Damage Functions for Existing IAMs and Areas of Research

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Kenneth Gillingham is currently on leave from Yale as a Senior Economist at the Council of Economic Advisers.

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Outline

1. Modeling Uncertainty Project results, with a focus on damages and the SCC.
   - Results from the NBER Working Paper version.
   - Note: All results presented here may change as we move towards submission and publication.

2. Thoughts on the questions to panelists.

Modeling Uncertainty Project

A systematic study of uncertainty in a set of IAMs:

- Determine the differences among models in the uncertainties.
- Provide benchmark pdfs for major parameters.
- Highlight areas where reducing uncertainties would have a high payoff.

Core Yale Team:

Kenneth Gillingham, William Nordhaus, Peter Christensen (UIllinois), Paul Sztorc.

Participating Modelers:

David Anthoff (UC Berkeley), Geoff Blanford (EPRI), Val Bosetti (FEEM), Haewon McJeon (JGCRI), John Reilly (MIT).

Participating Models

We thank six well-known IAMs for their participation:

- MIT IGSM (John Reilly)
- JGCRI GCAM (Haewon McJeon & Jae Edmonds)
- EPRI MERGE (Geoff Blanford)
- Yale DICE (William Nordhaus)
- Tol/Antoff FUND (David Anthoff)
- FEEM WITCH (Valentina Bosetti)

  – In feasibility study: PHOENIX and PAGE

Three Uncertain Input Variables

Modeling teams first ran a set of "feasibility runs":

- An emissions pulse, a pulse of global TFP, increase of global TFP growth, increased climate sensitivity, increased population, and a carbon tax.

Decision to focus on three that all models could handle:

- TFP growth
- Population growth
- Climate sensitivity (ECS)

For all three, a baseline and carbon tax run

Output (Results) Variables

We choose output variables that capture key features relevant to climate change that (most) models output:

- Consumption
- Emissions
- CO_2 concentrations
- Global mean surface temperature
- Damages/Social cost of carbon (subset of models)

We calculate an output pdf for each for each model

Methodology: Two-track Procedure

<u>Track 1</u>. Perform calibration runs and estimate a surface response function (SRF) for each model

<u>Track 2</u>. Develop pdfs of uncertain variables

Schematic Outline of Two-Track Method

Assume y = output variables; u = input parameters; H^m = model mapping for model m.

Steps:

1. Choose uncertain variables: ECS, TFP, Pop.
2. Model calibration runs: $y = H^m(u)$. Lattice Diagrams.
3. Fit "Surface response function," $y = R^m(u)$.
4. Derive pdfs for u variables, $f(u)$.
5. Perform Monte Carlo analysis for distribution of output variables, obtaining the pdf $g^m(y)$ for output variables.

$$g^m(y) = \int R^m(u) f(u) du$$

Track I: Calibration Runs and SRFs

- Calibration model runs on a 5 x 5 x 5 grid
  - The middle point of the grid is the modeler's baseline
  - The other points add and subtract from the baseline
  - Visualize results with a "lattice diagram"

- Run a baseline and carbon tax case for each grid

- Estimate the surface response functions
  - Find linear quadratic with interactions works well.

Track II: Develop PDFs

1. Population Growth
   – Using pdfs from IIASA's demography group
   – Cross-check with UN and Berkeley estimates

2. Temperature Sensitivity
   – Base our pdf on the literature referenced in the IPCC AR5

3. Total factor productivity
   – No evidence in the literature
   – Created our own expert survey

Six Overall Key Findings

1. Central projections (modelers' baselines) are remarkably similar, but models diverge at extremes for the parameters.
2. The pdfs of most key output variables are remarkably similar across models.
3. The climate-related variables are characterized by lower uncertainty than the economic variables.
4. There is much greater parametric uncertainty than structural uncertainty.
   – The one exception is for the social cost of carbon.
5. Lack of evidence for fat tails in the current models.
6. Uncertainty in TFP growth has a dominant effect on output uncertainty, overwhelming uncertainty in ECS or population.

Monte Carlo Results

- Results of Monte Carlo simulations for averages of all models.
- The table shows the values of all variables for 2100, except for the social cost of carbon, which is for 2020. Damages and SCC are for three models (WITCH, DICE, and FUND).

