Valuing the Greenland ice sheet and other complex geophysical phenomena

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For the last 40 y, economists have worked to put monetary values on environmental amenities to facilitate the cost–benefit analysis (CBA) of alternative policies (1–3). The motivation is simple: Policy choices inevitably require trade-offs. Resources devoted to climate change mitigation are resources not spent on curing diseases, improving education, alleviating poverty, or providing for national defense, not to mention enjoying private comforts and consumption. It is natural to hold governments and public policies accountable for ensuring that these trade-offs make sense in a transparent way, which is the essence of CBA.

A key feature in CBA related to climate change mitigation is the social cost of carbon (SCC), the dollar value associated with avoided damages from each ton of reduced carbon dioxide emissions. The SCC multiplied by total tons of CO_2 reduced by a given policy determines benefits; subtracting policy costs yields an estimate of net benefits. These net benefits can be compared across policies or even among various arenas of government activity to make choices and prioritize action.

In PNAS, Nordhaus (4) examines the effect of including Greenland ice sheet (GIS) melt in estimates of the SCC. This responds to the common-sense concern that a largely irreversible and complete melting of the GIS would raise mean sea level by 7 m and inundate many of the world's population centers. It also responds directly to one of the recommendations in a recent consensus study report of the National Academy of Sciences, Engineering, and Medicine (recommendation 4-3 of ref. 5) that a sea-level rise (SLR) component be included in the SCC modeling. More generally, Nordhaus (4) demonstrates how complex geophysical phenomena can be integrated with an economic analysis. He does this by distilling the properties of GIS melt into a simple 2-equation model, which is then included in his Dynamic Integrated model of Climate Economy (DICE). This model already includes both the costs of mitigating climate change and the conventional (non-GIS) damages from global temperature change.

Nordhaus's (4) methodological approach to integrating GIS melt into the SCC is a valuable guide for the economic analysis of other climate change issues and long-term environmental concerns more broadly. For example, there is debate over the temperature threshold that ultimately leads to GIS disintegration. There is further uncertainty about whether potential multiple stable equilibria exist, as well as the dynamics of moving between them. The author's 2-equation model captures these features, allows him to match more complex GIS models and available evidence, and permits sensitivity analysis across the important geophysical uncertainties. That is, Nordhaus's implicit guidance is to construct a simple model that mimics the economically relevant features and available evidence from state-of-the-art models, and allows sensitivity analysis across significant uncertainties.

Nordhaus's (4) quantitative result, perhaps surprisingly, finds an increase of at most 5% (and more typically <1%) in the estimated SCC value under a wide range of assumptions about GIS melt. That is, the direct consequences of including the estimated monetary damages from GIS melt in the SCC calculation is negligible.

What explains this small value? The potential damages from GIS melt are large but not existential. Nordhaus (4) assumes, based on Diaz and Keller's

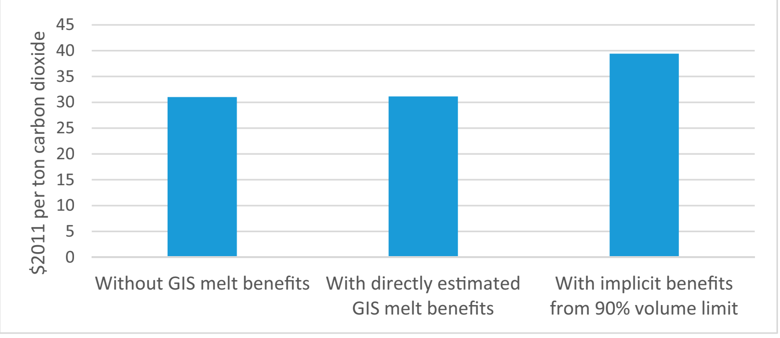

Fig. 1. Estimated 2015 social cost of carbon with and without GIS melt benefits. Data from table 2 and SI appendix, table J-2 of ref. 4.

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study (6), that each meter of SLR reduces global income by 1%, so complete disintegration of the GIS implies a 7% loss. In the no-policy baseline, only half of this melt occurs over 2,000 y (see figure 5 of ref. 4). Meanwhile, conventional damages amount to a 12% loss of income in the baseline after 400 y (7). Mechanically, smaller damages that extend over more than a millennium further into the future simply do not matter. Put another way, while the noted effects of GIS melt are large, they pale in comparison with damage estimates from other categories of impacts. Such categories range from health and mortality to agricultural losses, productivity declines, and storm damage (8).

An important next step will be to extend this approach to the Antarctic Ice Sheet—which is nearly ten times larger and could raise mean sea level by nearly 60 meters (9). Other geophysical phenomena could also have larger effects. Indeed, another contribution of the paper by Nordhaus (4) is suggesting ways to filter what other geophysical phenomena will matter for the SCC. Damages will need to be similar in magnitude and timing to conventional climate damages (if not larger and faster).

Of course, the economic analysis and CBA applied to environmental amenities is but one input to policy making, and criticism of such efforts has been around nearly as long as the analysis itself (10–12). Among the concerns is that we simply do not understand the interconnectedness of various outcomes and/or miss important effects. One way to work around the critique is to explore the cost of achieving a particular environmental outcome without regard to benefits of doing so.

