EXPERTS MEETING ON THE CHOICE OF MODELING PLATFORM FOR CARBON POLICY ANALYSIS

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Report to:

the Office of Policy Planning and Evaluation,
United States Environmental Protection Agency

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1. Introduction

US representatives from the State Department, along with representatives of other nations, are currently negotiating changes to the 1992 United Nations Framework Convention on Climate Change. Many expect that these negotiations will lead to the specification of targets and timetables for greenhouse gas emissions reductions or concentration stabilization. At the same time, an interagency team (IAT) composed of Environmental Protection Agency (EPA), Department of Energy (DOE) and Department of Commerce (COM) staff are looking into specific domestic policies to reduce greenhouse gas emissions in response to negotiated targets and timetables. (The interagency process reports to the State Department and the national Economic Council.) Part of their task is to examine the economic impact of proposed greenhouse gas policies on the US economy.

To provide support to the IAT, the Office of Policy Planning and Evaluation (OPPE) of EPA asked Resources for the Future (RFF) to gather a select group of experts to discuss the relative strengths and weaknesses of alternative modeling platforms. The three platforms most widely discussed as suitable for these analyses are computable general equilibrium models (CGE), macroeconometric forecasting models and hybrid energy-economy models of the type developed at Pacific Northwest Laboratories by Edmonds et al.[1]

On Wednesday November 6, 1996 RFF convened a one-day meeting of 15 individuals expert in one or more of the modeling platforms and invited approximately 20 government representatives drawn from the EPA, DOE, COM and the President's Council of Economic Advisors to observe the proceedings. The list of experts is provided as Appendix A to this report and the agenda for the meeting is provided as Appendix B. This brief report summarizes that meeting.

2. Meeting Logistics

The meeting was organized around three presentations based upon each of the three modeling platforms identified above. These presentations included a discussion of hybrid energy-economy models presented by John Weyant of Stanford University and the Energy Modeling Forum, CGE models presented by Peter Wilcoxen of the University if Texas at Austin, and macroeconometric forecasting models presented by Ralph Monaco of the University of Maryland and INFORUM. Each presenter was asked to address the list of areas below that reflected our perception of the needs of the IAT.

[1] For example, see Edmonds et al (1992).

2.1. Tax Recycling

Objective: To define options for recycling any revenues resulting from policy.

Questions:

- Which revenue recycling options will be modeled?
- Which criteria will be used to evaluate them, beyond straightforward GDP effects?
- Which models will be used to perform these simulations? How will their results be linked to the models used in Area Two?

2.2. Growth and Adjustment

Objective: To define the modeling framework that will unify the IAT's work, and to depict the interrelated issues of adjustment and growth in response to policy.

Questions:

- Which CGE models will be used to specify the intertwining of the economy's sectoral adjustment and its aggregate growth plan?
- What are the estimates of the most critical price and income elasticities in the model(s)? How does it (do they) handle investment?
- What characteristics of the models are most important in deriving the results obtained?
- What are our abilities to go "outside the model" for critical issues if needed?

2.3. Industry Highlights

Objective: To present a coherent story about the effects of policy on those specific industries most positively and most negatively affected.

Questions:

- What does Area Two suggest regarding industries in need of special analytic attention?
- Which industries are burdened the most and which benefit? What are the costs or benefits in each case?
- How might technology options or trade patterns unanticipated by modeling affect each of these? Can we incorporate this information into our models?
- Prepare an analytic and qualitative appraisal for each of the six industries most negatively affected and the six industries most positively affected by the proposed policy.

2.4. Implementation Issues

Objective: To identify those characteristics of implementation strategies that would make the results of policy deviate from modeling results.

Questions:
- To what extent can policies other than carbon or Btu taxes be made to look like such taxes for purposes of modeling?
- To what extent will policies other than carbon taxes (e.g., permit trading) have effects different from those taxes (innovation issues, efficiency issues, etc.)?
- Should the modeling focus on CO2 or "all greenhouse gases"? Can gasses other than CO2 be modeled effectively?
- How can banking and other forms of flexibility be best represented for modeling purposes?

2.5. Technological Innovation and Diffusion

Objective: To identify the economy's technological response to policy and to develop a strategy for incorporating it into our modeling efforts.

