

This version, posted May 21, 2014, does not match what was printed in the spring issue of the *Journal of Economic Perspectives*. Additional corrections were discovered after printing.

## Correction and Update: The Economic Effects of Climate Change<sup>†</sup>

Richard S. J. Tol

**G**remlins intervened in the preparation of my paper “The Economic Effects of Climate Change” published in the Spring 2009 issue of this journal. In Table 1 of that paper, titled “Estimates of the Welfare Impact of Climate Change,” minus signs were dropped from the two impact estimates, one by Plambeck and Hope (1996) and one by Hope (2006). In Figure 1 of that paper, titled “Fourteen Estimates of the Global Economic Impact of Climate Change,” and in the various analyses that support that figure, the minus sign was dropped from only one of the two estimates. An early study by Bill Nordhaus was misread. A coding error affected the upper bound of one of confidence intervals (the wider one) shown in the original Figure 1.

The corresponding Table 1 and Figure 1 below correct these errors. Figure 2 titled, “Twenty-One Estimates of the Global Economic Impact of Climate Change” adds two overlooked estimates from before the time of the original 2009 paper and five more recent ones. The confidence interval of the original erroneous impact curve overlaps with the corrected and updated one (compare Figure 1 to Figure 2). The parameters of the impact curves are not statistically significantly different from one another—neither between the original and the corrected impacts nor between the original and corrected and updated impacts, as you can see in Table 2. Estimates are few and the future is uncertain so that confidence intervals are wide.

■ *Richard S. J. Tol is Professor of Economics, University of Sussex, Falmer, United Kingdom. He is also Professor of the Economics of Climate Change, Institute for Environmental Studies and Department of Spatial Economics, Vrije Universiteit, Amsterdam, Netherlands; Research Fellow, Tinbergen Institute, Amsterdam, Netherlands; and Research Fellow, CESifo, Munich, Germany. His email address is [r.tol@sussex.ac.uk](mailto:r.tol@sussex.ac.uk).*

<sup>†</sup>To access the dataset, visit  
<http://dx.doi.org/10.1257/jep.28.2.221>

Table 1

**Corrected and Updated Estimates of the Welfare Impact of Climate Change***(changed estimates in bold; previously omitted estimates in italics)*

Study	Warming (°C)	Impact (% GDP)			
		Central estimate	SD	Min	Max
Estimates from papers summarized in Tol (2009)					
(Nordhaus 1994b)	3.0	−1.3			
(Nordhaus 1994a) <sup>c</sup>	3.0	−3.6		−21.0	0.0
(Fankhauser 1995)	2.5	−1.4			
(Tol 1995)	2.5	−1.9			
(Nordhaus and Yang 1996)	2.5	−1.7			
(Plambeck and Hope 1996)	2.5	−2.5 <sup>a</sup>		−11.4	−0.5
(Mendelsohn et al. 2000)	2.5	0.0			
	2.5	0.1			
(Nordhaus and Boyer 2000)	2.5	−1.5			
(Tol 2002)	1.0	2.3	1.0		
(Maddison 2003)	2.5	−0.1			
(Rehdanz and Maddison 2005)	1.0	−0.4			
(Hope 2006)	2.5	−0.9 <sup>b</sup>		−2.7 <sup>b</sup>	0.2 <sup>b</sup>
(Nordhaus 2006)	2.5	−0.9	0.1		
	3.0 <sup>c</sup>	−1.1 <sup>c</sup>	0.1 <sup>c</sup>		
(Nordhaus 2008) <sup>c</sup>	3.0 <sup>c</sup>	−2.5 <sup>c</sup>			
New estimates that appeared after Tol (2009)					
(Maddison and Rehdanz 2011) <sup>d</sup>	3.2	−11.5			
(Bosello et al. 2012) <sup>d</sup>	1.9	−0.5			
(Roson and van der Mensbrugghe 2012) <sup>d</sup>	2.9	−1.8			
	5.4	−4.6			
(Nordhaus 2013) <sup>d</sup>	2.9	−2.0			

Notes: The welfare impact of climate change is expressed as an equivalent income gain or loss in percent GDP. SD is standard deviation.

