

**Summary Minutes of the
U.S. Environmental Protection Agency
Science Advisory Board
Economy-Wide Modeling Panel Meeting
July 19 - 20, 2016**

Economy-Wide Modeling

Panel Members:

Dr. Peter Wilcoxon, Chair
Dr. Edward Balistreri
Dr. Richard Belzer
Dr. Linda Bui
Dr. Jared Carbone
Dr. Francisco de la Chesnaye
Dr. Alan Fox
Dr. Don Fullerton
Dr. Thomas Hertel (by phone)
Dr. Edward Leamer
Dr. W. David Montgomery
Dr. Gilbert Metcalf
Dr. Nick Muller
Dr. Sergey Paltsev
Mr. Richard Revesz
Dr. Lorenz Rhomberg
Dr. Adam Rose
Dr. V. Kerry Smith
Dr. Ian Sue Wing (by phone)
Dr. Mort Webster
Dr. Robertson Williams

Purpose: The Economy-Wide Modeling Panel discussed its draft responses to charge questions on social costs and social benefits and considered potential responses to charge questions on impacts and comparability.

Designated Federal Officer: Dr. Holly Stallworth, Designated Federal Officer

Other EPA Staff: Alex Marten, Ann Wolverton, Al McGartland, Robin Jenkins, Dave Evans, Chris Zarba, Tom Brennan, Tom Carpenter; Darryl Weatherhead, Carl Pasurka, Jared Creason, James McFarland, David Evans, Richard Garbaccio, Alex Macpherson, Robin Jenkins, Nathalie Simon

Public: Maria Hegstad (Inside EPA); Amanda Thomas (OMB)

Webcast or Teleconference Attendance: Margaret Caravelli (affiliation unknown); John Norman (ExxonMobil); Charmaine Hanson (EPA); Michael Papenfus (EPA); Linda Chappell (EPA); Brittany Bolen (Senate Environment and Public Works Committee); Elizabeth Miller (EPA); Jared Woollacott (RTI International)

Meeting Materials and Meeting Webpage:

The materials listed below may be found on the meeting webpage at:

<https://yosemite.epa.gov/sab/sabproduct.nsf//MeetingCalBOARD/D7F544899457C74885257F0700698545?OpenDocument>

Agency-provided Background Material	Crosswalk between Second Half of Charge for SAB Panel on Economy-Wide Modeling of the Benefits and Costs of Environmental Regulation and EPA White Papers/Memos. (PDF, 2 pp., 199,574 bytes)
Agency Briefing Material	National Center for Environmental Economics (NCEE) Presentation on Economic Impacts and Comparing Estimates of Social Costs, Social Benefits and Economic Impacts. (PDF, 11 pp., 388,033 bytes)
Agency Comment	Adobe Acrobat embedded comments from National Center for Environmental Economics (NCEE) on Economy-Wide Modeling Panel's 6-20-16 Draft. (PDF, 75 pp., 630,545 bytes)
Agency Comment	List of comments from National Center for Environmental Economics (NCEE) on Economy-Wide Modeling Panel's 6-20-16 Draft. (PDF, 4 pp., 35,645 bytes)
Committee Members' Comments	Panelist Tom Hertel's Comments on Competitiveness. (PDF, 6 pp., 442,829 bytes)
Draft text for Panel or Committee deliberation to develop draft report	Draft Panel Responses to Charge Questions on Social Costs and Social Benefits to Assist Meeting Deliberations, June 20, 2016. (PDF, 75 pp., 566,018 bytes)
Public comment submitted to the SAB Staff Office	US Chamber of Commerce, American Chemistry Council, American Forest & Paper Assoc., American Petroleum Inst., and American Wood Council cosigned comments. (PDF, 8 pp., 213,103 bytes)

July 19, 2016

Dr. Holly Stallworth, Designated Federal Officer for the Economy-Wide Modeling Panel, gave her opening statement noting the compliance of the Panel with the Federal Advisory Committee Act. Dr. Peter Wilcoxon, Panel Chair, reviewed the agenda and asked members to introduce themselves. He also asked each subgroup to name a lead writer for its assigned charge question.