Questions:
- What is the consensus view of the stock of CO2- (or "gas-") abating opportunities?
- What is the lesson of SOx and CFC experiences for this effort?
- What can we say from historical (and statistical) evidence regarding how the diffusion of technology is determined? Where we would specify a response other than that consistent with aggregate patterns of historical innovation, to what extent is that difference based on statistical evidence, engineering evidence, judgment, or other factors?
- What is the capital turnover rate in the CGE model used and how does it change under different scenarios?

2.6. International Linkages

Objective: To incorporate "rest of world" effects into the representation of policy.

Questions:
- What evidence regarding abatement possibilities in LDCs drives our view of the efficiency gains of Joint Implementation? Can an implementation strategy be assumed to realize these gains?

- What is the best strategy for building that evidence (efficiency of joint implementation) into the modeling effort?
- Which nations bear what costs and which receive benefits?
- What changing trade patterns do the models anticipate, and why might reality differ?

After each presentation the expert participants asked questions of the presenter and engaged in an open and wide ranging dialog regarding the appropriateness of each platform for the type of analyses the IAT will be asked to perform.

3. Results of the Meeting

3.1. Overview

Greenhouse gas abatement policies are likely to affect the economy in complex ways, and the costs of these policies will reflect these many effects. Making fossil energy use and CO_2 emissions more expensive -- either directly, through economic incentives like taxes or tradable permits, or indirectly, through command and control (CAC) techniques like mandated energy efficiency standards – causing changes in the types of energy produced and consumed, substitution between energy and nonenergy inputs, changes in the composition of economic activity that shift around other factors of production, changes in patterns of international trade, and changes in the pace and direction of technical innovation efforts.

To analyze these varied impacts and derive a summary measure of economic costs from carbon abatement is no easy task. The models used to this end must be able to address the areas of IAT concern laid out in the section above.

There is a huge range of models that can be used to address these issues and for our purposes we have grouped them into the categories noted above: macro-econometric forecasting models, CGE models, and more detailed energy/economy hybrid models. The lines of demarcation between these categories are not clear: many macro models have appended to them an energy sector; energy-economy models may be coupled with at least a rudimentary CGE representation of the economy; and CGE models may contain energy sector detail and some form of short-term adjustment constraints.

The challenge policy analysts in and out of government face is how to choose among the many models available for addressing the many questions arising in assessing the economic consequences of GHG limits. *One simple but important conclusion from our review of model options is that no one type of model, let alone specific model, can adequately address all the important issues.* There is a clear need for a portfolio approach in which the results of different models are considered. At the same time, we believe that there are some comparative advantages of different model types for different tasks -- it is not enough simply to look at results of a variety of models and implicitly combine or weight them to address specific policy questions. However, the question of how to synthesize the results of different models is a difficult one that we cannot fully answer here, though we do offer some initial suggestions. Moreover, some questions cannot be addressed adequately by any of the currently available model crop, underscoring the limitations of current analytical knowledge and tools.

3.2. Model Platforms

In this section we present a brief and quite general discussion of the strengths and weaknesses of the different modeling platforms examined during the meeting.

3.2.1 Macro Forecasting Models

Macroeconometric models provide a substantial capacity for analyzing the short-term consequences (adjustment paths) of certain kinds of policies based on the historical pattern of economic responses to similar stimuli. These models are fitted to data and constantly updated to reflect the changing economic structure and performance of the economy. They can provide a substantial amount of sectoral detail and trade interactions, and they contain or can be coupled to detailed representations of the energy sectors (primary energy and electricity). Because their emphasis is on macro responses, they can be used to look at issues such as revenue recycling from permit auctions (though there are questions about this capacity in practice, as discussed below). The sectoral detail makes possible an assessment of various CAC policies, such as energy efficiency standards, and the assessment of impacts from assumed technical innovations.

Perhaps the biggest drawback of these models is their lack of grounding in a fundamental representation of intertemporally optimizing agent behavior. This is not just a theoretical nicety, as Lucas has convincingly argued in other contexts.[2] Long-term climate policies are likely to significantly alter the structure of the economy, making reduced-form representations of behavior based on past experience increasingly problematic descriptors of future production, investment, and labor supply/consumption decisions. Another related major drawback of reduced-form macro models is the difficulty of disentangling how the timing of policies and expectations about their impacts might affect behavior. Macro models combine responses to unanticipated shocks like oil price rises with responses to smoother and more anticipated changes like revisions to the tax code. If, as one might argue, climate policies are likely to be long-term with substantial anticipation and time for adjustment, analyses based in part on the effects of unanticipated shocks will overstate the adjustment costs.

