IS THE GHOST IN THE MACHINE, OR THE DEVIL IN THE DETAILS? UNCERTAINTY AND MODEL COMPLEXITY IN LONG-RANGE ENERGY-ENVIRONMENTAL POLICY MODELING

Alan H. Sanstad
Lawrence Berkeley National Laboratory
(510) 486-6433
ahsanstad@lbl.gov

Michael Leifman
U. S. Department of Energy
(202) 586-6619
Michael.Leifman@ee.doe.gov

Overview

Over the past three decades, numerical energy-economic modeling has become the dominant tool for energy policy analysis, and is now playing a similar role in the analysis of climate change and policies to abate greenhouse gas emissions. However, the proliferation of models of this type, as well as their increasing complexity, has not resulted in convergence of results. Indeed, persistently wide ranges of model-generated policy prescriptions, among other issues, are drawing increasing stakeholder attention to unresolved problems in underlying methodology and the role of numerical models in policy development.

This paper presents initial work on a framework for the joint quantitative assessment of uncertainty in long-range policy modeling along the statistical, structural, and forecast dimensions. We investigate how the combination of model dimensionality, estimation error, and forecast uncertainty can interact to generate uncertainty in policy predictions considerably greater than commonly acknowledged or reported in the energy-environmental modeling literature. Both theoretical results and numerical examples are presented, and we discuss the implications of our findings in the context of current efforts to devise greenhouse gas abatement policies, and for future research.

Methods

Several emerging strands of research bear on the problem we have defined. Model validation and verification is receiving increasing attention across a range of disciplines as numerical modeling becomes an increasingly widespread basic and applied research methodology (e.g., Sargent 1999). Dawkins et al. (2001) discuss and critique the now virtually universal practice of (generally informal) calibration procedures in lieu of classical estimation techniques in applied economic general equilibrium modeling. Bayesian methods for analyzing uncertainty in complex computer codes have been developed (O'Hagan et al. 1998).

In the context of long-range numerical energy-environmental policy modeling, what these are other efforts imply is the need to improve the scientific foundations of model construction while simultaneously developing concepts of long-run analysis that improve upon ad hoc "scenario" techniques. We apply a result of Feldstein (1971) on incorporating the uncertainty in stochastic exogenous factors in forecasting models, combining it with decision-theoretic information criteria for least squares and maximum likelihood estimation (Burnham and Anderson 2002). This allows us to analyze the trade-offs entailed in increasing forecasting model dimensionality, stemming from the simultaneous increase in both explanatory power and uncertainty.

Results

We find that an increase in model dimensionality that improves validity by an information criterion can nevertheless result in an increase in uncertainty in policy-relevant forecasts that exceeds the gain in model explanatory power. We derive formulae to precisely characterize this trade-off in an abstract setting. We illustrate the result with a simple and generic energy demand forecasting model, and intepret our findings in light of the long-running debate over the relative merits of microeconomic and engineering-based models of this type.

Conclusions

The complexity of contemporary policy problems having to do with large-scale and long-run energy and environmental issues requires increasingly sophisticated analytical tools. Numerical policy modeling has emerged over the past three decades as the predominant methodology for policy analysis in this arena. However, modeling practice has not yet benfited from the systematic application of modern techniques of validation, decision-analysis, computational statistics, and related disciplines. Our results indicate the utility of moving toward a more rigorous foundation for numerical energy-environmental modeling.

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