Discussion of June 20, 2016 Draft of Panel's Responses

During this time slot, Dr. Ann Wolverton of the EPA National Center for Environmental Economics (NCEE) presented their comments on the Panel's 6-20-16 draft report. Dr. Wolverton's remarks highlighted several of the embedded comments on the 6-20-16 draft report posted on the meeting website as "Agency comment." Dr. Wolverton asked the Panel to clarify what new efforts were needed to incorporate unemployment in Computable General Equilibrium (CGE) modeling. She asked the Panel to clarify the application of the Harberger framework for the common practice of modeling a regulation as a productivity shock. She also asked the Panel to

offer more specificity in comparing a partial and general equilibrium demand elasticity, specifically what criteria could be used for establishing a benchmark deviation between the two elasticities that would indicate the need for CGE modeling. She asked for greater specificity in applying the Goulder and Williams paper (2003), specifically how EPA would go about determining which small shocks are potentially better or poorer candidates for CGE analysis.

Dr. Wolverton noted some inconsistency in the way CGE models are characterized in the Panel's report -- with some sections seeming to focus on dynamic models as the norm; other sections acknowledging that static CGE models are relatively common. As another general comment, Dr. Wolverton asked for clarification as to whether the advice/recommendations are limited to specific cases or is applicable to a more general class of regulations. She also asked the Panel for consistency and clarity as to whether it was saying a case-specific approach is needed to determine whether a CGE model adds value over a partial equilibrium (PE) approach. Dr. Wolverton cited a need for the Panel to clarify its recommendation for confidence intervals or sensitivity analysis. With respect to the Panel's list of considerations in model choices, Dr. Wolverton suggested that the Panel group the recommendations according to their current feasibility. Pointing to one particularly strong statement, she asked the Panel to consider whether it was suggesting that all the constraints affecting the choice of compliance methods could actually be accounted for in an economy-wide model.

In the section of the 6-20-16 draft report on linking models, Dr. Wolverton asked the Panel to elaborate on the tradeoffs between sequential calibration and disaggregating CGE models. She asked for clarification on what the Panel meant by a "hybrid approach" and noted some inconsistency in the Panel's references to various size thresholds that would indicate the need for economy-wide modeling.

With respect to the section of the 6-20-16 draft report on incorporating non-market values into a CGE model, Dr. Wolverton asked for the Panel's advice on what information would be needed to parameterize such a model. She also asked how EPA should think about applying advice based on analysis of benefits for the entire Clean Air Act in the context of a single air regulation. She noted that the SAB seems to agree that it is credible to model mortality and morbidity impacts as a change in time endowment, but asked for clarity on the contexts in which this approach is appropriate/technically feasible. For instance, how EPA should think through issues of consistency between end points in concentration-response functions used by EPA in its standard PE approach versus representation in a CGE model. Dr. Wolverton asked for clarification of the statement in the draft response recommending against quantifying productivity gains in a general equilibrium (GE) or PE model or in any benefit-cost analysis. Finally, she asked the Panel to distinguish between near-term recommendations and options for future research.

Subsequent to Dr. Wolverton's initial presentation, Dr. Wilcoxon urged the Panel to remember that EPA would be trying to implement its advice and to be careful of global statements that might overstate the Panel's intentions. Dr. Al McGartland, NCEE Director, offered a summary of the ways in which EPA could support research. Other panelists offered general comments on the 6-20-16 draft report. Dr. Belzer said it would be helpful to include in the Panels' report a section that lays out the kinds of concerns that would apply to both GE and PE analyses; another section identifying the circumstances in which GE modeling deserves more scrutiny because of its complexity, breadth and intended precision; and another section for all validation concerns. He also remarked that sections 4.4 and 4.5.1 need to be more responsive to the charge. Dr. Wilcoxon

stressed the need to distinguish between practical advice to EPA and more academic thoughts about where the field should go. Dr. Smith expressed a concern that the literature wasn't robust enough to answer the charge questions with as much specificity as EPA would like. Dr. Bui expressed a desire to give advice to EPA on when GE models were the most helpful.

