Richard Tol on climate policy

A critical view of an overview

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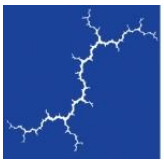
Frank Ackerman, PhD



Synapse
Energy Economics, Inc.

485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139

617.661.3248 | www.synapse-energy.com

INTRODUCTION

Richard Tol's 2013 article, "Targets for global climate policy: An overview," has been taken by some as a definitive summary of what economics has to say about climate change.[1] It became a central building block of Chapter 10 of the recent IPCC Working Group 2 report (Fifth Assessment Report, 2014), with some of its numbers appearing in the Working Group 2 Summary for Policymakers.[2]

After extensive analysis of multiple results from a number of authors, Tol reaches strong and surprising conclusions:

- climate change will be a net benefit to the world economy until about 2.25°C of warming has occurred
- the optimal carbon tax is a mere \$25/tC (or \$7/tCO_2)
- the economically "efficient" climate scenario is likely to lead to atmospheric concentration of greenhouse gases of more than 625 ppm CO_2-equivalent by the end of this century; lower targets might have ruinously high costs

Despite, in the end, almost acknowledging the peculiarity of these conclusions, Tol continues to claim that no compelling argument to the contrary has been made: "A convincing alternative to the intuitively incorrect conclusion that continued warming is optimum, is still elusive."

Tol's conclusions in this article do not follow logically from his data and analysis. Though claiming an authoritative and objective stance, he offers, in fact, a controversial reading of climate economics. Some of the bias is evident in the tone of voice: Tol's longstanding dislike of the Stern Review is on exhibit in the second sentence of the article. Subtler but more important biases are built into the collection and analysis of data throughout the article, as this critique will explain.

Tol offers a comfortingly specific delineation of the available data on climate economics, which falls into three groups. As he sees it (with my numbering)

1) "There are 16 studies and 17 estimates of the *global* welfare impacts of climate change…
2) "There are 75 studies of the social cost of carbon [marginal damages from another tonne of emissions], with 588 estimates…
3) "…a single group of estimates [of the impacts of climate policy, found in one review article] … includes the models with the best academic pedigree…"

This enumeration and categorization of the mass of available data is key to Tol's conclusions. Each of the three statements quoted above deserves a closer look.

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[1] Richard Tol (2013), "Targets for global climate policy: An overview," *Journal of Economic Dynamics and Control* 37, 911-928.

[2] For WG2, Chapter 10, see http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap10_FGDall.pdf; Section 10.9 and Appendix B rely heavily on Tol's 2013 article. For the WG2 Summary for Policymakers, see http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf.

1. ONLY SIXTEEN?

Suppose that, like Tol, we want to analyze the collective findings of economists on climate impacts. Is there, or could there be, a single, comprehensive set of data, combining work by multiple researchers, quantifying the global impacts of different degrees of global warming? How should we select the studies that would be included? Should we use only recent estimates, or do older data still count? Should multiple estimates from the same researcher be included? All of these questions would need to be answered, to ensure that our analysis was a well-defined, balanced reflection of the field.

Alternatively, as Tol does, we could go with a grab bag of whatever estimates are at hand. Tol treats each of 16 studies as a data point on the same graph, and draws a smooth curve through them (Tol 2013, Figure 1). That curve shows net benefits from warming between 0 and 2.25°C. The highest point on the graph – the one reflecting the greatest net benefits from warming – is from a 2002 study by Tol himself.

Tol has been down this path before. In a 2009 review article, he drew a nearly identical curve through 14 estimates.[3] His 2014 correction to that article opens with the statement, "Gremlins intervened in the preparation of my paper…", since 2 of the 14 estimates were reported incorrectly in 2009.[4] The on-line version of the 2014 correction opens with an editorial note, "This version … does not match what was printed… Additional corrections were discovered after printing."[5]

Even a stable, gremlin-free version of this curve is problematical, however. It treats a narrow and dated collection of studies as the best available estimates of the economic severity of climate change. The number of independent estimates in Tol's data is even smaller than the number of studies, due to repeated appearances of a few authors on the list. Of the 16 studies, 6 are authored or coauthored by William Nordhaus; 3 are by David Maddison; 2 are by Tol; and 2 are by Chris Hope. The remaining 3 studies are by economists who have collaborated with either Nordhaus or Tol.

