, achievements, and challenges that situate and characterize the IPCC as an intergovernmental organization that is tasked with producing global environmental assessments (GEAs). These include the process of working through consensus to assess and summarize climate science and the need to include knowledge from as many of the 195 IPCC nation-states as possible, despite the structural inequalities between developed and developing countries. To highlight salient features that are unique to the IPCC but that offer lessons for other organizations that conduct GEAs, we include case studies on the politics of climate denialism, the use of geoengineering in mitigation scenarios, and

the links between adaptive capacity, adaptation, and global development. We conclude with a discussion of institutional reflexivity. We consider how the IPCC can model an ethical and participatory response to climate change by critically examining, and being transparent about, the relation between science and politics.

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INTRODUCTION

Over the past 40 years, global environmental assessments (GEAs) that marshal scientific knowledge for policymakers and decision makers have become an essential feature of political life on all scales, from local to global (1, 2). Some organizations that produce GEAs, such as the Millennium Ecosystem Assessment (MEA) and Future Earth, involve multiple stakeholders, including scientific associations, environmental organizations, and industry groups (3, 4). The Intergovernmental Panel on Climate Change (IPCC), in contrast, includes 195 nation-states. The World Meteorological Foundation and the United Nations Environment Program formed the IPCC, which aims to characterize the state of knowledge about climate change in policy-relevant, but not prescriptive, assessments. It was preceded by several international forums devoted to climate science and policy responses to climate change; the first international scientific study of climate change, for example, began in 1967 with the Global Atmospheric Research Program (5–8). The architects of the IPCC drew from the successes and failures of earlier initiatives to try to ensure that the IPCC's assessment of climate science would be relevant to decision makers and policymakers (5, 8, 9). To this end, government representatives participate in the IPCC process by establishing research questions and priorities, and by approving finished reports for policymakers (7). The involvement of government representatives distinguishes the IPCC from other organizations that produce GEAs without the involvement of representatives of most of the world's nation-states and is one of the key features adopted by the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) when it was formally established in 2012 (10).

The involvement of governments in the IPCC has helped settle the complexities of climate science into forms that are tractable for policymakers and decision makers, helping transform climate change from a marginalized phenomenon to one that is now widely recognized as requiring action. Governments largely accept the IPCC's Assessment Reports as trustworthy; moreover, in the words of the first IPCC chair, the reports serve as a "fundamental prerequisite for successful climate negotiations" (5). As symbolized by the Nobel Peace Prize awarded to the IPCC in 2007, the IPCC is often invoked as a progressive way of engaging proactively with complex environmental change. It serves as a model for other GEAs, most notably for the IPBES, which was founded explicitly as an "IPCC-like" platform for biodiversity (10).

Given the IPCC's status as an exemplar for making environmental science tractable for policymakers and decision makers, this review critically evaluates the IPCC to offer insights into both the IPCC itself as well as issues that might be of interest to organizations using it as a model. Following previous scholarship that provided extensive studies of GEAs, we begin from the assumption that GEAs "are better conceptualized as social processes rather than published products" (1, p. 14). From this perspective, we examine the processes through which the IPCC assesses scientific knowledge about climate change. How does the IPCC transform the complexity of climate science into summaries for global policymakers? Additionally, how does an understanding of the social process of assessment shed light on the reports the IPCC produces? Do the organizational features of the IPCC, such as consensus, shape the assessments it produces, and if so, in what way? What political issues pertain to IPCC assessments of science?

In this review of the IPCC, we focus on the topics and issues that may be helpful for participants of other GEAs to consider. We begin our review by considering how science is assessed within two different parts of the IPCC process, namely in the authoring of Assessment Reports and in the Summary for Policymakers (SPMs). We then consider two case studies, each of which highlights the relationship between processes through which the IPCC produces assessments and public controversies. These case studies demonstrate the importance of transparency. In the second half of the review, we consider a feature that many organizations that produce GEAs engage with, which is the inclusion of knowledge from indigenous people and participants from the Global South. The case study on adaptation that follows highlights the complexities that are associated with the framing of climate change in the context of global development. We conclude with a discussion of institutional reflexivity and by reflecting on how the IPCC can build on its successes to embrace transformative change.

TIMELINE: CONDENSED HISTORY OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE AFTER THE 1992 RIO SUMMIT

The IPCC released its First Assessment Report in 1990, and Working Group I, which focuses on the physical sciences of climate change, published a follow-up Special Report specifically to inform the 1992 United Nations Convention on Environment and Development in Rio and the negotiations for the United Nations Framework Convention on Climate Change (UNFCCC) (5, 11). The IPCC's Second Assessment Report, released in 1995 and providing evidence of the human influence on the climate system, informed the Kyoto Protocol, which was agreed to in 1997, five years after the signing of the UNFCCC. Over the following years, countries engaged with the political question of whether or not to ratify the Kyoto Protocol. The Third Assessment Report, published in 2001, provided stronger evidence for the human impact on climate change as well as climate change's impact on humans. The Kyoto Protocol, which mandated reductions from developed nations, entered into force in 2005. The IPCC's Fourth Assessment Report (AR4) was released in 2007. For this work, the IPCC, jointly with Al Gore, was awarded the Nobel

Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (12). The AR4 provided information for the 2009 Conference of the Parties (COP) to the UNFCCC in Copenhagen. The Copenhagen meetings failed to negotiate an extension to the Kyoto Protocol, and the Kyoto Protocol's first commitment period ended in 2012 by which time an approach distinct from mandatory reductions by developed countries had begun to emerge in negotiations. The IPCC's Fifth Assessment Report (AR5) was released during 2013 and 2014 prior to the COP 21 in Paris, where the Paris Agreement was signed. The Paris Agreement is not an extension of the Kyoto Protocol. Rather than a schedule of mandatory reductions, as per the Kyoto Protocol, signatories of the Paris Agreement pledge to lower emissions and take other complementary actions on adaptation and support (their Nationally Determined Contributions), which are then reviewed periodically through global aggregate stocktakes.

CONSENSUS AND THE ASSESSMENT OF UNCERTAINTY

Summarizing Climate Science for Policymakers

The processes through which GEAs produce knowledge can be characterized according to design features that include the scale, goals, and capacity of the GEA, who participates in it, how science and policy interface, how the quality of the GEA is measured, the degree of transparency in the GEA, and how it is framed as a whole (3). Two additional design features, which we focus on in this section, are how uncertainty is treated and how dissenting opinions are handled (3). The ways in which these two design features are connected become particularly noticeable when assessing the risk of extreme events that are not known with high certainty. As seen in the case of the Third US National Climate Assessment, assessing climate science involves making trade-offs between a wealth of divergent and sometimes incommensurate data from across the social and natural sciences with an eye to making the final product relevant to stakeholders (13). To produce assessments of risk that are both relevant and not mired in conflicting information, GEAs must navigate not only the uncertainty of complex global environmental problems but also the specific organizational and institutional contexts through which they work. GEAs that work through consensus need to find common ground between experts from a wide diversity of scientific disciplines, which makes it difficult to settle on a single way to frame extreme events (14).

In the IPCC, a clear distinction exists between the processes of consensus that shape the line-by-line editing of SPM at plenary approval sessions, in which government representatives participate, and the writing of the Assessment Reports. Hundreds of authors and editors, mostly academics, volunteer to write Assessment Reports, which are intended to assess scientific publications without conducting original research. These reports are produced by three different Working Groups (WG), named The Physical Science Basis of Climate Change; Impacts, Adaptation and Vulnerability; and Mitigation. The size and scope of the WG reports have expanded since the First Assessment Report. In the most recent iteration, the AR5, each WG report contains more than 1,200 pages. An SPM of approximately 30 pages is produced for each WG report, as well as for the Synthesis Report. The full WG reports are endorsed by government representatives by accepting them, which means that they have not been edited line by line. Each SPM, however, goes through a process of line-by-line editing during approval plenaries in which government representatives approve the final version of the SPM (see **http://www.ipcc.ch/organization/organization_procedures.shtml**).

In this section, we first consider the consensus process that takes place in approval plenaries to produce SPMs. During approval plenaries attended by scientists and government representatives, the draft text of the SPM is presented one line at a time on an overhead screen. Government

representatives from any country can object to and potentially veto any line, requiring IPCC authors to rework the sentence in question until it is rewritten to everyone's satisfaction. In this sense, the SPM produces reports through processes of enforced consensus. Because government representatives participate in this process, and because they must approve of the precise wording of the text, SPMs have considerable weight in international climate negotiations. But there are differing points of view on the efficacy, necessity, and desirability of representing climate science through this consensus process (15–25). Some authors argue that the consensus process in approval plenaries results in sharper messages, the identification of better and more relevant questions, and greater investment by policymakers in the ultimate outcomes (26). In contrast, a well-known early critique of the IPCC argued that it resulted in bland outputs that do not engage with questions of high disagreement (27). More recently, some authors argue that the process imposes unity in the form of least-common denominator generalities on the very issues that, because they are politically challenging, may be of greatest policy relevance (28–30).

In their study of how eight SPMs produced for the AR4 and AR5 changed through the approval plenaries, Mach et al. (22) find that sensitive issues are often reworked and expanded through approval plenaries. But they also find that sometimes the most sensitive topics are expunged completely. Consider an example from the plenary to produce an SPM for the AR5 (30–32). Contention arose when data visualizations that depict greenhouse gas (GHG) emissions by country income group rather than by regional categories were contemplated for inclusion. Different ways of presenting the same data appeared to direct attention to different groups of countries, with corresponding implications for the political apportioning of responsibility. Knowing that the SPM would inform COP 21 in Paris, country representatives failed to agree on a form of data visualization that did not prejudge political interpretation.

Considering the SPM processes from a pragmatic perspective, it is more expedient and pragmatic to craft a better process than to strive for a rigid or a strictly policed separation of science and policy (32, 33). Specific proposals include enhanced visibility for the Technical Summary, which is subject to much less governmental scrutiny than is the SPM, and increasing the role for complementary bodies such as national scientific academies through complementary assessments and third-party oversight of the IPCC process (28, 34). When it is working at its best, the SPM process helps scientists to understand the politics of climate change and to ground climate politics in better science (31). But, as the above example shows, the SPM process produces reports that are inflected by the particular contexts that surround their production.