NCEE Overview of Charge Questions

Dr. Wolverton offered a brief summary of charge questions on impacts and comparability as shown in her presentation slides posted at the meeting webpage. Noting a heightened interest in short-run economic impacts, she covered the main topic areas of how EPA can use economy-wide models to gauge economic impacts and whether it is defensible for EPA to directly compare estimates of social costs, benefits and economic impacts when generated through different approaches. Dr. Wolverton concluded with a summary of the issues for which EPA needed guidance, as follows:

- when CGE models are useful for evaluating economic impacts, and for which types;
- whether CGE models can shed light on short-run impacts;
- how to interpret CGE results when comparing them to engineering or PE estimates for impacts not captured in a CGE analysis;
- how to ensure consistency across benefit-cost and economic impact analyses when using different modeling approaches;
- whether other economy-wide modeling approaches may add value and, if so, in what contexts;
- how to characterize and communicate results from CGE or other economy-wide approaches;
- how to verify and validate CGE or other economy-wide modeling results; and
- how to best explore key model assumptions/uncertainties and limitations.

Panelists offered various thoughts on how to determine when a rule is "large" versus when it is "small" – a task made more difficult by the lack of non-market values in CGE modeling. Dr. Fullerton mentioned that small analytical models may be useful in some circumstances. Dr. Metcalf reminded the Panel they were charged with focusing on when a CGE model might lead to a different answer from a PE model. He said *ex ante* judgments were needed about whether a regulation might have downstream consequences that should be captured with GE modeling. Panelists debated the connection between international competitiveness and leakage with one panelist noting that ozone had transboundary implications.

As there were 6 charge questions (numbered 1 – 6) on economic impacts followed by 5 charge questions (numbered 1 – 5) on comparing estimates, the charge questions are designated here with the same nomenclature used in the meeting agenda. For example, the first question in the Impacts section is referred to as "Impacts Question 1; likewise, the 3rd question in the comparability section is referred to as "Comparability Question 3."

Discussion of Impacts Question 1: Appropriate Use of CGE Models

This charge question asked to what extent CGE models are technically useful for shedding light on the economic impacts of an air regulation. Dr. Carbone said the White Paper on impacts

identifies the standard technical tools for incorporating transitional dynamics and short-run impacts, such as vintaging of capital. He stressed the feasibility of incorporating information from bottom-up models into CGE analysis and said that CGE models should not be viewed as a substitute for PE models, but rather as a complement. He also noted that the fixed costs of CGE model construction are falling, and that there may be a role for CGE models as an exploratory framework for analyzing regulations. Dr. Muller said there would always be a question as to the appropriate level of aggregation given spatially heterogeneous rules like ozone where the choice of abatement technology is a function of where a plant is located. He also noted that EPA will likely need a suite of models for analyzing different types of regulations but with a preference for using the simplest variant that serves its needs. He added that there is a balance between capturing detail and complexity and the transparency and tractability of the model. Dr. Fullerton said a purely static CGE model will at least indicate directions of change although most models will not answer the question of which firms shut down. Dr. Fullerton noted the importance of identifying employment effects of policy given the human suffering caused by job lay-offs. However, he noted that while CGE models can be used to get at long run tendencies, most impacts are short run due to dislocation, the need for re-training, etc., that are not captured in CGE models. Dr. Rose said economy-wide models would definitely be needed for a policy like a CO₂ tax or a CO₂ cap-and-trade program and that EPA might have to use a suite of models to get at certain impacts. Dr. Leamer noted that time series analysis is possible at small scales and CGE models should be based on accumulated knowledge about problems. Dr. Williams noted the importance of tracking household income in distributional analysis and observed that many CGE models have limited support for that. Several panelists emphasized that a suite of models may be needed. Dr. de la Chesnaye noted that power companies are concerned with bundles of regulations simultaneously, making analysis of a single regulation at a time difficult. Dr. Montgomery noted that evaluating bundles of regulations together would avoid potential problems of double-counting impacts.