3.2.2. CGE Models

Agent behaviors in CGE models are based on intertemporal optimizing decisions with varying degree of sectoral disaggregation and energy detail. This makes the models able to deal in a theoretical fashion with the variety of substitution and other responses engendered by increases in the shadow price of carbon emissions, especially patterns of investment and disinvestment over time. CGE models increasingly can incorporate the distinction between flexibility of capital *ex ante* versus *ex post* inflexibility when costs are sunk. The models are strong in analyzing the

[2] See Lucas (1973).

overall long-term effects of change in the tax structure, and they are developing a capacity for addressing how technology may change with changes in prices (though this capacity is still rudimentary). CGE models can also address international trade and capital flows induced by policy.

CGE models also have weaknesses. The lack of empirical record forces key parameters to be set judgmentally although the models developed over the years by Dale Jorgenson and his collaborators employed parameters estimated econometrically.[3] The level of sectoral or energy detail is often more limited than the other two approaches. This is a problem in particular in judging the performance of tradable permits (which exploit intra-sectoral as well as inter-sectional abatement cost differences), in looking at entry and exit of economic activities, and in assessing the effects of CAC. The ability to assess endogenous technical change remains limited (though this is true of other models as well). Importantly, CGE models do not yet adequately deal with short-term adjustment costs, although models like that of Goulder do have costs of adjustment.[4] Last but not least, dynamic CGE models are computationally burdensome and most often trade off sectoral detail to facilitate the solution of the intertemporal aspects of the model.

3.2.3 Energy-Economy Models

This class of models is quite diverse, ranging from extremely detailed engineering-economic energy sector models to much simpler production function representations of the energy sector. The energy-economy link similarly may reflect a very reduced-form representation of economic activity and energy demand, or a small-scale CGE framework. The most obvious advantage of this class of models is the capacity to address at a more detailed sectoral and sub-sectoral level the implications of both price and CAC policies on energy supply, transformation, and end use. This includes the important question of capital stock turnover. A variety of assumptions about technical progress can be examined as well.

The biggest limitation of these models is that the representation of the energy-economy interface and the overall impact of policies may be more crude than in frameworks with more economic detail. In particular, the representation of the cost of abatement as flowing primarily through specific energy sector investments will not capture the other costs arising from changes in the scale and composition of economic activity. In addition, engineering-economic models may fail to adequately capture opportunity costs of technical substitution, thus understating the costs of abatement policies. These models are typically based on a careful characterization of potential technical options, but without a full recognition of the tradeoffs faced by real economic agents.

[3] See for example Jorgenson and Wilcoxen (1997).

[4] See Goulder and Summers (1989).

3.3 General Conclusions About Model Synthesis

Because so much of the economic effects of GHG limitation policies will derive from their impacts on energy supply and demand, it seems clear that any modeling framework must contain enough energy detail to make assessment of these impacts possible. Of particular importance in this regard is the nature of capital stock change in electricity and energy-intensive manufacturing. This observation points to the virtue of the energy-economy models as tools for understanding the impacts on energy of different kinds of GHG limitation policies, including tradable permits and CAC, as well as the implications of different hypotheses about the potential for technical innovation (while guarding against underassessment of the opportunity costs of technical change).

Energy-economy models with a reasonably detailed representation of the economy will clearly be more useful in assessing the wider ripple effects of policy and the effects of tax or revenue changes than models with a rudimentary description of the economy. More detailed CGE models can and should be used to identify at a general level the potential long-term economic impacts of policies. Their results can also be used in concert with energy models lacking a detailed economic component to heuristically gauge impacts; e.g., rules of thumb from the CGE models can help improve the parameterization of energy models with reduced-form economic representations.

If one takes the view that GHG limitation policies will be announced well in advance of their implementation, then the analysis of short-term adjustment paths with macroeconometric models may be less useful. These models may have value in climate policy analysis primarily as ways to assess the short-term costs of very near-term (e.g., 2005) GHG reductions, and as a way of exploring the multiplier effects of trade linkages. Models with detailed representations of transportation services demands also can be helpful for assessing policies directed to this sector. However, this analysis must be rounded out with a clear understanding of the full opportunity costs of different policies for reducing transport sector emissions. The lack of empirical understanding of these costs is a gap that transcends the different modeling platforms.