Reconciling Risk and Process Ambiguity

As discussed above, IPCC SPMs are approved after being edited in plenary sessions that include government representatives, a forum that is better suited to achieving widespread agreement than for representing issues about which there are dissenting opinions (24). The goal of working by consensus also influences the shape of the Assessment Reports. Across the three WG, the IPCC considers a massive range of evidence, including observations of physical systems, estimations of social and individual behavior (in WGII and WGIII), scenarios derived from computer simulations, and paleoclimatic data. Each WG has its own cultural norms and ways of working. However, there are no agreed-upon objective methods for making inferences about how multiple lines of evidence should be considered together (35). This becomes particularly salient when attempting to represent the uncertainty of nonlinear climatic events through the consensus model because understanding the risk for abrupt change often requires subjective expertise to judge what conclusions can be inferred from multiple lines of evidence (36). In addition, many judgments about the uncertainty of climatic changes are inevitably subjective given that they are made by small groups

of experts (37). The IPCC explicitly acknowledges that a degree of subjective expert judgment is required to consider the evidence drawn from different sources. To grapple with the inherent subjectivity of expert judgments, the IPCC has included ways of drawing on experts who hold a wide range of views to author chapters of reports (38, pp. 1110–12; 39; see also 40).

The ideal of achieving consensus is tested by many types of uncertainty, including that which arises from not knowing how parts of the environment, such as ocean circulation and ice sheets, might interact to produce unanticipated surprises such as rapid sea level rise (41), as well as the choices of how to represent "social indeterminacy," or the inherent unpredictability of human values and behaviors, in economic models of climate impacts (42). These features are not unique to the IPCC; GEAs often reduce scientific complexity to provide policymakers sufficient certainty for action (14). In doing so, authors are guided by both formal rules as well as informal norms that have developed over time. The IPCC's official governance principles refer to the importance of consensus in its formal procedures. But ambiguity persists on several key points. Is consensus expected to arise from the literature itself, or does consensus reflect a judgment imposed by assessment authors? When consensus about particular statements is lacking, is it permissible instead to formulate a consensus about the extent of uncertainty and the reasons for disagreement through either quantitative or qualitative descriptions? In cases of utter and complete disagreement between authors, and if no central statement of fact can be agreed upon, should the subject of the disagreement be expunged from the Assessment Report, or should discordant views be incorporated? IPCC authors might provide different answers to these questions as they work to achieve consensus as a socially negotiated outcome.

In some cases, it may be useful to bring to light differences between authors. When assessing the state of large and complex physical systems, such as Antarctic ice sheets, there are often valid reasons to highlight individual viewpoints (which may signify bias in making judgments arising from limited information rather than errors), rather than trying to hide them beneath a proclaimed consensus (35, 43). In such cases, providing a detailed narrative of the deliberations by which authors reached, or failed to reach, consensus might help inform the IPCC's audiences of not only the physical system in consideration but also the processes through which the IPCC assesses knowledge. This approach would be especially enlightening when issues related to rare or unlikely extreme outcomes, such as ice sheet collapse or the rapid release of methane from permafrost, which might be systematically underrepresented in the consensus model, are the issue (44). From the perspective of users of the IPCC assessments, knowing the reasons for disagreements between experts can be helpful because it can provide a more detailed and nuanced understanding of the range of potential climate impacts (45).

Turning to broader public debates, including that discussed in the following case study, the weight of scientific consensus is often used to argue for the reality of climate change. But the consensus model of science has disquieting features. At a minimum, it might give the impression that the problem of climate change is manageable within dominant policy and political frameworks, which, perhaps counterintuitively, can serve as a disincentive for broader publics to become personally interested in the problem of climate change (25). Furthermore, voices that express dissent from the consensus view could be interpreted as legitimating the process through which the majority has expressed its views. That is, consensus could be defined as group agreement that the reported facts best represent the "position of the group" while acknowledging that some individuals have valid reasons to disagree about specific substantive scientific questions (21). This turns attention to the legitimacy of the processes through which decisions are made. In such cases of scientific pluralism, difference can be registered without being subsumed to consensus outcomes (16). The point we stress here is that processes internal to GEAs are related in dynamic and recursive ways to processes that are external to GEAs. As we discuss in the case study below, the

public often assesses GEAs in relation to the processes through which GEAs produce knowledge. In such cases, presenting climate science through the single edifice of consensus can backfire and be used as a reason to deny the GEA's credibility.