Despite the appearance of 16 different studies, Tol's data represent the views of a small circle of economists, some of them counted repeatedly as their estimates evolved over the years. As Tol notes later in his article, "the researchers who published impact estimates are from a small and close-knit community who may be subject to group-thinking, peer pressure and self-censoring."

Moreover, the studies are relatively old. Six of the 16 studies are from 1994-1996. In one of the early studies, Nordhaus surveyed 19 climate researchers, himself included, who answered a series of

[3] Richard Tol (2009), "The economic effects of climate change," *Journal of Economic Perspectives* 23, 29-51.

[4] Richard Tol (2014), "Correction and update: The economic effects of climate change," *Journal of Economic Perspectives* 28, 221-226.

[5] Available at http://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.28.2.221.

questions about the monetary value of damages they anticipated from climate change.[6] More than 20 years after that survey was conducted, how likely is it that the surviving members of Nordhaus' panel (some are now deceased) still hold the same expectations about climate change? The intervening years have been ones of immense development of research and understanding of climate change. It was ludicrous to continue, as of 2013, to present an expert opinion survey from the early 1990s as one of the world's only 16 reliable studies of global climate damages.

The remaining five Nordhaus estimates are largely analyses done with, or as inputs to, different vintages of the DICE model (or the closely related RICE model). Nordhaus, and his DICE and RICE models, have played central roles in climate economics. Nonetheless, it makes no sense to include, as if they were five independent, still-relevant estimates, studies that Nordhaus published in 1994, 1996, 2000, 2006, and 2008 – as Tol does. Indeed, the latest major publication from Nordhaus, from 2013, arguably should now be used in place of all of these older estimates.[7]

As Nordhaus himself said about an earlier review article by Tol, which also treated multiple Nordhaus studies (and multiple Tol studies) as independent observations, "the different studies are not independent samples from some underlying distribution… These are different versions or vintages of the same class of model and are clearly not independent."[8]

Alongside the overemphasis and multiple counting of a few researchers' estimates, the Tol method ignores many other studies that are relevant to a contemporary assessment of climate damages. The wide range of climate economics models, including the EMF models (discussed below) that Tol cites approvingly later in his article, all contain estimates of climate damages, in varying formats and degrees of disaggregation. There is a fast-growing literature on damages to specific sectors (such as agriculture) that are vulnerable to climate change. Tol's repetitive and antiquated collection of 16 favorite studies fills one small shelf in the rapidly expanding library of research on global climate damages.

2. SHRINKING THE SCC

For the social cost of carbon (SCC), Tol relies on a larger set of 75 studies. Many of them contain multiple estimates for different scenarios, yielding a total of 588 estimates. The mean estimate is $196/tC, and the median is $135/tC (or about $53 and $37, respectively, per tonne of CO_2). These moderately high values, however, are barely mentioned in Tol's review. He quickly shifts his focus to the subset of estimates that assumed a high discount rate. For the 145 estimates that used his preferred discount

[6] William Nordhaus (1994), "Expert opinion on climate change," *American Scientist* 82, 45-51, available at http://stephenschneider.stanford.edu/Publications/PDF_Papers/NordhausSM.pdf.

[7] William Nordhaus (2013), *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World* (Yale University Press).

[8] William Nordhaus (2011), "Estimates of the social cost of carbon: Background and results from the RICE-2011 model," Yale University, http://www.econ.yale.edu/~nordhaus/homepage/documents/CFDP1826.pdf. Quote from 22-23.

rate, the mean SCC is $25/tC and the median is $23 (or $6-$7/t CO_2). The only SCC estimate mentioned in his conclusion is $25/tC. Thus three-fourths of the numerous SCC estimates he collected are, in effect, ignored, in order to focus on the remaining one-fourth – which happen to have a much lower average.

To extract patterns from these estimates, either from the whole sample or from the high-discount-rate subset, Tol employs a statistical technique known as "kernel density estimation" – in essence, a method of drawing a smooth curve through a scattering of points, making as few advance assumptions as possible about the shape of the curve. This technique does, however, start with the assumption that all the points are drawn from the same underlying distribution. It makes no sense if applied to points that are drawn from different, incompatible distributions.

It is as though Tol's estimation procedure were attempting to answer the question, "If all the published SCC values were independent estimates based on the same underlying assumptions, what would the overall probability distribution look like?" This is not a plausible framework for analyzing the SCC literature. Even among estimates using the same discount rate, there are immense differences in assumptions about economic growth, emissions, and other relevant factors.

