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COMMENTARY

3.5 °C in 2100?

BY JAMES K. BOYCE AND RAYMOND S. BRADLEY | **JULY 2018**

The 'optimal' warming recommended by leading economic models surpasses the Paris Agreement target by a wide margin.

Is a 3.5 °C increase in global mean surface air temperature (GMAT) above pre-industrial levels at the turn of the next century a sensible goal for international climate policy? This is the startling conclusion reached by leading integrated assessment models that apply the conventional economic tools of cost-benefit analysis to climate change.

The 3.5 °C optimum for the year 2100 is the recommended course of action in the Dynamic Integrated Climate-Economy (DICE) model developed by economist William Nordhaus of Yale University.[1,2] The DICE model is well-known, and among leading integrated assessment models its results occupy the middle ground. Following the path it prescribes, temperatures would continue to rise after the turn of the century, surpassing 4 °C by 2200. Such temperature increases are far above the science-based 1.5-2 °C target endorsed in the 2015 Paris Agreement.

Back to the Pliocene

The last time the earth experienced a GMAT 3.5 °C above the pre-industrial level was in the mid-Pliocene epoch, about 3.2 million yrs ago.[3] There were large geographical variations in the extent of warming then compared to now, and at high northern latitudes temperature anomalies were at least three times greater.[4,5] Eustatic sea-level was at least 6m above present, and perhaps as much as 20m, with uncertainty as to the level due to dynamic topography and glacial isostatic adjustments.[6]

Melting ice sheets and sea-level rise are unavoidable consequences of a GMAT increase of 3.5 °C. Reaching an 'equilibrium' state (in which there is ice sheet stability under a sustained warmer period) could take centuries. It is likely, however, that with warming above 2 °C global sea-level will have increased by 1-2m by 2100, with significant impacts on coastal cities worldwide.[7] Additional impacts will include ocean acidification and the death of coral reefs,[8] and the contamination of coastal aquifers by sea-water intrusion. These changes will have severe societal impacts and major economic consequences.

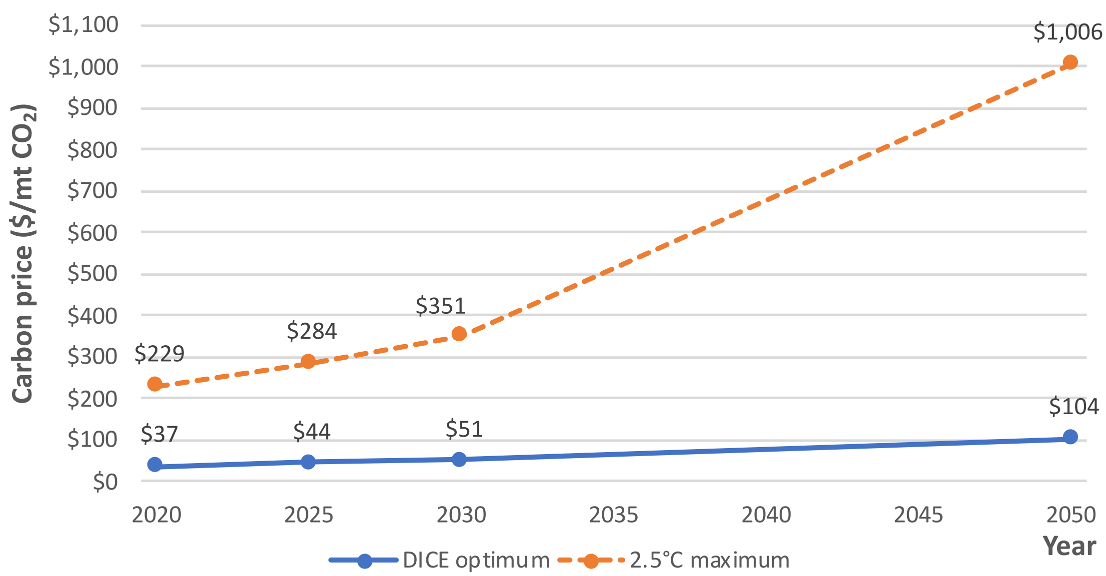
Efficiency or a science-based target?