Discussion of Impacts Question 2: Impacts on International Competitiveness

After lunch, panelists took up this question, which asked whether a CGE model could shed light on the international competitiveness effects of air regulations. On the phone, Dr. Hertel discussed the Armington approach, which assumes that domestic goods within an industry are identical but fundamentally differentiated from imported goods, which in turn are differentiated by country of origin. Dr. Hertel noted that since international trade is increasingly dominated by a relatively small group of large firms, the Armington model is becoming less applicable to this context. Dr. Hertel stressed the potential relevance of variation in the emissions intensity of output across firms when analyzing air regulations (versus labor intensity, which is the focus of the Melitz specification). Dr. Balistreri talked about the structural sensitivity of models and suggested a large open-economy approach could be appropriate for some types of air regulations (e.g., carbon). He pondered when it is important to model the behavior of foreign agents and when it is appropriate to just approximate that behavior. In particular, he noted that it is not clear that there is much to be gained by the use of a multi-region model for analyzing the impacts of criteria air pollution regulations. For imperfect competition, he said analysts should use the information from the econometrics literature to provide some sense of the local parameterization of the model. Dr. Balistreri cautioned that trade responses vary dramatically between the Armington structure and the Melitz structures. However, he noted that there is little research on how regulation affects the size distribution or cost structure of firms, which

becomes important when moving to an I-O structure with heterogeneous firms. Finally, Dr. Balistreri mentioned that dynamic models are particularly sensitive to capital flows and the balance of payments closure.

Dr. Fox said it was reasonable to use a single country model for non-greenhouse gas pollutants whose effects were contained within the U.S. when analyzing effects from a domestic perspective and no treaty is involved. Dr. Fox said that if firm relocation is expected, moving to a Melitz structure that recognizes firm heterogeneity is recommended. He also noted that the position of a US industry in the global supply chain is important and can be affected by regulation. Dr. Montgomery said economy-wide models would be needed to address how resources that might be used for compliance would be reallocated after output reduction. A balance of payments constraint in the model would be helpful in tracing shifts in output and net exports among domestic industries. However, he noted that a key challenge when examining competitiveness effects is appropriately identifying regulated sub-sectors; disaggregation can matter when predicting output effects. Dr. Balistreri agreed on the importance of appropriate disaggregation to target the industry being regulated. Dr. Montgomery also noted that global leakage and inter-industry leakage for pollutants that fall under the National Ambient Air Quality Standards (NAAQS) program would be hard to trace using emissions factors, given that it would not necessarily track with fuel usage. Dr. Montgomery said some PE models could be very useful in shedding light on competitiveness effects, citing a Cal-Poly study that estimated trade effects with a well-structured supply and demand PE model with overseas and domestic information. Dr. Smith noted that regulatory impact analyses (RIAs) emphasize impacts on small firms and it would be desirable to track the size distribution of impacted firms. Dr. Fox observed that heterogeneity is not confined to domestic vs. imported goods: many products are heterogeneous in the domestic economy even within narrow classifications.

Discussion of Impacts Question 3: Criteria for Evaluating CGE Models Used to Assess Impacts

This question asked about criteria that should be used to evaluate the scientific defensibility of CGE models. Borrowing from the human health risk assessment paradigm, Dr. Rhomberg stressed the importance of problem formulation rather than letting the answers drive the questions. Dr. Paltsev said the appropriate “criteria” are a matter of comparing alternatives. He cautioned that models can mislead more than inform if they convey a false sense of accuracy. He listed a set of best practices to follow for models used by EPA or outside organizations, including: sensitivity to alternative assumptions/representations; model documentation and public access to source code; a history of use/publications as a check on the consistency of model results over time; justification for functional form and elasticity assumptions; compliance with the basic requirements of a CGE model (e.g., supported by theory), and exploration of reasons for any markedly different results. Examining the code is necessary to see how a model solves, he said. He added that it is important to be careful in reporting/representing impacts from a model with a representative agent (e.g., labor –leisure choice), and be clear regarding what this type of model can and cannot tell you. In addition, he mentioned that perfect foresight models can be difficult to solve when they include a high degree of electric sector detail for air pollution analysis.

