Shutting Down the Thermohaline Circulation

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Online Appendix A. Meta-analysis

The meta-analysis is detailed in Tol (2015). Twenty-seven estimates of the total welfare impact of climate change were taken from twenty-two studies. Various impact functions were fitted to the data. A piecewise linear function is, by far, the best fit. This function defines an optimal temperature. Welfare falls linearly if the temperature is above or below the optimum.

Thirteen estimates report at least some regional detail; the remaining fourteen only show a global total. Regressing the regional estimates on the natural logarithm of per capita income and annual mean temperature, both regionally averaged, suggests that the welfare loss due to a 2.5°C warming is 1.2% of income less, with a standard deviation of 0.6%, for a country that is twice as rich and 0.4% less, with a standard deviation of 0.1%, for a country that is 1°C colder.

The function estimated using the regional results is used to impute national impact estimates. We ensure that the national estimates add up to the estimated regional and global totals by shifting the imputed values, that is, by changing the intercept.

Having thus obtained twenty-seven estimates of the national welfare impact of climate change, we fit a piecewise linear impact function for each country. Table A1 shows the parameters. All data and computations are shown in http://users.sussex.ac.uk/~rt220/totalimpactaer.xlsx. The full set of results for this paper is at http://users.sussex.ac.uk/~rt220/hosingaer.xlsx.

TABLE A1— PARAMETERS OF THE PIECEWISE LINEAR IMPACT FUNCTION

	Cold Slope	Optimum temperature	Hot Slope
Global impacts	-0.7	1.0	-1.4
Average of country results			
No weights	-7.1 (5.4)	0.3 (1.3)	-3.3 (1.4)
Population weights	-6.1 (5.2)	0.4 (1.2)	-3.3 (1.8)
GDP weights	-2.2 (3.3)	1.7 (1.5)	-1.7 (1.8)

Notes: "Global impacts" shows the parameters, fitted by least squares, to the globally aggregated impacts. "Average of country results" shows the average and standard deviation of the parameters fitted to the national impacts. "No weights" shows the unweighted average and standard deviation of the country results, "population weights" weights the results by the population size in 2005, and "GDP weights" uses 2005 GDP as weights. The optimum temperature is measured in degrees Celsius. The slopes are measured in welfare loss (in percent equivalent income change) per degree Celsius. The cold slope applies to temperatures below the optimum, the hot slope to temperatures above.

Source: Author calculations.

Online Appendix B. FUND, version 4.0

We use version 4.0 of the Climate Framework for Uncertainty, Negotiation and Distribution for this paper. The major innovation in FUND 4.0 is that the model can be run with a country level resolution in addition to the regional level resolution of previous FUND releases. The world is divided into 198 countries or 16 regions. Both resolution modes use the same equations, but a different set of parameter values that are matched to the respective resolution. The regional resolution version of FUND 4.0 is almost identical to the previous FUND 3.10 version, except for a few minor updates that are described in the full model documentation. FUND 3.10 is equivalent to FUND 3.9, but was rewritten in the julia programming language.

The parameters for the national version of FUND were obtained as follows. For many parameters the regional value was used for all countries in that region, if the definition of the parameter made such an approach feasible (e.g. if a benchmark impact parameter was expressed as a share of GDP, it was reused as the benchmark impact for all countries in that region). The sea-level rise impact component was recalibrated from World Bank Data; see http://data.worldbank.org/. The scenarios of population and economic growth were initialized with World Bank country level data, and then follow the same trajectory as the regional resolution scenarios of FUND. Details of the national resolution calibration can be found in the calibration code that is part of the standard FUND 4.0 source code.

The FUND source code is open source under the MIT license and available at http://www.fund-model.org. The FUND homepage also has the full model documentation. FUND 4.0 is programmed in the open source julia programming language (http://www.julialang.org), and uses the open source Mimi component framework for integrated assessment models (https://github.com/davidanthoff/Mimi.jl). The full set of results for this paper is at http://users.sussex.ac.uk/~rt220/FUNDresultsaer.xlsx.