The incongruence between the 3.5 °C prescription and the Paris target results from profoundly different decision-making criteria. In cost-benefit analysis, the normative objective is efficiency, defined as maximization of the net benefits minus costs converted into present values by means of a discount rate. In the case of climate change, such calculations entail multiple difficulties, simplifications, and arbitrary assumptions.[9,10] Very little is known about the economic cost of returning the planet to temperatures last experienced in the Pliocene. The DICE model uses what its authors term a 'highly simplified' damage function, one that is based on studies that *'generally omit several important factors (the economic value of losses from biodiversity, ocean acidification, and political reactions), extreme events (sea-level rise, changes in ocean circulation, and accelerated climate change), impacts that are inherently difficult to model (catastrophic events and very long-term warming), and uncertainty.'* To adjust for these omissions, the model simply adds 25 percent to the monetized damages.[11]

At the 4.25%/yr discount rate used in the DICE model, damages 100 years from today are discounted by a factor of 64: the present value of $1 million a century from now is less than $16,000, implying that it would be inefficient to pay more than that today to avert the harm. At the 1.4% discount rate used in the Stern Review, the 2007 study commissioned by the UK government, the same damages would be discounted only by a factor of 4, yielding a present value of about $250,000.[12] Which is the right value? Should we discount the well-being of future generations at all? These are ethical questions that science cannot answer.

The normative criterion underlying the Paris target is safety, based on the conclusions of climate scientists, rather than economic efficiency. The 1.5-2 °C goal is intended to conform to the United Nations Framework Convention on Climate Change (UNFCCC) aim of preventing 'dangerous anthropogenic interference' with Earth's climate. The UNFCCC does not require its signatories to act only insofar as the discounted economic benefits of preventing dangerous climate impacts exceed the economic costs. In a similar vein, the Clean Air Act, which provides the legal basis for regulation of greenhouse gas emissions in the US, directs the Environmental Protection Agency (EPA) to set air quality standards for 'the protection of public health and welfare,' allowing 'an adequate margin of safety' – not to weigh the benefits of clean air against its costs.

Figure: Carbon Price Paths



The carbon price needed to limit the rise in global temperature to 2.5 °C is considerably higher than the 'optimal' price prescribed by an economic model that weighs benefits against costs. The global CO_2 price is here expressed in constant 2010 US dollars. Source: Both trajectories are based on the DICE model, reported in Nordhaus PNAS 114 (2017), Table 1.

There is room for disagreement, of course, in determining what is 'safe,' but this criterion requires fewer arbitrary judgments than the economic efficiency criterion applied in cost-benefit analysis. There is no need to assign monetary values to the damages that would result from different emission trajectories, for example, nor any need to pick a discount rate by which to convert these into present values.

The social cost of carbon revisited

The 'social cost of carbon' (SCC) expresses the results of cost-benefit analysis by means of an optimal carbon price, meant to indicate what society should be willing to spend to curtail emissions. A carbon price of $1/mt $CO_{2\text{-}e}$ would add about $0.01 to the price of a gallon of gasoline, and $0.43 to the price of a barrel of oil. The SCC prescribed by the DICE model rises from about US$35/mt $CO_{2\text{-}e}$ in 2020 to about $100 in 2050 (in constant 2010 dollars). In other words, the model implies that it would be optimal to increase gasoline prices by $0.35/gal in 2020 and by about $1.00/gal at mid-century.

Much higher carbon prices are likely to be necessary to meet the Paris goal of limiting the GMAT increase to 1.5-2 °C. According to the DICE model, holding the temperature increase even to 2.5 °C would require a carbon price that starts at about $230/mt $CO_{2\text{-}e}$ in 2020 and rises to $1,000/mt by mid-century.