Dr. Metcalf said it was important to focus on criteria for economy-wide models rather than

models per se. On this subject, he called attention to Section 3 of NCEE's White Paper (2016) on *Economy-Wide Modeling: Evaluating the Economic Impacts of Air Regulations*, which laid out the challenges of using a CGE model that lacks the granularity needed for impact assessment. As criteria, he suggested strong microeconomic foundations, the ability to model regulatory impacts at a sufficiently detailed level, the ability to capture interactions across markets, regions and household groups. He noted that a strength of CGE modeling is that it can capture factor price effects, but also noted that existing models don't fully capture the difficulties workers face from sectoral changes in labor demand: e.g., when coal sector employment falls and information technology (IT) employment rises. Dr. Webster complimented NCEE for its articulation of the type of information typically requested of their analyses, e.g. impacts on consumers, distributional effects. Dr. Webster said if EPA needs to know the net effects across sectors, then it's self-evident that CGE is needed, but if EPA needs to know if a particular coal plant will retire, then a PE model may be best for that. Dr. Webster and other panelists agreed that EPA needed both sets of tools. Dr. Smith mentioned 5 criteria EPA has traditionally used for evaluating models in general: literature reviews or "criteria documents," meta-analysis, model comparison forums, litigation, and performance when confronted with stylized facts. He suggested that a set of stylized facts be developed for CGE models. Mr. Revesz emphasized that EPA needs criteria that can be used to judge quickly whether outside models are credible in order to respond to comments on proposed rules. Dr. Williams mentioned that reproducing history is not a good test of CGE models due to difficulty of identifying and modeling the large number of complex shocks impacting the economy over time.

Discussion of Impacts Question 4: Labor Impacts Under Full Employment Closures

This question asks what types of labor impacts could be credibly identified and assessed by a CGE model in the presence of a full employment assumption. Dr. Sue Wing spoke about ways to more transparently address labor market frictions within the full employment paradigm by looking at reallocation under different elasticities of transformation. Dr. Williams said a full employment CGE model could not answer questions about the numbers of jobs or effects on unemployment but it could answer questions about the wage rate, total labor income and labor force participation because it provides a long-run equilibrium. He said it would be possible to approximate "job equivalents" but this statistic was too often misinterpreted as actual jobs—reporting labor hours is preferable. He also noted that most CGE models can't distinguish between participation and labor hours decisions because they use a single labor supply elasticity. Dr. Leamer warned the Panel that some proposed refinements to modeling unemployment in CGE models are dramatically simplified relative to actual labor markets. In addition, he mentioned that normal economies have huge job churn from month to month (large numbers of job creations and job destructions), and that gauging employment effects in a growth cycle of the economy would be very different from gauging employment effects in a recession. Dr. Smith mentioned that EPA recently sponsored a workshop on employment impacts of environmental policy, which has been published in the *Review of Environmental Economics and Policy* and includes several relevant papers. Dr. Rose discussed the Keynesian closure used in some models and also noted that automation and technical change are causing significant changes in the labor market independent of regulation.

July 20, 2016

The Panel resumed its discussion of charge questions with Impacts Question 5.

Discussion of Impacts Question 5: Modeling Transition Costs and Factor Market Disequilibrium