CASE STUDY: ON DENIALISM AND TRANSPARENCY

The IPCC is situated within a larger field that includes the geopolitics of international climate negotiations, environmental groups that argue for more urgent action, nongovernmental organizations that advocate for climate justice, and lobby groups opposed to regulating GHG emissions (46). Energy companies, fossil fuel lobby groups, trade organizations and free-market think tanks have targeted the IPCC from its inception and have significantly influenced the public perception of the legitimacy of climate science (47). For example, in the early 1990s, a coal industry trade group ran a major public relations and advertising campaign that attacked the IPCC in a bid to undermine public support for the regulation of GHG emissions (48). The Paris Agreement signed at COP 21 signals a shift in the stance of many major energy corporations, which comes in the context of increased attention to how financial markets can continue to grow while addressing climate change (49). But any shift in how energy corporations position themselves vis-à-vis climate change should be understood within the history of their intransigence.

Long after the vast majority of climate scientists actively publishing in peer-reviewed journals concluded that human activity impacts the climate, ideologically and politically motivated attacks on science continued to be given credence by politicians and members of the public (50–53). A study of American newspaper articles about climate change from 1988 to 2002 finds that opponents to GHG regulations made claims that were not grounded in peer-reviewed science but gained high visibility in the mass media in part because the cultural norms of American newspaper journalism equates objectivity with reportage of both sides of an argument (54). The network of fossil fuel corporations, conservative think tanks, and public relations firms that lobbies against climate science successfully developed an "anti-reflexive" discourse that enshrines a reductive and absolutist model of the scientific method, any perceived deviation from which is used to justify the wholesale rejection of scientific expertise (55). These arguments built on tactics developed by corporations seeking to prevent regulation through exploiting uncertainty in science (56). One of the tactics successfully used to discredit climate science is typified by Frederick Seitz's 1996 commentary in the *Wall Street Journal* in which he argued that the IPCC did not follow its own rules for peer review. Subsequent analysis showed that the IPCC did not transgress any of its rules of peer review, which in fact are more rigorous than the standards of peer review that academic journals typically try to uphold (47, 57). This tactic of discrediting the processes through which the IPCC works came to the fore again in the media controversy that erupted in the lead-up to the 2009 UNFCCC meeting in Copenhagen. Emails were hacked from the University of East Anglia and released publicly. Many of the attacks on the IPCC were expressed as epistemological concerns (58, 59).

Numerous independent reviews were conducted on the IPCC as a direct consequence of the hacked email scandal (for accounts of the so-called Climategate affair, see 19, 58–63). No intentional wrongdoing by IPCC or any of the scientists involved was found, but the IPCC was urged to make its processes more transparent and its reports more readable (64). The IPCC hired a communications director and formulated a communications strategy that covers a range of issues, including responding rapidly to situations as they occur in the media, as well as efforts to communicate more clearly to its target audiences. The IPCC *Expert Meeting on Communication* (2016) reviewed the work on communication undertaken in the AR5 and made suggestions for further improvement; the emphasis on further improving communication for the AR6 was the

subject of a resolution passed at the 43rd Session of the IPCC, on April 10–13, 2016 (65). Thus, one of the results of the hacked email scandal and the subsequent report from the IAC was that the IPCC paid far greater attention to communication through the process of writing the AR5 (e.g., 66). A similar push for transparency also followed the negative media attention given to the IPCC in the aftermath of Seitz's 1996 commentary in the *Wall Street Journal* discussed above (67).

One of the lessons that emerged from this controversy is that scientific facts do not travel by themselves; rather, it takes work to articulate scientific knowledge in ways and means that resonate with audiences (48). Because scientific facts cannot simply present themselves, ideologically motivated attacks on climate science cannot be countered only by providing more or better science without addressing the social and political contexts in which such facts become salient (68). This became evident in the aftermath of one set of critiques that focused on factual errors in the AR4 that were traced back to the Netherlands Environmental Assessment Agency (PBL) (69, 70). Hajer (69, p. 462), as director of the PBL, responded by having the PBL conduct a review of the AR4 while engaging proactively with the mass media by going on television and radio shows, running a blog, and maintaining a practice of "actively responding to false claims made in public debate." Hajer used his experience with the intense media scrutiny of 2009–2010 to argue that the legitimacy of the IPCC is guaranteed neither by its institutional affiliations with UN-sponsored organizations nor by the social authority of science. Given the presence of antagonistic audiences who distrust climate science, the IPCC has to perform its authority by communicating effectively. From this perspective, the IPCC needs to be more transparent about the social contexts and the conditions of uncertainty that inform the production of knowledge (62). Being transparent about the limits of certainty might help persuade ambivalent members of the public to trust in the IPCC's expertise (71, 72).

CASE STUDY: GEOENGINEERING THE "SOLUTION SPACE"?

The IPCC's goal is to "provide policy-relevant but not policy-prescriptive information on key aspects of climate change" including ways to avoid dangerous climate change (see **http://www.ipcc.ch/pdf/press/ipcc-statement-principles-procedures-02-2010.pdf**). In providing such information, the IPCC includes scenarios that involve geoengineering techniques. Geoengineering includes a wide range of interventions including negative emissions technologies, carbon capture and removal, carbon dioxide removal (CDR), and solar radiation management. There are significant costs and potential risks associated with geoengineering, which differ with each specific technique under consideration (73). The ecological risks of implementing geoengineering projects on a scale large enough to make a difference to global warming are not well understood (74), and projections of the potential for them to reduce warming are limited by uncertainties regarding the amount of amplification that thawing permafrost, clouds, and other biophysical feedbacks might provide (75). It is far from guaranteed that such techniques can be developed and deployed with sufficient speed and scale to prevent dangerous climate change (76).