Once again, as in the previous analysis of 16 studies, a handful of authors dominate the database – in fact, the same handful. Tol himself appears as an author of 20 of the 75 studies; Chris Hope is an author of 11 (including one overlap with Tol), and Nordhaus is an author of 9 more. Thus more than half of Tol's identified SCC studies are written (or co-written) by Tol, Hope, and Nordhaus. Do the 39 studies by these three authors represent 39 independent analyses – or multiple vintages of the same small number of underlying models?

I am a coauthor of 2 of the studies in Tol's database, with 19 estimates. One of these studies, with 16 estimates, was designed to show the effect on the SCC of variation in key assumptions, including the discount rate, climate sensitivity, and the shape of the damage function.[9] Tol reports all 16 of these estimates in his database, assigning them widely varying weights according to a formula that is never explained. We did not, however, assign weights to our 16 estimates; we merely suggested that none of them should be ignored.

My other study in the database, with 3 reported estimates, is ironically a critique of Tol's own FUND model.[10] Our article noted that FUND, as used for the US government's 2010 SCC calculation, produced a central estimate of just under $6 per ton of CO_2, much lower than other models. After discussing a flaw in FUND version 3.5 (the flaw is not present in newer versions of FUND), we offered two simple, ad hoc fixes for the flaw. Holding everything else unchanged, these two fixes raised the FUND SCC to either $16 or $18. In addition, our article reported that if FUND's damage calculations were replaced by the DICE damage function, FUND would estimate an SCC of $31.

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[9] Frank Ackerman and Elizabeth A. Stanton (2012), "Climate risks and carbon prices," *Economics E-journal* 6, 2012-10.

[10] Frank Ackerman and Charles Munitz (2012), "Climate damages in the FUND model: A disaggregated analysis," *Ecological Economics* 77, 219-224. See the appendix for discussion of Tol's response to this article.

Tol's analysis of the SCC literature for his 2013 article incorrectly claims that our study developed three estimates: $6, $16 and $18/t CO_2. All three of these estimates were counted as using Tol's preferred high discount rate. This is a serious misrepresentation of our work. We did not estimate the $6 SCC; we simply reported on the fact that Tol had estimated it. By including this as our estimate, he is double-counting his own work.

We also did not propose the $16 and $18 results as estimates of the SCC. As we said in the article, "These changes are introduced solely to explore the sensitivity of FUND outputs [to the equation in question], not as recommendations for a corrected model structure; the authors of FUND have, quite reasonably, responded that this simple tinkering with one equation is not an appropriate way to revise the model." If anything, the $31 "FUND with DICE damages" estimate, which Tol ignored, is the least bad of the bunch – but none of them represent our own estimate of the SCC. We did not endorse Tol's high discount rate for calculation of the SCC; we simply used it while exploring the sensitivity of FUND to other issues.

Though I have not yet determined whether Tol misrepresents other studies in this way, his offhand and inadequate representation of the results of my own work gives me cause for concern about the others.

3. MAKING UP THE MISSING ESTIMATES

Finally, in order to project the costs of emission reduction, Tol relies on one published set of estimates, from the Energy Modeling Forum (EMF) 22 model comparison.[11] EMF 22 compared projections from 10 models, including Tol's FUND model, for various scenarios. It provides comparable results from these models for a number of policy objectives. There are two problems here: there are other equally worthy models and analyses, which have been arbitrarily excluded; and Tol has "imputed" and then relied on his own values for scenarios which the EMF models were unable to represent.

Tol simply asserts without documentation that EMF 22 "includes the models with the best academic pedigree." He ignores a European research project exploring low-carbon stabilization scenarios, which used a partially overlapping set of models, but reached quite different results.[12] EMF 22 was led by leading American climate economics modelers, while the European project was led by researchers from the Potsdam Institute for Climate Change Research (PIK) and the Cambridge Center for Climate Change Mitigation Research (4CMR). All of their models come with solid academic backing; as noted, some of their model choices overlap. One survey was published in a special issue of *Energy Economics* in 2009,

[11] Leon Clarke et al. (2009), "International climate policy architectures: Overview of the EMF 22 international scenarios," *Energy Economics* 31, S64-S81.

[12] Ottmar Edenhofer et al. (2010), "The economics of low stabilization: Model comparison of mitigation strategies and costs," *Energy Journal* 31, Special Issue 1, 11-48.

the other in a special issue of *Energy Journal* in 2010. The score appears to be tied on academic credentials; Tol's preference for the EMF 22 conclusions must be based on other criteria.

