Uncertainty Analysis in Integrated Assessment Models

Major Steps Over the Last Year

Kenneth Gillingham
Major Progress Since Snowmass 2012

- Fall 2012
  - Further analyzed Snowmass 2012 “feasibility” results
  - Developed decomposition methodology
- February 2013 meeting
  - Reviewed first round results
  - Decided to simplify to 3 variables
  - Agreed to “two-track” methodology
  - Discussed approaches to determining PDFs
- Spring/Summer 2013
  - Developed Snowmass 2013 protocol
  - Participating models completed protocol
First Round: Snowmass 2012 Feasibility Exercise

7 models performed a “feasibility” exercise

1. Each model began with a baseline (no policy) run

2. Six sensitivity runs are performed
   - Reduce output by a one-time decline of 5% of world GDP in 2020
   - Increase world GDP growth rate by 0.5 % per year 2020-2100
   - Change equilibrium climate sensitivity by +1 °C
   - Increase population growth by 1 % per year from 2020 to 2050
   - CO₂ tax from $13 in 2010 to $427 in 2100 (from AMPERE AM3ND1)
   - Add an emissions pulse of 10 Gt of CO₂ in 2020
Which Scenarios Are Feasible?

• Reduce output by a one-time decline of 5% of world GDP in 2020
  • Feasible: EPPA, GCAM, MERGE, PHOENIX, RICE, WITCH
  • Not feasible: PAGE

• Increase world GDP growth rate by 0.5 % per year 2020-2100
  • Feasible: All models

• Change equilibrium climate sensitivity by +1 °C
  • Feasible: EPPA, GCAM, MERGE, PAGE, RICE, WITCH
  • Not feasible: PHOENIX
Which Scenarios Are Feasible? (cont.)

- Increase population growth by 1% per year from 2020 to 2050
  - Feasible: All models
- CO$_2$ tax from $13$ in 2010 to $427$ in 2100 (from AMPERE AM3ND1)
  - Feasible: EPPA, GCAM, MERGE, PHOENIX, RICE, WITCH
  - Not feasible: PAGE
- Add an emissions pulse of 10 Gt of CO$_2$ in 2020
  - Feasible: EPPA, GCAM, MERGE, PAGE, RICE, WITCH
  - Not feasible: PHOENIX
These Results Led to Decision: Start with Three Uncertain Parameters

We chose three uncertain parameters based on importance and ability to easily perturb across (nearly all) models:

1. Population growth
2. Productivity growth
3. Temperature sensitivity
Next Decisions

• Where to get the distributions of the uncertain input parameters $f(\alpha)$?

• How to take these input distributions to the models?
  – Have each model run full Monte Carlo simulations?
  – Two-track approach?
PDFs from Where?

Where to get the distributions of the uncertain input parameters $f(\alpha)$?

• Decision: Literature when possible, expert elicitation when not possible.

• Will discuss this more this afternoon
Taking Input Distributions to the Models

How to take these input distributions to the models?

• Decision: Two-track approach
“Decomposition Procedure”

1. On one front we push forward on expert elicitations
2. On the second front we begin model runs:
   - Determine the support of $f(\alpha)$
   - Divide the domain of each element of $\alpha$ into $S$ intervals
   - Include the endpoints of each interval
   - Populate a grid (or matrix) of $\alpha$
   - Run the models for each point in the entire grid

We will discuss the integration of the two this afternoon
Decomposition Approach

• This approach has advantages
  – If we have a limited number of input parameters, then the approach is simple, easy to implement, and would not require thousands of runs
  – Provides insight into the correlation structure
  – *Does not require knowing the PDFs of the input variables first*

• Has some disadvantages
  – May not easily extend to multiple correlated parameters
  – We need to predetermine the support of $f(\alpha)$
How To Determine the Support of $f(\alpha)$?

This determines the computational complexity of the approach

• Need to decide on the size of the intervals
• Need to know the plausible range of the parameters
  – What is the plausible range of the temperature sensitivity parameter?

This is an important discussion...

how far out to sample in the tails of $f(\alpha)$?
Second Round: Snowmass 2013 Protocol

6 models participated in filling out the grid (125 x 2 = 250 runs)

• Perform a set of runs to fill in the 3-dimensional grid:
  – Add to baseline TSC: +3°C, +1.5°C, 0°C, -1.5°C, -3°C (equilibrium °C per CO2 doubling)
  – Add to the baseline TFP growth: +1%, +0.5%, 0%, -0.5%, -1% (annually until 2100, no change in growth rate afterwards)
  – Add to the baseline population growth: +1%, +0.5%, 0%, -0.5%, -1% (annually until 2100, no change in growth rate afterwards)

• Grid was filled in for both the modeler’s baseline and a carbon tax policy
  – CO2 tax from $13 in 2010 to $427 in 2100 (from AMPERE AM3ND1)
Things We Realized

• -3°C is not very useful when the baseline TSC is 3°C!
• Interestingly, in several models, the carbon tax policy hardly changed the estimate of air surface temperature, particularly in some of the high cases
  – One question is exactly what is covered under the tax
  – AMPERE covers all greenhouse gases
  – Do we want to cover sectors where taxation is largely infeasible?
Visualizing the Results

• One way to visualize the results is to plot at the surface
  – Since we can’t see in 4D, we are limited to 3D graphs
  – Consider the y-axis the output variable and the two x-axes as two of
    the uncertain input variables
  – Can also show the range from the third input variable with additional
    lines

• Note some of these results just came in, so we are still going through them
Emissions 2100

Population Growth Factor
One Take-away

- One initial take-away:
  - Models are very consistent in terms of 2100 output, but much less consistent in terms of temperature and CO$_2$ emissions