How might we use the cost of an environmental target to make policy choices, absent benefit estimates? Ethical, political, precautionary, or other considerations, rather than benefit estimates, may argue for a particular environmental goal such as limiting GIS melt. By translating that goal into an aggregate dollar cost per ton CO_2, interpreting that cost as an "implicit benefit," and then applying that value widely to evaluate individual policies, disparate policies can be harmonized to reduce the cost of achieving the goal. This facilitates what is referred to as cost-effectiveness analysis and is precisely the approach taken in the United Kingdom to value CO_2 emission reductions more broadly. They have established a "target-consistent" carbon value based on the estimated aggregate abatement cost necessary to meet their 2050 emission target of 80% below 1990 levels (13).

An important caveat is that estimated costs alone should not be viewed as the argument for a particular target or goal. There must be some consideration for what that cost is achieving and why the costs are worthwhile. As noted, these considerations might be ethical, political, precautionary, or economic. But once the target or goal is deemed worthwhile (as in the United Kingdom or for a GIS melt limit), the cost estimates of the chosen goal can be used as implicit, minimum benefit estimates for further decision making about individual policies.

Nordhaus demonstrates how complex geophysical phenomena can be integrated with economic analysis and paves the way for other impacts to be examined in the future.

Nordhaus (4) does exactly this implicit benefit calculation as an alternative to his direct damage estimates. He estimates that for the GIS to maintain at least 90% of its current volume, the SCC would need to be 28% higher—$39 per ton CO_2 rather than $31 per ton CO_2—compared with an estimate that ignores the GIS. In a sensitivity analysis that doubles the assumed GIS melt rate—an assumption that Nordhaus notes goes beyond any estimates in recent Intergovernmental Panel on Climate Change reports—the required SCC nearly triples. If societal concerns lead to a 90% melt limit, the relevant, implicit value place in CO_2 mitigation should be higher.

In summary, valuing the GIS and other climate change impacts is an important contribution to the climate change policy debate. Benefit estimates require the discipline to trace through how and why a particular policy choice is economically worthwhile when stacked up against other public and private choices. This CBA approach provides valuable, relatively transparent evidence to inform decision making. That is not to say that benefit estimates and CBA alone should determine societal goals or policy. Ethical, political, or other concerns, often in conjunction with cost estimates, can be equally or more important. Nordhaus's (4) direct benefit estimates—that GIS melt has a minimal effect on overall benefit estimates—imply that these other concerns would have to justify a focus on the GIS. If such concerns were sufficient for a decision to significantly limit GIS melt, the implicit benefit would argue for raising the SCC in the analysis of individual policies (Fig. 1). Alongside these particular estimates, Nordhaus demonstrates how complex geophysical phenomena can be integrated with economic analysis and paves the way for other impacts to be examined in the future.

1 M. A. Livermore, R. L. Revesz, *Globalization of Cost-Benefit Analysis in Environmental Policy* (Oxford University Press, London, 2013).
2 US Government, White House, Executive Order 12044: Improving government regulations. *Fed. Regist.* **43**, 12661 (1978).
3 HM Treasury, *Investment Appraisal and Discounting Techniques and the Use of the Test Discount Rate in the Public Sector* (Public Sector Economic Group, HM Treasury, London, 1980).
4 W. Nordhaus, Economics of the disintegration of the Greenland ice sheet. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 12261–12269 (2019).
5 National Academies of Sciences, Engineering, and Medicine, Valuing climate damages: Updating estimation of the social cost of carbon dioxide (2017). https://www.nap.edu/read/24651/chapter/3#14. Accessed 15 May 2017.
6 D. Diaz, K. Keller, A potential disintegration of the west Antarctic ice sheet: Implications for economic analyses of climate policy. *Am. Econ. Rev.* **106**, 607–611 (2016).
7 W. D. Nordhaus, DICE/RICE models: Scientific and economic background on DICE models (2017). https://sites.google.com/site/williamdnordhaus/dice-rice. Accessed 13 May 2019.
8 S. Hsiang *et al.*, Estimating economic damage from climate change in the United States. *Science* **356**, 1362–1369 (2017).
9 P Fretwell *et al.*, Bedmap2: Improved ice bed, surface and thickness datasets for Antarctica. *The Cryosphere* **7**, 375–393 (2013).
10 S. Kelman, Cost-benefit analysis: An ethical critique. *Regulation* **5**, 33–40 (1981).
11 R. H. Frank, Why is cost-benefit analysis so controversial? *J. Legal Stud.* **29**, 913–930 (2000).
12 L. Heinzerling, "Why Care About the Polar Bear? Economic Analysis of Natural Resources Law and Policy" in *The Evolution of Natural Resources Law and Policy*, L. J. MacDonnel, S. F. Bates, Eds. (American Bar Association, Chicago, 2010), pp. 53–76.
13 Department of Energy and Climate Change, UK Government, Carbon valuation in UK policy appraisal: A revised approach (2009). https://hub.globalccsinstitute.com/publications/carbon-valuation-uk-policy-appraisal-revised-approach. Accessed 13 May 2019.