Assessing Methodological Uncertainties in Energy-Economic and Integrated Assessment Modeling

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Sources of uncertainty in SRES, and their implications

- Box 1-1: Can be interpreted as saying that primarily a single source of uncertainty - 'inherent' - arises from the fact that it's essentially impossible to predict the future with much confidence
- Other sources of uncertainty: data on past and present trends, modeling issues and choices, and the relations among them - that is, *methodological uncertainty*
- SRES multi-model approach characterized as "methodological pluralism:" Implicitly, would appear to mean that all models and/or modeling choices are assumed equally plausible
- However, if likelihoods are going to be assigned to these (or succeeding) projections, then some comparative evaluation is needed of data, models, and choices

Two pertinent examples

- 1) Study for the National Energy Policy Plan of 1983 (analyzed in Sanstad et al. 2002):
  - Five model-generated projections of long-run U. S. energy demand were documented (included energy system, macro-economic, and linear programming models)
  - Comparisons of year 2000 projections to actuals reveals that aggregate relations between energy demand and price fundamentally mis-projected, in the same manner across models (One explanation: underestimation of technological change)
- This exemplifies the limits of methodological pluralism as a means of hedging against sins of omission/commission (I.e., everyone can be wrong in the same way)

Examples, cont.

- 2) EMF-16 study of Kyoto Protocol
  - Modelers' reference case projections tend to diverge sharply during the 21st century (in some regions immediately)
  - Estimates of marginal costs of carbon abatement varied greatly - by up to a factor of five

- Given that this Kyoto experiment involved a major perturbation to essentially the *current* energy-economy, this spread in the results provides an indication of the extent of "non-inherent" uncertainties.

Analyzing methodological uncertainties: Meta-analysis of model outputs

- Qualitative:
  - Weyant and Hill 1999: Variations in baseline projections and marginal cost estimates due to differing assumptions on economic growth, fuel costs, capital stock turnover, substitution/demand elasticities, etc.
- Quantitative:
  - Repetto and Austin 1997: Regressed model cost predictions on structural and policy regime assumptions - policy regime and inclusion of benefits most important
  - Fischer and Morgenstern 2003, Hawellek et al. 2004: Regressed cost predictions primarily on structural features.

How could this kind of analysis be extended?

- General observation 1: There exists a great deal of model documentation, but variation in detail - Parameter sources and selection criteria, empirical foundations, and calibration and verification practices not always apparent to the non-specialist
- General observation 2: The heterogeneity of the models plus the considerable number and complexity of specific data/modeling issues would appear to make full inter-model comparisons intractable
- Ergo: There are questions to investigate, but to make any progress in analyzing methodological uncertainty, some narrowing of scope is required

Focusing on technological change

- One way to proceed:
  - Put aside the general problem of the lack of "endogeneity" in modeling technological change
  - That is: Take for granted the standard assumptions of cost minimization, efficient markets, and autonomous technological change
  - Choose a dimension along which to evaluate: A natural candidate is the measurement, calibration, and parameterization of technological change - including the "AEEI."

Technological change, cont.

- Note that this would require renewed attention to the empirical (non-simulation modeling) literature - the "AEEI" question remains unsettled
- On the modeling side, questions to ask include:
  - How is technological change represented in the model, and exactly how is "AEEI" or a similar concept defined?
  - What data were drawn upon to use in the models?
  - What statistical methods, if any, were used to analyze these data?
  - What parameters determine rates of AEEIs, and how were these selected?
  - How is the choice of these parameters related to selection of substitution elasticities?
  - What calibration procedures were used, and how do these relate to parameterization of technological change?
  - How sensitive are modelers' reference cases to assumed rate(s) of AEEI?

A complementary strategy: The example of PCMDI

- Program for Climate Model Diagnosis and Inter-comparison, at Lawrence Livermore National Laboratory
- Develops methods for the quantitative "diagnosis, validation, and inter-comparison" of global climate models
- Core activities: Developing protocols and empirical resources for evaluating systematic errors in models - I.e., statistical 'backcasting' experiments comparing model predictions against measured variables

An "economic PCMDI experiment"?

- An obvious (?) thought: Apply some version of this approach to energy-economic/IA models, I.e., have the models simulate some (maximal) period of time ending as close to the present as possible
- Although the models are not intended to replicate history, they are in part based on interpretations of historical trends and patterns
- Issues to be addressed include:
  - Aggregate data availability and quality: This experiment could only be done for some regions - U.S. and E.U.?
  - Dis-aggregate data availability and quality: There are no time series data to match to model outputs at level of detailed technologies
  - Selection of error criteria: Mean-squared error not the only possible measure

Techniques for model "diagnosis"

- Linville and Coffey 2000: Generalized sensitivity analysis through modified Monte Carlo procedure - identifying non-linearities and joint distributions of uncertain parameters
- Miller 1998: "Active Nonlinear Tests" - identifying non-linearities through genetic algorithm-based procedure
- Bayesian model evaluation and calibration methods, e.g., O'Hagan et al. 1998

Observations on modeling

- "…the [GCM] models do not account for key variables that influence the climate system. Despite this, the alarmists continue to use these models…to support their theories of man-made global warming."
- "[According to] the most widely-cited and most definitive economic analysis of Kyoto, [it] would cost 2.4 million U. S. jobs and reduce GDP by about $300 billion annually."
- Senator James Inhofe, July 2003

Concluding remarks

- The Senator's statements illustrate a certain asymmetry in the climate policy debate (at least in the realm of cost estimation): Uncertainty in climate models is heavily scrutinized, while uncertainty in economic models is basically ignored (and subject to exploitation)
- Assigning likelihoods to long-term socio-economic scenarios requires, as a first step, better understanding of the methodological uncertainties in construction and application of energy-economic and IA models
- There seems to be ample room for progress toward this end - to better distinguish among the "known, the unknown and the unknowable" in this kind of modeling