<sup>a</sup> This estimate was reported incorrectly as 2.5 percent in Table 1 but correctly as −2.5 percent in Figure 1 of Tol (2009).

<sup>b</sup> This estimate was reported incorrectly as 0.9 percent with confidence interval as [0.02, 2.7] in Table 1 and Figure 1 of Tol (2009).

<sup>c</sup> These estimates, an additional one from Nordhaus (2006) and one from Nordhaus (2008), are overlooked estimates that did not make it into Tol (2009).

<sup>d</sup> This estimate was published after Tol (2009).

<sup>e</sup> This estimate was reported as −4.8 in Table 1 and Figure 1 of Tol (2009).

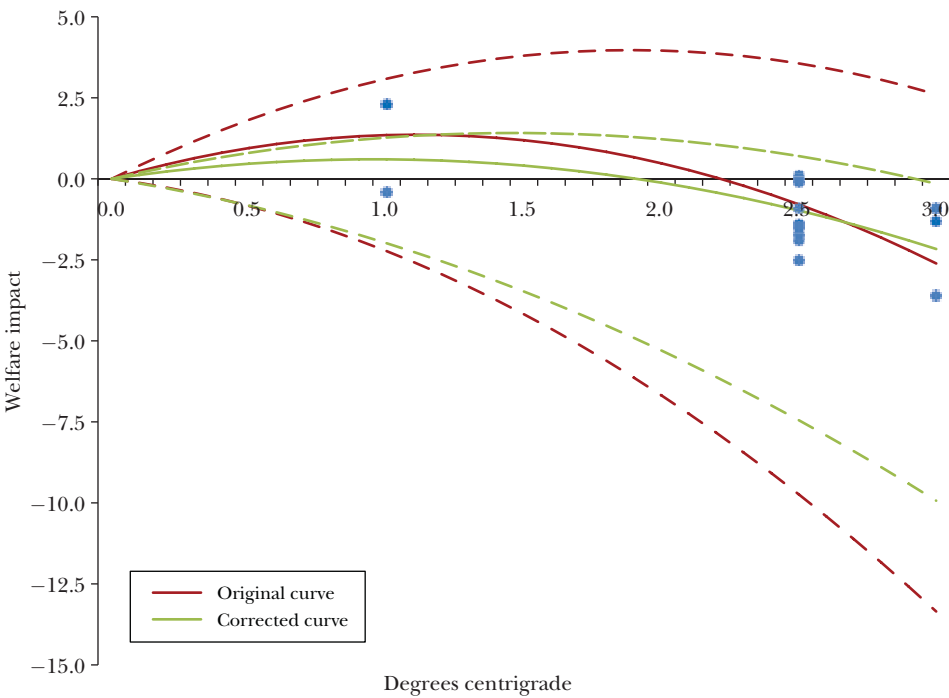
I nonetheless highlight two differences between the old and the new results. First, unlike the original curve (Tol 2009, Figure 1) in which there were net benefits of climate change associated with warming below about 2°C, in the corrected and updated curve (Figure 2), impacts are always negative, at least in expectation. This is irrelevant for policy because, as I discussed in that paper, the net benefits reported for earlier stages of climate change were sunk benefits; these benefits would have been reaped regardless of mitigation policy. Second, the corrected and updated damages do not accelerate as fast for more pronounced warming. For instance, the

Table 2  
Estimates of the Parameters of the Climate Change Impact Curve

<i>Parameter</i>	<i>Unit</i>	<i>Original</i>		<i>Corrected</i>		<i>Corrected and updated</i>	
<b>Expectation</b>							
Linear	%GDPΔ°C <sup>−1</sup>	2.46	(1.25)	1.26	(0.95)	−0.25	(0.59)
Quadratic	%GDPΔ°C <sup>−2</sup>	−1.11	(0.48)	−0.66	(0.36)	−0.16	(0.17)
<b>Standard deviation</b>							
Optimistic	%GDPΔ°C <sup>−1</sup>	0.87	(0.28)	0.34	(0.13)	0.27	(0.11)
Pessimistic	%GDPΔ°C <sup>−1</sup>	1.79	(0.87)	1.29	(0.59)	1.01	(0.52)