Variable	Linear				Linear-quadratic-interactions				
	Mean	Standard deviation	10-90 %ile	99 %ile	Mean	Standard deviation	10-90 %ile	99 %ile	Coeff of Variation
CO2 concentrations	888	233	597	1,429	895	247	595	1,672	0.28
Temperature	3.60	0.89	2.26	5.89	3.87	0.89	2.25	6.29	0.23
Output	583	533	1,368	1,825	649	637	1,370	2,975	0.98
Output (log)	664	807	1,343	3,878	664	807	1,343	3,878	1.21
Emissions	112.56	73.10	187.51	282.59	115.12	80.82	187.16	381.98	0.70
Population	12,142	2,378	6,094	17,661	10,245	2,401	6,092	16,816	0.23
Radiative Forcings	7.40	1.60	4.11	11.13	7.40	1.63	4.12	11.81	0.22
Damages	27.41	32.96	84.51	104.36	32.39	41.88	84.90	191.91	1.29
SCC	16.26	7.05	17.68	35.43	13.30	6.95	16.16	36.19	0.52

Note: All dollars values are in terms of real 2005 dollars.

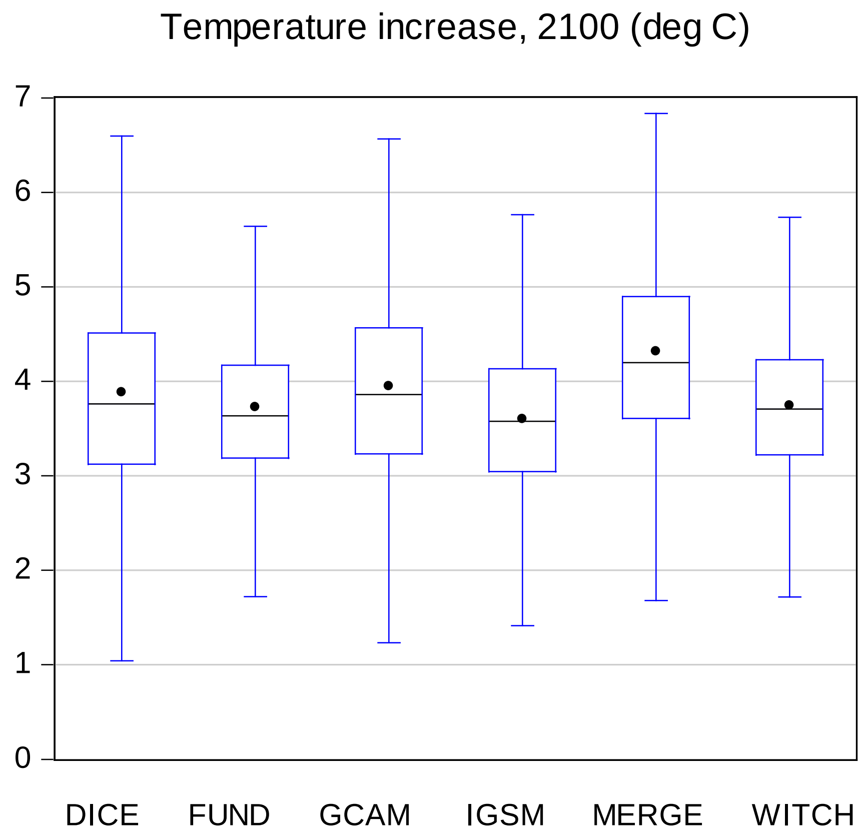
Temperature Change

- Distribution of 2100 Temperature change in the base case (degrees C above pre-industrial).

Temperature	0.1 %ile	1 %ile	5 %ile	10%ile	25%ile	50%ile	75%ile	90%ile	95%ile	99%ile	99.9%ile
DICE	1.60	1.97	2.38	2.64	3.12	3.76	4.51	5.29	5.80	6.88	8.28
FUND	1.96	2.30	2.63	2.83	3.19	3.64	4.17	4.74	5.12	5.92	6.96
GCAM	1.59	2.02	2.46	2.73	3.23	3.86	4.56	5.27	5.73	6.64	7.79
IGSM	1.30	1.82	2.31	2.58	3.05	3.58	4.13	4.65	4.97	5.58	6.29
MERGE	2.20	2.56	2.93	3.16	3.61	4.20	4.90	5.63	6.12	7.13	8.46
WITCH	1.83	2.21	2.60	2.82	3.22	3.71	4.23	4.72	5.01	5.58	6.22
Average	1.75	2.14	2.55	2.79	3.24	3.79	4.42	5.05	5.46	6.29	7.33