3.4. Conclusions About Specific Issues

In this section we briefly address some of the most important (from our perspective) specific challenges facing analysts of the economic consequences of GHG abatement. In some cases we can offer concrete suggestions; in other cases we can only note an important gap in current analytical capability.

3.4.1. Scope of Policies That Can be Analyzed

All the platforms have a capacity to deal with carbon taxes and thus formally with a comprehensive system of tradable emissions allowances (we address issues of revenue recycling below). However, this seems inadequate: it is necessary also to be able to look at mixes of different policies across sectors, e.g., sector-specific emissions caps or mixtures of caps with CAC. It follows that sectoral detail is an important consideration. Other things equal, we would expect the energy-economy models to be particularly useful in addressing long-term policy impacts.

3.4.2. Intertemporal Implementation and Expectations

The three types of platforms we are considering either assume perfect foresight or (with the macroeconometric models) "data-driven" expectations. Neither assumption is ideal, but no practical option is available ("rational expectations" econometric models cannot provide enough detail in practice to be useful in this context). The perfect foresight assumption is a reasonable point of departure for long-term analysis of reasonably well anticipated policies, given the limitations of current rational expectations approaches, while the macroeconometric models can provide some insights on short-term adjustments to policy surprises.

Expectations are particularly important in the context of intertemporal implementation of GHG limits. Suppose, in particular, that the limits are introduced as constraints on cumulative emissions over a longer period of time, rather than as an emissions target to be met by a particular year. Several studies indicate significant potential cost savings with this intertemporally flexible approach. However, realizing these savings does presume considerable foresight by decisionmakers in the timing of investments and in the development and introduction of new technologies. These savings should be tested with sensitivity analysis. In addition, policies that afford less flexibility but may be more enforceable and thus credible in practice -- such as a sequence of declining emissions targets which can be met with some borrowing against future emissions limits -- need to be scrutinized.

3.4.3. Revenue Recycling

Both theory and modeling work to date indicate that policies which raise revenue that can be used to adjust the overall tax system may have considerably different impacts from revenue-neutral policies. CGE models have considerable strengths in assessing the long-term consequences of such policy actions. Macroeconometric models also have a long history of analyzing the shorter-term consequences of fiscal policy changes. In these models, however, it is important to understand better the mechanisms that drive, e.g., investment booms from reduced corporate tax burdens, and to compare the predictions of the CGE and macroeconometric models to this end. It is also important to understand how firm behavior is changed by different methods for allocating emissions permits. For example, firms which obtain allotments in excess of their requirements experience windfalls, while the reverse is true of firms that are net buyers. Is the windfall assumed to increase investment or just add to shareholder value? And if investment is spurred in that part of the economy receiving a windfall, would investment elsewhere be reduced? Until these kinds of issues can be clarified, doubts will persist about the conclusions drawn about revenue recycling from this class of models.

3.4.4. Trade Issues

Ideally, in analyzing the consequences of a domestic US GHG policy it would be informative, other things equal, to have a trade module in any of the platforms we have been discussing and to solve for endogenous goods and capital flows. Such detail is important for analyzing policy consequences in smaller or more open economies, and to some extent for analyzing sectoral impacts in the US. What seems to matter most in calculating aggregate costs of US is how the change in US energy prices that any policy is likely to deliver affects trade and capital flows between the US and its trading partners. A weakened trade position will *ceteris paribus* increase the cost of the policy. All the platforms we have been discussing are capable of endogenously determining the vector of US energy prices without the need for a comprehensive international trade module.

Both CGE and macroeconometric models are capable of modeling the trade flows and perhaps the capital flows as well. However, to properly assess the trade effects, one must also know the changing patterns of energy prices and other macro variables within the countries of the trading partners (perhaps changing in response to similar policies). This requires either a world type model or access to the results of individual country models.

3.4.5 Technical Progress

If technical progress brings forth increases in energy efficiency greater than we have experienced in the past (perhaps induced by a climate policy intended to bring forth such results) the cost of mitigating GHG emissions will be reduced. Given the importance of technical change to the cost of the policies in question, how well the modeling platforms deal with technical progress and in particular endogenous or induced technical progress, in large part determines the confidence we can have in the results of the policy analysis. Unfortunately, the current set of platforms and models deals with technical progress at best in a rather crude fashion and at worst in a wholly *ad hoc* manner.