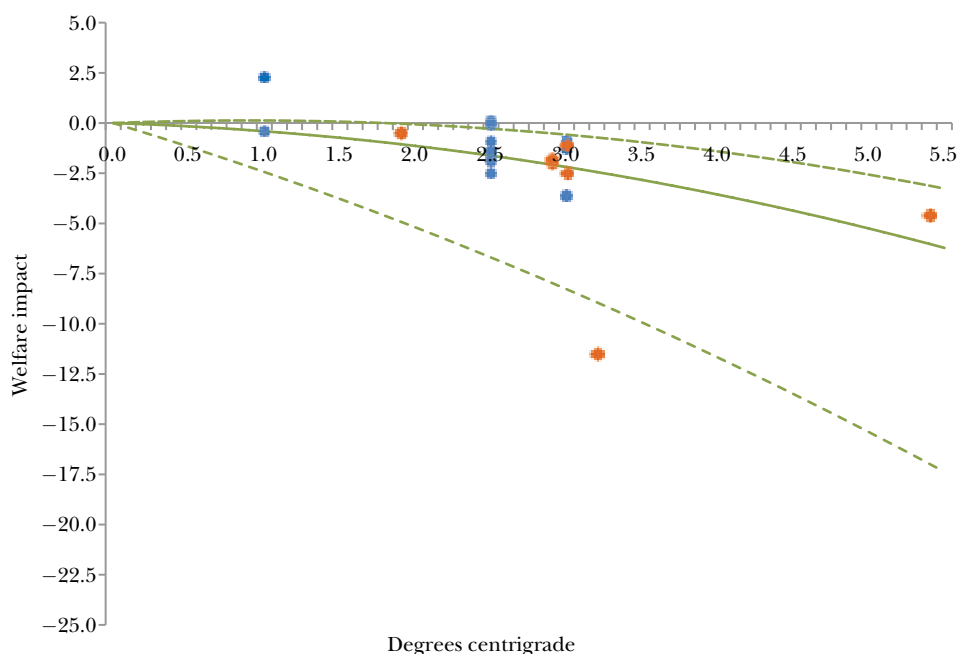
Notes: Table 2 gives the parameters of the curves in Figures 1 and 2. Impacts are measured in percent GDP for temperatures of degrees Celsius; the units of the parameters of the impact curve follow. Standard errors are shown in parentheses.

Figure 1  
Fourteen Estimates of the Global Economic Impact of Climate Change



Notes: Figure 1 shows 14 estimates of the global economic impact of climate change, expressed as the welfare-equivalent income gain or loss, as a function of the increase in the annual global mean surface air temperature relative to preindustrial times. The dots represent the estimates (from Table 1). The central lines are the original and corrected least squares fits. The dashed lines are the boundaries of the original and corrected 95 percent confidence intervals. The corrected expectation starts lower (on the left) but ends higher (on the right) than the original one; the corrected confidence interval is tighter than the original one.

Figure 2

**Twenty-One Estimates of the Global Economic Impact of Climate Change**

*Notes:* Figure 2 shows 21 estimates of the global economic impact of climate change, expressed as the welfare-equivalent income gain or loss, as a function of the increase in the annual global mean surface air temperature relative to preindustrial times. The figure includes two overlooked estimates from before the time of the original 2009 paper and five more recent ones. The dots and diamonds represent the estimates (from Table 1); dots were included in Tol (2009); diamonds are additional estimates. The central line is the least squares fit. The dashed lines are the boundaries of the 95 percent confidence interval.

original impact curve projects an impact of  $-15$  ( $-7$  to  $-33$ ) percent of income for a  $5^{\circ}\text{C}$  warming, whereas the corrected and updated curve has  $-5$  ( $-3$  to  $-15$ ) percent. This is relevant because the benefits of climate policy are correspondingly revised downwards.

The data for this erratum and update are now available at the JEP website along with the paper at <http://e-jep.org>.