In addition to questions about the technical feasibility and ecological risks associated with geoengineering, ethical and political questions pertain to the role that CDR play in Integrated Assessment Models (IAMs), which are used to model the economic and ecological impacts associated with different mitigation scenarios. The inclusion of CDR in IAMs allows for scenarios to exceed emission reduction targets in the near term on the assumption that geoengineering will compensate for excess emissions at some point in the future (77). Despite their unproven qualities, CDR techniques play a significant role in the IPCC AR5 mitigation scenarios (78). Indeed, as Rockström et al. (79) point out, the geoengineering techniques required by IPCC scenarios to keep warming below 2°C would have to absorb about the same amount of anthropogenic carbon

as is currently absorbed by the oceans. Avoiding dangerous climate change by pinning our hopes on such as-yet-undeveloped technologies is, they argue, the "world's biggest gamble."

In section 3.3.7 of AR5 WGIII, the IPCC discusses ethical questions pertaining to CDR and SRM, including arguments for and against them. But even so, by treating geoengineering techniques as in-principle feasible interventions into the carbon cycle, the IPCC is, according to some scholars, helping turn them from a collection of ideas into practices (80). In addition to uncertainty about the effectiveness, costs, and benefits of geoengineering interventions, some techniques would require constant deployment and concomitant management, which would make the initial decision to deploy them political: Who should be granted the authority to manage geoengineering techniques (7)? Given the politicization of geoengineering and the geopolitics of international climate negotiations, some scholars argue the IPCC should not use geoengineering techniques to portray dangerous climate change as avoidable in the first place (81).

We emphasize that the CDR techniques that are used in the IPCC scenarios could also be potentially filled by social transformations and shifts in human individual and collective behavior. The difficulty is that such social transformations are almost impossible to model in a form that is compatible with the IPCC scenarios. In other words, it is easier to model geoengineering technologies than it is to model social transformations which are inherently unpredictable. At a minimum, the role that CDR techniques play in IPCC scenarios should be made transparent to the IPCC's audience (23). More broadly, the lesson here is that even when providing information that is policy-relevant but not policy-prescriptive, as per the IPCC's mandate, solutions to global environmental problems might use analytical tools that embed within them biases of one or another type of solution.

AUTHORSHIP, INCLUSION, AND DIVERSITY

When the newly elected Chair of the IPCC, Hoesung Lee (2015) declared that promoting the involvement of developing country scientists was a cornerstone for his tenure, he was articulating a theme of inclusivity that has been present since the IPCC's inception (82). Bert Bolin, the first chair of the IPCC, noted during the IPCC's inception that it is of crucial importance for developing countries to fully participate in the IPCC (5, pp. 55–56). From its founding, the IPCC has recognized and tried to address the relative lack of authors from developing countries, for example, by paying expenses for developing country authors to attend meetings (5, 9). From 1990 to 2007, the number of IPCC authors from developing countries quadrupled, but their numbers are still proportionally low. The number of authors from developed countries also increased over the same period of time; only 17% of authors in the AR4 are from developing countries (83). As a result, there is still a significant "north-south divide" that results in an overrepresentation of science from OECD countries or countries that are classified as high income by the World Bank (84). In addition, indigenous knowledge is underrepresented in the IPCC (85).

Quantitative bibliometric analysis of climate change publications reveals not only that climate change research is concentrated in the developed countries, but also that developed countries tend to focus more on issues of mitigation whereas developing countries focus more on adaptation, droughts, and disease impacts (86). This tendency is also reflected in the composition of the IPCC; where representation from developing countries has improved, much of it is focused on WGII, which publishes regional chapters on impacts and adaptation (83). Science that is conducted in developing countries, which contribute the least to GHG emissions but are the most vulnerable to climate change impacts, often has a different focus than in developed countries, which tend to focus more on large-scale positivist understandings of the physical system and the economics of mitigation (87). Many authors from developing countries who participated in WGIII's AR5 did so

through coauthorship relationships and "institutional pathways" that are based in the developed world (88). This might be responsible for the "strong harmonization of views [in AR5 WGIII], compared with the diversity one finds across the social sciences of climate change more broadly" (88, p. 98). The forgoing considerations give rise to the question, how should the IPCC engage with the realities of unequal global development and the vast differences between rich and poor nations.

The IPCC takes diversity criteria seriously in the production of its Assessment Reports, from the selection of authors to reflect United Nations geographic regions to the more informal consideration of gender, age, career stage, and ethnicity in the composition of each chapter writing group. And most IPCC authors, no matter where they are from or what discipline they work within, are concerned about the impacts of climate change on vulnerable populations. The difficulty is that the IPCC as an organization acts within the context of global structural inequalities. As a result, the IPCC must draw its authors from a context of unequal access to resources such as educational training and institutional support. But there are pragmatic steps that can be taken by institutions and individuals from across geographic regions to work toward the better inclusion of diversity (84). The IPCC has innovated strategies to improve capacity building, one of which was to recruit early-career scientists to managerial roles in chapter writing processes for WGII and WGIII. Such programs can assist with equalizing quality among chapters and can provide early-career scientists with an opportunity to participate in the IPCC process (89).