One striking difference is that EMF 22 had trouble modeling scenarios that reached low carbon targets: almost all of their attempts at 450 ppm CO_2-eq scenarios failed, as did some of their 550 ppm scenarios. The European model comparison had much greater success in modeling the costs of scenarios down to 400 ppm CO_2-eq. Use of these modeling results would have led to lower estimates of the costs of low-carbon targets.

Tol ignored the European group, which succeeded in modeling low-carbon targets, instead using EMF 22 results to demonstrate the high cost of those targets. Since EMF did not have a full set of results for his purposes, Tol imputed (created his own numbers for) what he believes the EMF analysis would have found for low-carbon targets, performing what he described, in a previous article, as a meta-analysis.[13]

In comments on Tol's earlier article on the EMF results, Terry Barker and Douglas Crawford-Brown pointed out that the techniques of meta-analysis, often applied in science to combine comparable data sets from related studies, do not apply here because the EMF studies "are not random samples from the same underlying statistical distribution of effects… and there is no measure of statistical significance associated with a model result."[14] This is similar to the comment, noted above, that Nordhaus made about a different Tol literature review; a collection of incompatible study results is not a statistical sample to which standard methods of estimation can meaningfully be applied.

Barker and Crawford-Brown observed that the EMF models did not always run appropriate scenarios at lower carbon targets: "…the models that failed to find a solution for the 450 ppm case can be regarded as not fit for the purpose of reaching the 450 ppm target if their failure is due to inadequate coverage of mitigation options…"[15] They also discussed other models and analyses that would paint a richer picture of low-carbon stabilization scenarios and costs.

CONCLUSION

Tol's 2013 review article, despite its appearance of objectivity, is founded on faulty selection of data and analyses, and contains interpretive flaws that make its facile conclusions unsupportable. First, it highlights 16 studies, some of them very old, from a handful of authors, as if they represented all we know about climate damages. Second, it identifies a larger number of studies of the social cost of

[13] Massimo Tavoni and Richard Tol (2010), "Counting only the hits? The risks of underestimating the costs of stringent climate policy," Climatic Change 100, 769-778.

[14] Terry Barker and Douglas Crawford-Brown (2013), "Are estimated costs of stringent mitigation biased?", *Climatic Change* 121, 129-138; quotes from 132.

[15] Barker and Crawford-Brown (2013), 135.

carbon, more than half from the same handful of authors, and then focuses almost entirely on the subset of results with a high discount rate. Where it reports on my own work, the survey clearly misrepresents the original published source. Third, it purports to prove that low-carbon stabilization targets are expensive by ignoring models and analyses that reach these targets, but making ad hoc adjustments to other analyses that fail to describe a path to a stable climate.

The field of economic analysis of climate change is a work in progress, with many interesting, sometimes contradictory, developments and approaches appearing in recent years. Most of the field, and most of what economists are writing about climate change, cannot be seen through the narrow, distorting lens of Tol's review article.

APPENDIX: PERSONAL DISCLOSURE

By way of disclosure, this is not the first time that I have disagreed with Richard Tol's analysis of climate economics. A previous article of mine[16], critiquing Tol's FUND model, inspired him to launch a relentless, multi-year campaign to have the article retracted, and to discredit me – including hostile letters about me to my former and current employers.[17]

On the one hand, I am delighted to report that this campaign was essentially a total failure. The article was not retracted, and achieved much higher visibility due to Tol's critiques. I very much appreciate the support of numerous economists, and of my former and current employers, who have all made public statements opposing the vendetta against me and my article.

On the other hand, the ensuing debate – focused on a specific flaw in FUND 3.5, which has been fixed in later versions – has distracted attention from the underlying issues which my coauthor and I sought to raise in our article. Compared to many other researchers, Tol's work in general argues for an overly optimistic view of climate change, and a correspondingly less urgent approach to climate policy.

Understanding the basis for this deep divergence of views is more important and interesting than rehashing past conflicts. I think we're done with who said what about division by zero – but who comes to what conclusions about the economics of climate change, and why, remains a crucial subject for ongoing, open intellectual debate.

[16] Frank Ackerman and Charles Munitz (2012), "Climate damages in the FUND model: A disaggregated analysis," *Ecological Economics* 77, 219-224.

[17] See http://frankackerman.com/tol-controversy/ for description and documentation.