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PERSPECTIVE

Moving beyond benefit–cost analysis of climate change

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Abstract

The conventional benefit–cost approach to understanding the climate problem has serious limitations. Fortunately, an alternative way of thinking about the problem has arisen in recent decades, based on analyzing the cost effectiveness of achieving a normatively defined warming target. This approach yields important insights, showing that delaying action is costly, required emissions reductions are rapid, and most proved reserves of fossil fuels will need to stay in the ground if we're to stabilize the climate. I call this method 'working forward toward a goal', and it is one that will see wide application in the years ahead.

1. Introduction

The recent article in ERL by Luderer *et al* [1] is exemplary in the clarity of its approach and the cogency of its recommendations, demonstrating that further dithering on the climate issue increases the costs of mitigation and makes it more difficult to achieve climate stabilization. Its findings are compelling in large part because it uses an approach to assessing the climate problem that diverges from the usual benefit–cost framing (which purports to characterize marginal costs and benefits of climate action far into the future, as, for example, in Nordhaus [2]). That divergence is all to the good, because the benefit–cost approach, while it has been useful in many contexts, has serious limitations that call into question its utility for analyzing climate change [3–8].[1]

This new way of thinking, which I call 'working forward toward a goal', involves assessing the *cost effectiveness* of different paths for meeting a normatively determined target. It has its origins in the realization that stabilizing the climate at a certain temperature (e.g., a warming limit of 2 Celsius degrees above pre-industrial times) implies a particular emissions budget, which represents the total cumulative greenhouse gas emissions compatible with that temperature goal. This approach had its first fully developed incarnation in 1989 in Krause *et al* [9] (which was subsequently republished in 1992 [10]). It was developed further in Caldeira *et al* [11] and Meinshausen *et al* [12], and has recently served as the basis for the International Energy Agency's analysis of climate options for several years running [13–15].

Such an approach has many advantages. It encapsulates our knowledge from the latest climate models on how cumulative emissions affect global temperatures, placing the focus squarely on how to stabilize those temperatures. It puts the most important value judgment up-front, embodied in the normatively determined warming limit, instead of burying key value judgments in economic model parameters or in ostensibly scientifically chosen concepts such as the

[1] In particular, estimating benefits is much more difficult than estimating costs, both because of complexities in comparing utility functions over time and between people [5], and because we still don't (and probably never will) understand all the feedbacks and complexities in the climate system as we push it further out of equilibrium. Long-term *cost* estimation presents challenges that should make us cautious in using those estimates also, which is why I advocate mainly focusing on cost-effectiveness evaluation of achieving short-term goals and continually re-evaluating our direction as circumstances dictate [4].

discount rate. It gives clear guidance for the rate of emissions reductions required to meet the chosen warming limit, thus allowing us to determine if we're 'on track' for meeting the ultimate goal, and allowing us to adjust course if we're not hitting those near-term targets. It also allows us to estimate the costs of delaying action or excluding certain mitigation options, and provides an analytical basis for discussions about equitably allocating the emissions budget. Finally, instead of pretending that we can calculate an 'optimal' technology path based on guesses at mitigation and damage cost curves decades hence, it relegates economic analysis to the important but less grandiose role of comparing the cost effectiveness of currently available options for meeting near-term emissions goals.

'Working forward toward a goal' is a more business-oriented framing of the climate problem [4]. It mirrors the way companies face big strategic challenges, because they know that accurately forecasting the future of economic and social systems is impossible [16, 17], so they set a goal and figure out what they'd have to do to meet it, then adjust course as developments dictate. To do so, they implement many different options, evaluate continuously, and do more of what works and less of what doesn't. Such an approach, which the National Research Council [18] dubs 'iterative risk management', recognizes the limitations of economic models and frees us from the mostly self-imposed conceptual constraints that make it hard to envision a future much different from the world as it exists today [4].

2. Key insights from working forward toward a goal

The key insights from this approach relate to the costs of delay, the rate of needed emissions reductions, and the amount of fossil fuels we can burn and stay within the warming limit. These insights are not yet fully appreciated by policy makers, even in countries that accepted the 2 Celsius degree warming limit in 2009 in Copenhagen, but they are robust and important, so I summarize them below.

2.1. The costs of delay

Delaying action eats up the emissions budget, locks in emissions-intensive infrastructure, and makes the required reductions much more costly and difficult later. The IEA, using the 'working forward toward a goal' approach, estimated the costs of delay at about $0.5 trillion US for every year we put off serious climate action [13].

Conversely, early action through technology deployment brings the costs of technologies down through learning-by-doing, which is one manifestation of increasing returns to scale [19]. Because of these and other factors, *our choices now affect our options later*, which is known in the technical literature as *path dependence* [19, 20]. Luderer *et al* highlight the importance of such effects to the economic outcome on climate mitigation, but most conventional models of the economy ignore them [19, 21], with the likely effect of overestimating the costs of reducing emissions [22, p. 151].

2.2. The rate of needed emissions reductions

Having a high chance of meeting the 2 Celsius degree warming limit implies very rapid greenhouse gas emissions reductions in the next few decades. The exact figures depend upon our risk tolerance and other factors, but the overall lesson is the important thing: the required reductions are so rapid (3–4% of year 2012 emissions every year for the next three decades) that they will likely force us to scrap some capital in the energy sector [4], and that's something we should be prepared to do, along with minimizing the construction of new emissions-intensive infrastructure.