The justification for inclusivity of science produced in and for developing countries is multifaceted. The credibility of the IPCC in some countries is potentially undermined if it is seen as only representing Western science. In addition, greater diversity arguably enhances the epistemological rigor of the IPCC by including authors from different backgrounds who might bring perspectives that are missing from less diverse groups (90). Precedents have been established for how individual field studies can increase the sophistication of their scientific methods through working collaboratively with Indigenous communities (91). The pragmatic challenge for organizations such as the IPCC is how to translate insights about the benefits of collaboration, which are often contingent on building relations of trust with specific groups and individuals over time, from field studies to the assessment of knowledge through consensus.

It is clear that involvement in the IPCC benefits researchers from developing countries; the scholarly output (measured as peer-reviewed publications) of Coordinating Lead Authors and Lead Authors from least-developed countries increased in the 5-year interval following their involvement in an IPCC report (92). But different geographical contexts often have different ways of judging the quality and relevance of scientific knowledge. Developing country scientists may have different but equally valid epistemological norms as those found in developed countries, but those norms might be downplayed in favor of so-called Western standards (93). The "geographies of science" is a relevant political issue because determining what counts as legitimate knowledge about climate change is intimately associated with normative questions about the governance of environmental change (94). For this reason, redressing the imbalance of knowledge in GEAs requires more than simply increasing the numbers of authors from developing nations; it also is a matter of maintaining critical awareness of the assumptions that inform the social authority of science in developed countries (95, 96). As will be seen in the following case study, this comes to the fore when we consider how adaptation is framed in the IPCC.

Case Study: Adaptation, Adaptive Capacity, and the Global Development Industry

The IPCC's institutional structure was designed in the late 1980s to render climate change as a scientifically credible and a politically tractable phenomenon. At that time, the politics of climate

change was figured in terms of the overall reduction of GHG emissions and the so-called sinks for atmospheric carbon. The international politics of climate change, for most of the IPCC's history, retained this initial focus on abatement and mitigation. The topic of adaptation was shunned partly because it could be interpreted as giving the fossil fuel industry a free pass or capitulating to the status quo. However, since the IPCC's founding in 1988, the impacts of climate change have become more pronounced, and some of the world's most vulnerable people are already experiencing the negative impacts of climate change, which makes discussion of adaptation imperative (97–99). There is little doubt that adaptation is gaining more attention (99). The Paris Agreement signaled the importance of adaptation in Article 7.1. According to the Adaptation Fund set up by the Kyoto Protocol, it "has committed US $357.5 million to support 55 concrete, localized climate adaptation and resilience projects in 48 countries, with more than 3.7 million direct beneficiaries" since 2010 (see **https://www.adaptation-fund.org/adaptation-fund-board-chair-delivers-key-speech-cop22-outlining-funds-growth-demand-value/**). At the same time, developed countries are already spending considerable sums on their own adaptation programs. As Georgeson et al. (100, p. 584) contend, "The total global spend in 2014/15 on adaptation and resilience to climate change was £223 billion [. . .] 0.38% of global GDP." The adaptation economy is starting to become big business.

Given the increasing importance of adaptation, some authors argue an important task ought to be to define adaptation and standardize the criteria by which it can be measured in a uniform way (101–103). This, they argue, would facilitate the tracking of adaptation and the periodic stocktake that the UNFCCC agreed to in COP 21. Adaptation could be tracked in much the same way that global health is measured, and indicators could be developed to monitor adaptation in ways that are "consistent, comparable, comprehensive and coherent" (101). But as the authors point out, there is little agreement on how adaptation—and the related conceptual apparatus of resilience and vulnerability—should be understood in the literature. Adaptation, resilience and vulnerability are intimately linked with factors that are not related directly to physical climate change, such as poverty, class, gender, ethnicity, age, (dis)ability and citizenship status, all of which profoundly influence people's ability to adapt to adverse climatic events (104). Although most conceptualizations of vulnerability include social factors, such as the impacts of colonialism on indigenous peoples, some conceptualizations of vulnerability privilege social, and others ecological, factors (105). From the perspective of political ecology, for example, the pernicious cycles of ever-increasing debt that smallholder farmers are enmeshed within by historical and political circumstances constrain their ability to adapt to changes in climate (106). Increasing attention is being given to contextual vulnerability and the social, economic, cultural, and political forces that both constrain and enable humans' ability to respond to changes in climate (107). But as the WGII's AR5 itself discusses in chapter 14, section 5.1 ("What Is to Be Measured?"), studies of contextual vulnerability, and the social, political, and economic factors that influence adaptive capacity, focus on dynamic relations that are hard to translate into a universally applicable set of measurement indicators (108). Given that, as discussed in the previous section, developing countries focus more on adaptation, and given the lack of consensus on what adaption is or how it should be measured, it is worthwhile to consider how adaptation is configured not only within the IPCC but also the broader context of global development.