When the US government's Interagency Working Group on the Social Cost of Carbon ran three models (including DICE) to determine the official SCC for US policy making, it arrived at a central SCC estimate for 2020 of $42/mt $CO_{2\text{-e}}$, similar to that of the DICE model.[13] The sensitivity of SCC calculations to arbitrary assumptions was displayed when the Trump administration entered office, disbanded the Interagency Working Group, and recalculated the SCC. In the regulatory impact analysis for repeal of the Obama-era Clean Power Plan, the EPA under the current administration lowered the SCC to only $1-6/mt by raising the discount rate and excluding from its analysis all benefits from mitigation that would accrue outside U.S. borders.[14]

Target-consistent climate policy

An alternative approach to carbon pricing would start from science-based targets for emissions reduction. The goal of cutting emissions by 80% between 2020 and 2050, for example, could be attained by setting a cap on the amount of fossil fuels allowed to enter the economy that declines by 5.22%/yr. Permits would be issued up to this limit. A carbon tax could serve as the floor price for permits, and if required to maintain the cap, a higher carbon price could be set by permit auctions.[15]

The carbon price in a target-consistent policy cannot be predicted in advance with much certainty. If cost-reducing innovations in energy efficiency and alternative fuels proceed rapidly, the carbon price will be lower than if technological change proves to be slow. If a booming economy boosts energy demand, the price will be higher than during a downturn. Regardless of these unknowns, a carbon price anchored to quantitative emission targets can guarantee that we hold the GMAT increase to the 1.5-2 °C range of the Paris Agreement rather than 3.5 °C or more.

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References

1 Nordhaus, W.D. 2017a. Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 114(7), 1518-1523.

2 Nordhaus, W.D. 2017b. Projections and uncertainties about climate change in an era of minimal climate policies. Cambridge, MA: National Bureau for Economic Research, Working Paper 22933. September.

3 Dowsett, H.J., Robinson, M.M., Haywood, A.M., Hill, D.J., Dolan, A.M., Stoll, D.K., Chan, W.L., Abe-Ouchi, A., Chandler, M.A., Rosenbloom, N.A. and Otto-Bliesner, B.L., 2012. Assessing confidence in Pliocene sea surface temperatures to evaluate predictive models. *Nature Climate Change*, 2(5), 365-371.

4 Salzmann, U., Dolan, A.M., Haywood, A.M., Chan, W.L., Voss, J., Hill, D.J., Abe-Ouchi, A., Otto-Bliesner, B., Bragg, F.J., Chandler, M.A. and Contoux, C., 2013. Challenges in quantifying Pliocene terrestrial warming revealed by data–model discord. *Nature Climate Change*, 3(11), 969-974.

5 Chandran, D. and Peltier, W.R., 2018. On the mechanisms of warming the mid-Pliocene and the inference of a hierarchy of climate sensitivities with relevance to the understanding of climate futures. *Climate of the Past Discussions*, https://doi.org/10.5194/cp-2018-18.

6 Dutton, A., Carlson, A.E., Long, A.J., Milne, G.A., Clark, P.U., DeConto, R., Horton, B.P., Rahmstorf, S. and Raymo, M.E., 2015. Sea-level rise due to polar ice-sheet mass loss during past warm periods. *Science*, 349 (6244).

7 Jevrejeva, S., Jackson, L.P., Riva, R.E., Grinsted, A. and Moore, J.C., 2016. Coastal sea level rise with warming above 2 C. *Proceedings of the National Academy of Sciences*, 113(47), 13342-13347.

8 Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K. and Knowlton, N., 2007. Coral reefs under rapid climate change and ocean acidification. *Science,* 318(5857), 1737-1742.

9 Ackerman, F., S.J. DeCanio, R.B. Howarth and K. Sheeran. 2009. Limitations of integrated assessment models of climate change. *Climatic Change*, 95, 297-315.

10 Pindyck, R.S. 2013. Climate change policy: what do the models tell us? *Journal of Economic Literature* 51(3), 860-872.

11 Nordhaus, W.D. and P. Sztorc. 2013. DICE 2013R: *Introduction and User's Manual. New Haven*: Cowles Foundation.

12 Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.

13 US Interagency Group on the Social Cost of Greenhouse Gases. 2016. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. August.

14 US Environmental Protection Agency. 2017. Regulatory Impact Analysis for Review of the Clean Power Plan: Proposal. October.

15 Boyce, J.K. 2018. Carbon pricing: effectiveness and equity. *Ecological Economics*, 150, 52-61.