At the present time only the CGE models base their treatment of technical change on rudimentary economic theory (see Jorgenson and Wilcoxen 1997) and only the recent work of Goulder and Schneider (1996) lays out the foundations for a model that is capable of explaining endogenous or induced technical progress on the basis of economic behavior.

3.4.6. Dealing With Uncertainty

An overarching theme in the previous snippets has been uncertainty. None of the model types is particularly well suited to analysis of structural uncertainty -- uncertainty about key longer-term relationships like innovation rates, versus uncertainty about an exogenous driver like oil prices. Reduced-form stochastic sensitivity analyses (like ICAM[5]) are valuable adjuncts to the structural models, because they can highlight (within limits) which kinds of uncertainties seem to be most significant, thereby allowing scarce model parameter manipulation capacity to be focused on the key relationships.

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5 See http://hdgc.epp.cmu.edu/main.html.

4. Conclusions

The experts meeting touched upon many issues from which we have chosen a subset to discuss in the previous section. In this concluding section we attempt to single out the three most important results from the meeting and briefly provide our views.

The first result, provided in the overview to section 3 was that no one model or model platform is sufficiently general to deal with all the analyses the IAT will be required to perform. Therefore, the choice of platform and model depends upon the form of the policy (e.g., carbon tax, emission permit, or CAC) and the type of question asked (e.g., effect of tax recycling, or effect of policy on growth and adjustment). We think it is fair to say that this view was shared almost universally by the experts in the meeting.

The second result has to do with the formation of expectations by the agents of the economy. Expectations are likely to be important in the analysis of many government policies, but seem crucial in the analysis of GHG policy. Since this policy will play itself out over decades and the cost of the policy will depend upon the degree to which agents can smoothly transition from one energy price regime to another, the formation of their expectations is crucial. Therefore, to have confidence in the results of our policy analyses we must have confidence that our models are dealing with the expectation formation process in a manner consistent with our best knowledge of that process.

Within the expert group there was not unanimity over the platform most capable of modeling expectations. Our own view is that the CGE models (and their energy/economy cousins with at least a rudimentary general equilibrium module), based on strict microeconomic representations of firm and household behavior, treat the expectation formation process in a manner roughly consistent with our best understanding of the phenomena.

The third result has to do with technical change. As noted above, there is no other economic phenomena that can so affect the cost of the GHG policy to the extent of technical progress. How technical change is modeled and how the empirical parameters of the model are set are crucial to the confidence we can have in the policy analysis results.

From the perspective of model design (setting aside the empirical parameterization), the work of Goulder and Schneider (1996) has quite clearly pointed out how important it is that the modeling of innovative activity explicitly account for the resources that are employed to produce innovation and technical progress. Failure to do so means that the cost of a GHG policy can be grossly overstated, particularly if the policy is designed to induce technical change. Macroeconomic models and energy-economy hybrids use fully exogenous rates of technical progress and do not explicitly account for the resource cost of innovation. Therefore, it seems that whatever the policy analyzed, it is imperative that a CGE model of the Goulder - Schneider type or similar ilk be run to answer the technical change questions.

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Appendix A
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Appendix B

Experts Modeling Forum

in Support of Domestic US Greenhouse Gas Policy Analysis

November 6, 1996, 9:00 am
Kimball Conference Center
1400 16th Street NW
Washington, DC 20036

Hosted by: Resources for the Future

9:00 am	**Continental breakfast**
9:30 am	**Introductory remarks** Paul Portney, *President, Resources for the Future* Ray Kopp, *Senior Fellow and Director of the Quality of the Environment Division, Resources for the Future* Mike Toman, *Senior Fellow, and Director of the Climate Economics and Policy Program*, *Resources for the Future*
10:00 am	**Strengths and weakness of macro forecasting models** Ralph Monaco, *University of Maryland/INFORUM*
10:30 am	**Strengths and weakness of hybrid models** John Weyant, *Stanford University/Energy Modeling Forum*
11:00 am	**Strengths and weakness of computable general equilibrium models** Peter Wilcoxen, *University of Texas - Austin*
11:30 am	**General discussion among participants**
12:30 pm	**Questions to the participant from invited guests**
1:15 pm	**Lunch break**
2:00 pm	**Continued discussion among participants**
4:00 pm	**Questions to the participants from invited guests**
5:00 pm	**Adjourn**