The IPCC only gave scant attention to adaptation in its first two Assessment Reports, treating it primarily as a "residual" phenomenon that results from the failure to mitigate climate change in particular local contexts (109). Starting with the Third Assessment Report published in 2001, however, adaptation became increasingly important in the IPCC. Early work in climate change adaptation drew from the literature on natural disasters in which human vulnerability is conceptualized as exposure to hazards, as well as work on the resilience of complex social-ecological systems

(110–112). This literature developed the concept of adaptive capacity that theorizes adaptation as a generalizable quality which allows human societies to adapt to negative events. This dominant conceptualization of adaptive capacity posits it as a central mechanism through which countries can develop along the pathways established by postwar modernization and industrial development (113, 114). Moore (109, p. 76) puts it succinctly: "Because adaptive capacity might be conceivably limited by any factor of development, almost any development project could be reframed as an adaptation project." Aided by this conceptualization of adaptive capacity, established international aid agencies have stepped easily from the paradigm of postwar modernist development into climate change adaptation. However, the uptake of climate change adaptation programs by international development agencies is problematic if, instead of challenging carbon-intensive pathways and paradigms of development that privilege some groups of people over others, it simply allows for the continuation of "development as usual" (114). Moreover, from a critical perspective, the development industry's history of linking local places in the Global South, which are now targeted for adaptation programs, with global flows of power and capital is itself implicated in the production of vulnerability (115, 116).

The IPCC treated adaptation in its first three Assessment Reports largely in a linear model of science for policy (117). More recently, the IPCC's representation of adaptation and global development has become less univocal. For example, the SPM of the WGII's AR5 states that it has "very high confidence" that "differences in vulnerability and exposure arise from nonclimatic factors and from multidimensional inequalities often produced by uneven development processes" (117, p. 6). And the IPCC explicitly addressed the politics of adaptation in its 2012 Special Report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (118). Published between the AR4 and AR5, the report included social transformation as an additional category of resilience and recommended that policymakers consider the long-term transformation of social, economic, and political structures as a viable means of adapting to climate change. From this perspective, concepts of social justice should be at the forefront of efforts to transform development pathways by purposefully transforming the social, cultural, economic, and political constraints of adaptation (119–121).

CONCLUSION

Toward Institutional Reflexivity and Social Learning in Global Environmental Assessments

Literature from organizational studies, psychology, sociology, and environmental economics offers a wealth of insights into how organizations might change their behavior in response to climate change, as well as the potential barriers that prevent effective learning from taking place within organizations (e.g., 122–124). The IPCC itself, in chapter 16 of WGII's AR5, for example, considers the role that organizations and institutions at various scales play in facilitating adaptation to climate change (125). This raises the issue of double- or even triple-loop learning and how well organizations can use knowledge to alter their own behavior in light of climate change (126). Within the literature on climate change and social learning, the concept of reflexivity is particularly helpful because it describes the capacity for humans to consciously reflect upon the organizational procedures and practices through which organizations such as the IPCC produce knowledge (127–131). Reflexivity describes "the ability of a society to critically reflect upon its organizing principles in response to new conditions, and then modify them if necessary" (129, p. 17). Applying the reflexive turn to the IPCC "calls attention to . . . [its] epistemological and normative frameworks and thus, . . . it opens up a space to consider and evaluate the full range of alternative institutional design options

as opposed to implementing a one-size-fits-all model of expertise" (131, p. 81). For this reason, institutional reflexivity often involves challenging established routines, practices, and beliefs.

As seen in its history of trying to standardize representations of uncertainty, the IPCC has a long institutional record of trying to reformulate its policies and procedures in light of new information (132). And IPCC authors often engage in reflexive dialogue about how IPCC policies and procedures could be changed (e.g., 133, 134). Features of the IPCC's design are routinely made part of such conversations, including how the IPCC is framed. Beck et al. (96, 131) argue that the IPCC has largely "bought into" the interpretive framework that assumes the primary problem with climate change is a lack of scientific knowledge, and that the audience with whom the IPCC should be most concerned is policymakers. This global risk framework excludes the public and risks alienating them from becoming invested in the problem of climate change (96, 131). Instead of framing climate change as a problem that can be solved by experts following formal rules of procedure, the reflexive turn suggests that the IPCC should be open to the diversity of social priorities that different audiences articulate in relation to climate change. From this perspective, "[t]he ideal is a 'reflexive institution' which is inclusive and deliberative and allows multiple, culturally-embedded versions to be discussed, and a collective vision to be produced. It allows contrasting framings to be debated, and different political and value positions to be acknowledged" (2, p. 567).