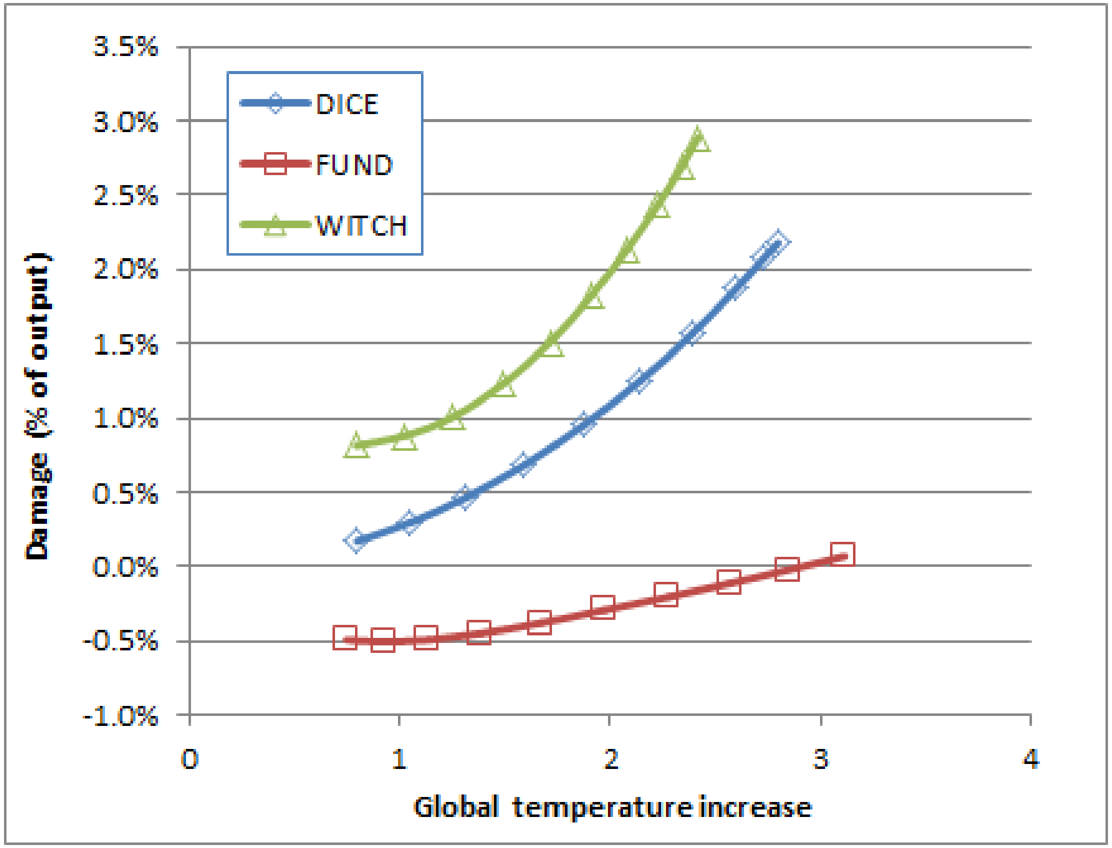
Temperature Change

- Box plot of 2100 Temperature change in the base case (degrees C above pre-industrial)



Illustrative quasi-damage functions

- Implied quasi-damage functions plot damages against the total temperature increase over time (in base case).



Thoughts on the Panelist Questions

1. How can the characterization of damages be improved through incorporating existing evidence?
   - Essentially, it comes down to a mapping of temperature change to economic harm.
   - There are many new studies, but I am not convinced that we have fully nailed the question.
     - There is a fundamental empirical identification challenge here.
   - I believe that there is value in an independent literature review of the existing studies.
     - Synthesizing the studies is a challenge, for they provide different information.
   - I'd like to see work that acknowledges the uncertainty in damage functions.

Thoughts on the Panelist Questions

2. What improvements can be made to the models?
   - Without additional empirical evidence, I am skeptical that there is much that can be done for non-market impacts.
   - Without additional scientific evidence on catastrophes, I am not sure how much more we can do on catastrophes.
   - I see room for adaptation investments to be explicitly modeled. This is much understudied and relates closely to vulnerability and resiliency.
     - One could imagine building in an investment module that reduces the damages.
     - Then we would want a damage function that does not account for adaptation.
     - The challenge is in calibrating these relationships.

Thoughts on the Panelist Questions

3. What about aggregate versus disaggregate damages?
   - When we talk about disaggregate damages, I am worried about both under-counting and double-counting.
   - That said, I believe that there is room to make headway in estimating individual sector damage functions
     - Right now much of the evidence we have is only from a few sectors.

Thoughts on the Panelist Questions

4. What criteria can we use to assess the reliability of new damage functions and approaches?
   - I think that we are looking for solid empirical evidence for estimates of the parameter we are interested in.
   - Any exercise should pass the “laugh test” – if you are extrapolating out and get crazy results, you might want to reconsider and/or really work hard to understand the mechanisms underlying the result.
     - This is particularly true when it comes to the question of damages affecting growth.

Thoughts on the Panelist Questions

5. Highest priority research areas
   - Estimating damages in other sectors and countries, as well as non-market damages.
   - Finding approaches for identifying adaptation.
   - Exploring the mechanisms for why and how climate change may influence economic growth.
   - Further work to better characterize uncertainty.

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