2.3. The amount of fossil fuels we can still burn

Meeting the 2 Celsius degree warming limit implies that a significant fraction of proved fossil fuel reserves simply cannot be burned [4], or we'll need to figure out a way to sequester carbon in a safe way (which is not currently feasible on the scales needed, though it has been proved in some applications). This line of argument has achieved recent prominence through the writings of Bill McKibben [23] and Al Gore [24], but it was first put forth in 1989 in Krause *et al* [9], and it's a direct result of the 'working forward toward a warming limit' method.

This conclusion is ominous for those now fighting to build more emissions-intensive infrastructure. There's a real business risk to them because once the world finally accepts that rapid reductions of emission are required (which must happen soon if we're to have any chance of stabilizing the climate), those investors will lose their money. When markets turn, they do so with terrifying speed, and this time will be no exception.

3. Conclusions

The conventional benefit–cost approach to understanding the climate problem has serious limitations. Fortunately, an alternative way of thinking about the problem has arisen in recent decades that yields important insights, showing that delaying action is costly, required emissions reductions are rapid, and most proved reserves of fossil fuels will need to stay in the ground if we're to stabilize the climate. I call this method 'working forward toward a goal', and it's one that will see wide application as we face the climate challenge in the years ahead.

References

[1] Luderer G, Pietzcker R C, Bertram Ch, Kriegler E, Meinshausen M and Edenhofer O 2013 Economic mitigation challenges: how further delay closes the door for achieving climate targets *Environ. Res. Lett.* **8** 034033

[2] Nordhaus W D 2008 *A Question of Balance: Weighing the Options on Global Warming Policies* (New Haven, CT: Yale University Press)

[3] Jaeger C C and Jaeger J 2011 Three views of two degrees *Reg. Environ. Change* **11** (suppl.) 15–26

[4] Koomey J G 2012 *Cold Cash, Cool Climate: Science-Based Advice for Ecological Entrepreneurs* (Burlingame, CA: Analytics Press) (www.analyticspress.com/cccc.html)

[5] DeCanio S J 2003 *Economic Models of Climate Change: A Critique* (Basingstoke: Palgrave-Macmillan)

[6] Weitzman M L 2011 *Fat-tailed uncertainty in the economics of catastrophic climate change* February 23 (http://scholar.harvard.edu/weitzman)

[7] Ackerman F, DeCanio S J, Howarth R B and Sheeran K 2009 Limitations of integrated assessment models of climate change *Clim. Change* **95** 297–315

[8] Krause F, Haites E, Howarth R and Koomey J G 1993 *Cutting Carbon Emissions–Burden or Benefit?: The Economics of Energy-Tax and Non-Price Policies* (El Cerrito, CA: International Project for Sustainable Energy Paths) (www.mediafire.com/file/y4r0n4vcvv4257s/cuttingCemissionsburdenorbenefitbook.pdf)

[9] Krause F, Bach W and Koomey J 1989 *From Warming Fate to Warming Limit: Benchmarks to a Global Climate Convention* (El Cerrito, CA: International Project for Sustainable Energy Paths) (www.mediafire.com/file/pzwrsyo1j89axzd/Warmingfatetowarminglimitbook.pdf)

[10] Krause F, Bach W and Koomey J G 1992 *Energy Policy in the Greenhouse* (New York: Wiley)

[11] Caldeira K, Jain A K and Hoffert M I 2003 Climate sensitivity uncertainty and the need for energy without CO_2 emission *Science* **299** 2052–4

[12] Meinshausen M, Meinshausen N, Hare W, Raper S C B, Frieler K, Knutti R, Frame D J and Allen M R 2009 Greenhouse-gas emission targets for limiting global warming to 2 °C *Nature* **458** 1158–62

[13] IEA 2010 *World Energy Outlook 2010* (Paris: International Energy Agency, Organization for Economic Cooperation and Development (OECD)) November 9 (www.worldenergyoutlook.org/)

[14] IEA 2011 *World Energy Outlook 2011* (Paris: International Energy Agency, Organization for Economic Cooperation and Development (OECD)) November 9 (www.worldenergyoutlook.org/)

[15] IEA 2012 *World Energy Outlook 2012* (Paris: International Energy Agency, Organization for Economic Cooperation and Development (OECD)) November 12 (www.worldenergyoutlook.org/)
[16] Scher I and Koomey J G 2011 Is accurate forecasting of economic systems possible? *Clim. Change* **104** 473–9
[17] Koomey J G, Craig P, Gadgil A and Lorenzetti D 2003 Improving long-range energy modeling: a plea for historical retrospectives *Energy J.* **24** 75–92 (also LBNL-52448)
[18] NRC 2011 *America's Climate Choices* (Washington, DC: National Research Council of the National Academies. The National Academies Press) (http://nas-sites.org/americasclimatechoices/sample-page/panel-reports/americas-climate-choices-final-report/)
[19] Arthur W B 1994 *Increasing Returns and Path Dependence in the Economy* (Ann Arbor, MI: The University of Michigan Press) (http://amzn.to/17fqPVH)
[20] Gritsevskyi A and Nakicenovic N 2000 Modeling uncertainty of induced technological change *Energy Policy* **28** 907–21
[21] Arthur W B 1990 Positive feedbacks in the economy *Sci. Am.* **262** 92–9
[22] IPCC 2007 *Climate Change 2007: Mitigation of Climate Change—Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed B Metz, O Davidson, P Bosch, R Dave and L Meyer (Cambridge: Cambridge University Press) (www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml)
[23] McKibben B 2012 Global warming's terrifying new math *Rolling Stone Magazine* (www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719)
[24] Gore A and Blood D 2013 The coming carbon asset bubble *Wall Str. J.* (http://online.wsj.com/news/articles/SB10001424052702304655104579163663464339836?mod=hp_opinion)