The openness suggested by the concept of reflexivity could be considered when making trade-offs between possible courses of action. The Pragmatic Enlightened Model (PEM) is one model for doing so (135, 136). As proponents of the PEM point out, assessments such as the IPCC's are tasked with providing not only an understanding of the physical sciences of environmental change, but also solutions. Because solutions often entangle facts and values and pertain to issues characterized by complexity and uncertainty—and because organizations such as the IPCC are mandated to remain neutral with respect to policy—a goal of the PEM is to clearly outline what different policy options and their implications are, and make them the subject of wider public debate. That is, rather than the technocratic model, which assumes that science can determine all relevant options, or the decisionist model, which assumes policymakers should have priority over determining what options are best, the PEM includes spaces for participatory public deliberation. The deliberative model involves iterative conversations between scientists, policymakers, and public groups. By including the public in deciding how best to respond to climate change, the model attempts to "integrate ethical principles into decision-making on specific policy options" (137, pp. 299–300). The intended result of this kind of deliberation is a set of alternative policy pathways that make their values, assumptions, and uncertainties transparent (136).

Revisiting Consensus, Uncertainty, Controversy, and the Authority of Science

As studies of the processes through which GEAs produce knowledge have shown, the relation between science and policy cannot be reduced to a generic approach; GEAs often succeed or fail depending on how well they articulate the relation between science and policy for their given context (3). Given the complexity and politically contentious subject of climate change, the IPCC has had to navigate a particularly challenging set of circumstances. As seen in the case studies above, the IPCC's credibility is challenged, on one hand, by those who take issue with the IPCC's engagement with geoengineering, and, on the other hand, by denialists who wish to discredit the need for regulating GHG emissions in the first place. The IPCC also risks losing salience for developing countries if it is perceived as privileging knowledge that adheres to normative standards of developed countries, only addresses issues that are most relevant for developed countries, or frames adaptation in ways that do not consider the political economy of globalized social relations.

Furthermore, many users of scientific assessments are concerned with the possibility of extreme events and will turn elsewhere if they find the IPCC's assessment procedures exclude qualified judgments of risk. Different publics have different criteria for judging the IPCC, but many of them might be addressed by the IPCC by being more transparent about the processes through which it assesses knowledge.

The public does not necessarily need to be protected from uncertainty; disagreement between scientists will not inevitably lead to public confusion, even though, as seen above, denialists use disagreement as a reason for inaction (15). Indeed, the practice of surfacing dissenting views might actually increase the degree of credibility the IPCC is accorded in public. If people can see that different views are registered inside the IPCC, then it reduces the need to construct a single authoritative edifice in the attempt to safeguard the IPCC's social authority (25). There are practical difficulties associated with this course of action. In the case of climate change, there is a well-funded and well-organized lobby that has direct financial interests in delegitimizing the IPCC (47). In comparison to the consortium of actors who oppose climate science, the IPCC has a vanishingly small budget for public relations and communications. As such, the IPCC often has to mobilize the particular expertise of Working Group chairs and cochairs as well as the communications specialists who might be involved in the IPCC. Politically and ideologically motivated attacks against GEAs, such as those that took place in the hacked email scandal of 2009, are not likely to be assuaged simply by shoring up assertions of scientific certainty (138). Rather, successful engagement with controversy can be managed through demonstrating transparency—transparency that includes an openness to the social processes through which knowledge is produced as well as to doubts expressed by the public (69). This transparency should extend to the role that geoengineering plays in mitigation scenarios. Transparency should be understood as the result of an active and intentional process, not the inevitable by-product of science properly conducted. As Granjou et al. (139) argue in relation to the IPBES, transparency involves a performative element in which certain aspects of the assessment remain backstage while others are intentionally brought forward.

Over its 30-year history, the IPCC has achieved its main objective: identifying a scientific basis for climate change policy that is by and large not disputed by its member governments and that can inform actions taken in other forums, such as the UNFCCC. This alone is an indisputably valuable and singular accomplishment. The IPCC has played a significant role in bringing the dangers of climate change to attention. In this review, we took a critical perspective on the IPCC in an effort to inform other organizations, most notably the IPBES. The involvement of governments in the IPBES and its commitment to release a series of assessments over time is largely informed by the IPCC's experience (140, 141). There are key differences between IPBES and the IPCC; unlike the IPCC, the IPBES made a commitment to support "knowledge generation, capacity-building, and policy support," which are areas that exceed the IPCC's mandate (142). In addition, the IPBES formally includes indigenous and local knowledge, even if it is not yet clear precisely how such knowledge will be included (139). And although a recent study of the composition of the gender and disciplinary composition of multidisciplinary expert panels in the IPBES between 2013 and 2015 shows some improvement, there remains "significant room for improvement" (143). The IPBES is in a position to capitalize on some of the lessons learned through the IPCC's experience with global environmental change (95, 144).

Climate change has rapidly moved from a marginal issue to one that many governments recognize as one of the most urgent challenges. Scholars from across the humanities and social and natural sciences are confronting the ethical, political, and practical quandaries of reaching what some have termed the Earth's planetary boundaries and the realization that humans are acting on a planetary scale (e.g., 98, 130, 145, 146). The IPCC has undoubtedly played a significant role in shifting consciousness about humans' relation with the Earth. To maintain its social relevance,

the IPCC and other organizations that produce GEAs would do well to try to model the social transformations they wish to see in the world.

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