Transient Temperature Response Modeling in IAMs: The Effects of Over Simplification on the SCC

Response to Comments

Alex L. Marten*

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We would like to thank all the reviewers and readers for their excellent comments. There is no doubt that they have helped to make this a stronger paper. Below we have provided responses to the reviewers' general comments, followed by individual responses to the more detailed comments provided by the reviewers.

General Comments

Discount Rate Sensitivity Analysis

One reviewer made the very astute observation that the choice of discount rates within the paper's sensitivity analysis were in fact not that different. While the form (Ramsey vs. Constant) was quite different, the effective rates for the two cases were in fact very similar (3% and approximately 3.5%). We thank the reviewer for pointing out this important observation. To improve the sensitivity analysis and get a more complete picture of how the discount rate effects the results we have expanded this part of the paper. At the same time we chose to simplify this sensitivity analysis by focusing solely on constant discount rates. While there are many good reasons to to consider non-constant discount rates in the context of climate change policy (e.g., Weitzman (1998), Newell and Pizer (2003), Dasgupta (2008)), this approach has the benefit of reducing the number of moving parts thereby increasing the ease by which the sensitivity analysis results may be interpreted. For this sensitivity analysis we now use the same range of values (2.5%, 3%, and 5%) as was used by the recent U.S. Interagency Working Group on the SCC. This range is very similar to the effective range suggested by both reviewers. The introduction of the substantially higher 5% discount rate, which places relatively more emphasis on the near term, had important implications for interpreting the results when using the FUND temperature response model which differs substantially from the upwelling diffusion energy balance models over short-run.

Damage Function Sensitivity Analysis

A reviewer also commented on the damage function sensitivity analysis, suggesting that the choice of the DICE2007 and Weitzman (2010) damage function specifications may not capture the full range of concern.

*National Center for Environmental Economics, U.S. Environmental Protection Agency, Washington, DC 20460. Email: marten.alex@epa.gov.

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The reviewer noted that the damage functions used in the FUND (and the most recent PAGE) model allow for moderate levels of warming to provide some benefits to society and are therefore relatively lower than even the DICE2007 specification. As noted by the reviewer the complexity of the FUND model does not allow for it's damage function to be easily be represented by the simple polynomial in temperature used in this paper. Therefore we follow the reviewers advice and derive an approximation of the FUND damage function for illustrative purposes and use this in the sensitivity analysis along with the other two specifications of the damage function. The specific details regarding how the approximation was derived are laid out in Appendix C of the paper. We thank the reviewer for this excellent suggestion. Along with the changes to the discount rate sensitivity analysis we feel that the paper now presents a much broader range of the important parameters and gives a more thorough look at the range of results.

Comparison with Previous Literature

It was noted by multiple reviewers that the paper, particularly Section 4.1, could be strengthened with by including a more detailed comparison with the previous literature, particularly the work of van Vuuren et al. (2011) and Warren et al. (2010). We fully agree with these comments and thank the reviewers for this excellent suggestion. Given the similarities between parts of our exercise in Section 4.1 and the one which was conducted and presented in Figure 3 of van Vuuren et al. (2011) a comparison was not difficult and we agree with the reviewers in regards to it's usefulness. Therefore in Section 4.1 of our paper we have added text in multiple locations to highlight that our findings are in line with the previous literature. We have also noted the specific differences in the model versions examined in our paper compared with those considered in the previous studies as per one reviewer's suggestion.

We have also expanded our discussion of these previous studies in the paper's introduction to give the reader a better understanding of just how comprehensive and important those studies really are. We have also added language to better explain how this work expands upon that existing literature following the reviewers' suggestions.

Detailed Comments

- *References to Figure 4.1 and Table 1 show up as question marks in text.*
  - Thank you. We have fixed this issue in the latest manuscript.
- *Page 18: "marginal elasticity of substitution" should be "marginal elasticity of consumption".*
  - Thank you for pointing this out. However, due to the switch to using constant discount rates as described above this no longer appears in the text.
- *References of Van Vuuren et al. and Warren et al. should be updated (they are published by now).*
  - Thank you for pointing out this error in the citations. We have updated them.
- *P2 The statement 'their findings suggest that simplified IAMs produce results within the range of more complex models' is not quite right. For example van Vuuren et al. (p. 269) state that 'the response in DICE99 and FUND is slower than that of the comprehensive models included in the IPCC AR4 range'. The statement that 'the long term increase of all IAMs are within the sizeable uncertainty*

range ...' refers to the long term temperature increase out to 2200 or 2300. The introduction needs to quote that the Warren et al. highlight the potential implications of their findings for the values of SCC that might subsequently be derived, and that this study actually quantifies this. The introduction should also discuss that this paper differs from those two papers in comparing the results with a climate model developed by the authors.