■ *I am grateful to Bob Ward for finding a small error, to David Anthoff and Mike Mastandrea for finding bigger ones, to Doug Arent for checking things again and again, to David Autor and Tim Taylor for their understanding, and to Ann Norman for superb editorial support. All remaining errors are, of course, mine and mine only.*

## References

- Bosello, Francesco, Fabio Eboli, and Roberta Pierfederici.** 2012. "Assessing the Economic Impacts of Climate Change." *Review of Environment Energy and Economics*, February 10.
- Fankhauser, Samuel.** 1995. *Valuing Climate Change—The Economics of the Greenhouse*, 1st edition. London: EarthScan.
- Hope, Chris.** 2006. "The Marginal Impact of CO<sub>2</sub> from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern." *Integrated Assessment Journal* 6(1): 19–56.
- Maddison, David.** 2003. "The Amenity Value of the Climate: The Household Production Function Approach." *Resource and Energy Economics* 25(2): 155–75.
- Maddison, David, and Katrin Rehdanz.** 2011. "The Impact of Climate on Life Satisfaction." *Ecological Economics* 70(12): 2437–45.
- Mendelsohn, Robert, Wendy Morrison, Michael E. Schlesinger, and Natalia G. Andronova.** 2000. "Country-Specific Market Impacts of Climate Change." *Climatic Change* 45(3–4): 553–69.
- Nordhaus, William D.** 1994a. "Expert Opinion on Climate Change." *American Scientist* 82(1): 45–51.
- Nordhaus, William D.** 1994b. *Managing the Global Commons: The Economics of Climate Change*. Cambridge: The MIT Press.
- Nordhaus, William D.** 2006. "Geography and Macroeconomics: New Data and New Findings." *Proceedings of the National Academy of Science* 103(10): 3510–17.
- Nordhaus, William D.** 2008. *A Question of Balance—Weighing the Options on Global Warming Policies*. New Haven: Yale University Press.
- Nordhaus, William D.** 2013. *The Climate Casino—Risk, Uncertainty, and Economics for a Warming World*. New Haven: Yale University Press.
- Nordhaus, William D., and Joseph Boyer.** 2000. *Warming the World: Economic Models of Global Warming*. The MIT Press.
- Nordhaus, William D., and Zili Yang.** 1996. "A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Policy." *American Economic Review* 86(4): 741–65.
- Plambeck, Erica L., and Chris Hope.** 1996. "PAGE95—An Updated Valuation of the Impacts of Global Warming." *Energy Policy* 24(9): 783–93.
- Rehdanz, Katrin, and David J. Maddison.** 2005. "Climate and Happiness." *Ecological Economics* 52(1): 111–25.
- Roson, Roberto, and Dominique Van der Mensbrugghe.** 2012. "Climate Change and Economic Growth: Impacts and Interactions." *International Journal of Sustainable Economy* 4(3): 270–85.
- Tol, Richard S. J.** 1995. "The Damage Costs of Climate Change toward More Comprehensive Calculations." *Environmental and Resource Economics* 5(4): 353–74.
- Tol, Richard S. J.** 2002. "Estimates of the Damage Costs of Climate Change—Part I: Benchmark Estimates." *Environmental and Resource Economics* 21(1): 47–73.
- Tol, Richard S. J.** 2009. "The Economic Effects of Climate Change." *Journal of Economic Perspectives* 23(2): 29–51.



**This article has been cited by:**

1. Daiju Narita, Katrin Rehdanz. 2016. Economic impact of ocean acidification on shellfish production in Europe. *Journal of Environmental Planning and Management* 1-19. [[CrossRef](#)]
2. Servaas Storm. 2016. How the Invisible Hand is Supposed to Adjust the Natural Thermostat: A Guide for the Perplexed. *Science and Engineering Ethics* . [[CrossRef](#)]
3. Mai Farid, Michael Keen, Michael Papaioannou, Ian Parry, Catherine Pattillo, Anna Ter-Martirosyan. 2016. After Paris: Fiscal, Macroeconomic and Financial Implications of Global Climate Change. *Staff Discussion Notes* **16**:01, 1. [[CrossRef](#)]
4. J.C.J.M. van den Bergh, W.J.W. Botzen. 2015. Monetary valuation of the social cost of CO2 emissions: A critical survey. *Ecological Economics* **114**, 33-46. [[CrossRef](#)]