Commentary

Climate damages in the *FUND* model: A comment

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In a recent paper published in this journal (Ackerman and Munitz, 2012), Ackerman and Munitz (AM) present a sectoral decomposition of the impacts of climate change as represented in *FUND*, an integrated assessment model, and contrast the results with and without uncertainty. We welcome outside scrutiny of our work, even if in this case it adds little to what we knew already (Anthoff and Tol, 2011; Anthoff et al., 2011). AM also take issue with the range of uncertainty about the impacts of climate change reported in the peer-reviewed literature, an issue that is outside our control.

AM further claim that the equation describing the impacts of climate change on agriculture comes "dangerously close" to dividing by zero and that "the *FUND* estimate of the [social cost of carbon] is significantly affected" by these runs. This claim is incorrect, based on inconclusive diagnostic tests used by AM.

AM report two tests for dividing-by-zero. In both tests, AM change the statistical properties of the Monte Carlo analysis and compare the expectation of the social cost of carbon from their modified version of *FUND* with estimates from the original model. In the original model, there are 16 composite distributions that are Normal∗Normal/Normal, and 16 that are Normal/Normal. In one test, AM replace these probability density functions with Normal distributions. In the other test, they replace 16 probability density functions with Normal distributions, and 16 others with Normal∗Normal distributions. Although they preserve the modes of the distributions (at least in the first test), AM change the means, all higher moments and all cross-moments.

For both tests, AM find a difference between their estimate of the social cost of carbon and ours. This is exactly as expected: Different parameters and different distributions lead to different results. The two "tests" of AM are therefore inconclusive. By no means is this an indication of any problem with either the original or, indeed, the modified model.

There are appropriate tests for dividing by zero. Our standard diagnostic test compares the mean social cost of carbon to the trimmed mean, leaving out the smallest and largest realizations. A singularity in the code, such as a division by near-zero, would lead to a few very large or very small realizations and a substantial difference between mean and trimmed mean. In a diagnostic test implemented in response to the alleged problem, we trim the realizations that are closest to the suspected division-by-zero. Because *FUND*'s code is large and complex, with multiple programmers and frequent changes, we run these and other diagnostic tests for each and every new analysis. Needless to say, we do not release results if our tests reveal that something is wrong.

We have been in repeated contact with AM on this matter. We helped with configuring the code to run on their machines. Mr Ackerman then contacted us because he thought he had found a division-by-zero error. We explained why his tests are inconclusive; AM's "not an appropriate way" (p. 222) echoes this. Well before the AM paper was submitted, we shared the results of our standard diagnostic test and the one specifically tailored to the alleged problem. Neither test reveals a problem.

We are surprised that AM nevertheless chose to publish their division-by-zero claim, while remaining silent on the results of these diagnostic tests.

Acknowledgments

References

Ackerman, F., Munitz, C., 2012. Climate damages in the FUND model: a disaggregated analysis. Ecological Economics 77 (0), 219–224.
Anthoff, D., Tol, R.S.J., 2011. The uncertainty about the social cost of carbon: a decomposition analysis using FUND. Working Paper 404. Economic and Social Research Institute, Dublin.
Anthoff, D., Rose, S.K., Tol, R.S.J., Waldhoff, S., 2011. Regional and sectoral estimates of the social cost of carbon: an application of FUND. Working Paper 375. Economic and Social Research Institute, Dublin.

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