  - We very much appreciate the reviewer's comments on our characterization of the results from these previous studies. We have replaced the slightly ambiguous phrase "within the range" with a statement that these previous studies do find some differences among the model's projections.
  - We have also replaced our statement that the authors of the previous studies noted "the differences are large enough to have potential policy implications" with a more specific statement that the authors noted the differences could affect the SCC and attributed that to Warren et al. (2010) as suggested by the reviewer.

- *P5. 'The parameters for the distribution are calibrated ...' make clear who calibrated this in what context.*

  - We have added text to clarify that we are the ones who calibrated the parameters of the distribution for this paper.

- *P5. Use of 'slight': cf Fig 5, van Vuuren et al. Are the differences slight? They are perhaps small, and their existence does not invalidate the utility of this study.*

  - It appears that there may have been some adjustment by the model developers in the more recent versions of their IAMs which accounts for the apparent discrepancy between this statement and Figure 5 of van Vuuren et al. (2011). For the model versions examined in this paper FUND 3.5, DICE 2010, and PAGE 2002 the values of $\Delta Q_{2\times}$ within the IAMs are set to be 3.71, 3.8, and 3.71 W/m^2, respectively (based on an the code for each model). Given the magnitude of this difference we are comfortable with our use of the term "slight". If this difference was not .09 W/m^2 and was still what appears to be a difference of about 1 W/m^2 between FUND and PAGE as in Figure 5 of van Vuuren et al. (2011) (which is based on previous versions of the models) then we agree that different terminology would be warranted. We have added a footnote to the paper to highlight the actual numerical difference in this parameter within the models themselves to avoid any confusion.

- *P6. Define v. before it is used.*

  - Thank you for pointing this out, we now define the parameter before its use.

- *P7. 'these specific values are not crucial for the results presented in this paper'. Can you support this statement by either a logical argument or a statement that some sensitivity runs were carried out?*

  - Thank you for pointing out the ambiguity in that statement. We have clarified the statement to note that we conducted some sensitivity analysis using the parameter ranges presented in Baker and Roe (2009) and found the general results of this paper to hold.

- *P10. More clarity needed on this page. Figure number missing. 'In the first experiment' presumably you mean 'the first experiment using the UDEB model'. Figure ?? shows the results from which models? Which parameters were varied? Keeping all this in the Figure caption makes it difficult to follow the procedure.*

  - We have updated the missing figure number, thank you.
  - We have changed the first sentence to get rid of the text "In the first experiment" in favor of more descriptive language to setup the section. In addition we have added to our description of the experiment in the text to make the setup clearer to the reader. All of the information within the figure caption is laid out in the first six sentences of the section.

- *P10. 'Initially ...the temperature response ... project much slower warming ...' point out that this agrees with van Vuuren et al. (p. 268).*

  - Thank you for pointing this out. We have added language to point out this similarity in results as part of our overall revision of this section to better link its results with the previous literature.

- *p.10. 'This is a significantly faster rate of warming'. The text around here needs rewording so that the reader can more easily follow the statements about faster and slower warming on different timescales.*

  - We thank the reviewer for this suggestion and agree that the original discussion may have caused unnecessary confusion for the reader. We have revised this section to improve the readability.

- *p.10 'miss this characteristic'. I see that this is true but please explain more clearly to the reader by referring to the Figures, how it is shown there that characteristic is missed.*

  - We have added text explaining more explicitly that this issue may be seen manifesting itself in the figures through the high level of the temperature anomalies in the upper end of the distributions plotted.

- *p.14 the comparison of UDEB with MAGICC, thus validating it against an accepted published code, should appear immediately after the description to UDEB.*

  - Thank you for this suggestion. We have added language after the UDEB model description to note that given the same scenario it will generate projections of temperature anomalies that are in line with MAGICC, and alert readers to the fact that this will be demonstrated later in the paper.

- *P15. The text in the last paragraph needs clarifying with regard to the methodology used. It seems that you fixed the climate sensitivity in the models, but please reword.*

  - Upon rereading this part of the paper we agree that it could benefit from a more explicit description of what is being examined in the plot, and thank the reviewer for pointing this out. We have added/reworded language to make this clearer to the reader.

- *P17. This is an extremely important finding. Make more of this in the abstract and conclusion.*

  - We thank the reviewer for this suggestion and have added text to both the abstract and the conclusion to highlight this finding.

- *p.17. Please explain to readers why when the climate sensitivity is higher, temperature shoots up and then falls, whereas in the median case with lower climate sensitivity it rises and stabilises.*

  - For the plots on page 17, which I believe are the point of reference for this comment, in each case the response will theoretically asymptote to zero in so much as the emissions perturbation fully decays and the two scenarios become equivalent in the long run.

- *p. 18 Table ??*

  - Thank you, the reference has been fixed.

- *p. 19. What did Stern use for n, as opposed to Nordhaus? Suppose n was lower? It might be interesting to see those results too in the table, if it does not involve a large amount of extra work.*

  - We agree with both reviewers on the usefulness of extending the range of the discount rates considered in the sensitivity analysis. We refer to the section on General Comments for an overview of changes made in this regard.

References

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