This question asks whether there were ways to loosen the full employment assumption to examine transition costs in capital or labor markets. Dr. Belzer stated that the full employment assumption is problematic all the time, not just during “recession,” which the public intuitively understands differently than the official definition. He also noted the importance of overall regulatory burden on businesses at both the Federal and state levels. These effects are much broader and deeper than the employment/labor supply question; firms may be more affected by government regulations elsewhere (e.g., negative interest rates) than environmental regulations; and CGE modeling should account for the array of major regulatory mandates firms face that lead to business risk aversion with respect to compliance decision-making. Dr. Smith mentioned that the workshop discussed in the previous question had several papers bearing on this topic as well. He also said loosening the full employment assumption could possibly be accomplished by relaxing the effects of instantaneous adjustment. One could begin with a plausibility check by examining how much difference alternative assumptions make, which could be considered within a simple static analytic CGE model. Such an analysis would begin by researching the relationship between substitution elasticities with quasi-fixed inputs vis-à-vis elasticities that allow full adjustment of all inputs. The envelope condition would allow a comparison of the linkage between short and long run adjustment. This might be easier than getting the dynamics worked out, he said. Dr. Leamer noted that housing costs and commute patterns are strongly linked in Southern California and that air regulations can affect both. Dr. Bui also acknowledged that there are longer transitions between jobs in the baseline given structural changes in the economy.

Dr. Williams described various ways structural and cyclical unemployment could be modeled, noting that most of this work appears in the labor and macroeconomic literatures, not the environmental economics literature. A common approach used in European models is to have the labor market clear above the minimum wage to reflect unions, etc., but he doesn’t think this approach reflects the U.S. experience. Dr. Williams described the use of a Keynesian closure, which may adequately represent the short run when there is excess capacity (i.e., labor supply is not binding) but pointed out that demand-driven models lack micro-foundations. He noted that introducing search frictions into the model (i.e., modeling occupational switching that incorporates the transition costs as workers move from one sector to another) may be the most promising option because it matches key stylized facts with respect to non-zero unemployment even under full employment conditions. He also suggested the possibility of modeling wage stickiness. However, Dr. Williams noted the limitations of these approaches since they only capture frictional unemployment and not cyclical or structural unemployment.

Dr. Williams identified two possible ways to capture cyclical/structural aspects: a new Keynesian Dynamic Stochastic General Equilibrium (DSGE) modeling approach – noting this is not a trivial exercise since these models are not set up to address environmental questions – and worker heterogeneity to capture skill/occupation mismatch. He is not aware of any existing model that does this. The macro literature considers other types of adjustment costs such as

experience with a specific job at a particular firm, but these have not been incorporated into a CGE model. With regard to relaxing the CGE assumption that prices adjust instantaneously, Dr. Williams noted that new Keynesian DSGE models are used to explore price stickiness but it is difficult to model this phenomena in a way consistent with micro-foundations, and the particulars can matter with respect to how the process is modeled.

Dr. Metcalf pointed out the question lumped together failure to address capital markets with failure to address labor markets as though they were similarly handled. He said that modelers have been incorporating capital market adjustments into CGE models for some time, but the bottom line is that the profession is not ready to address unemployment in CGE models. He opined that it may be better to use a problem-driven approach to describe employment impacts specific to the regulatory context, and that a PE approach may be preferable for direct impacts in a regulated sector. He added that, because it is difficult to model, an analysis could qualitatively acknowledge the increased difficulty of finding jobs in a recession. Dr. Bui noted that more research is needed about job losers, complicating detailed impact analysis by demographic groups. Dr. Paltsev agreed with Dr. Metcalf's conclusions and stated that the Panel should clearly state that jobs lost or jobs created cannot be predicted by a CGE model with full employment. Likewise, Dr. Montgomery added that he would like to see the Panel say that any effort to claim estimates of job losses or gains from a PE analysis that covers only the directed regulated industry should be discounted. With regard to CGE analyses of employment effects, Dr. Montgomery noted that analyses should be clear about whether they are describing voluntary or involuntary unemployment. Dr. Smith noted that household production is not usually included in CGE models, complicating analysis of the welfare impacts of individuals moving in and out of the labor force.

Discussion of Impacts Question 6: Considerations for Economy-Wide Analysis of Air Regulations

This question asks whether there were other economy-wide modeling approaches that EPA should consider for evaluating the short-run impacts of an air regulation. Dr. Rose reviewed a list of alternative models like Input-Output (I-O) models, IMPLAN, Inforum LIFT and REMI. He stated that I-O models are not up to the task, and noted that LIFT and REMI are useful for forecasting. He also noted that REMI is not used at the national level but is a primary tool for the evaluation of state policy. Dr. Muller said the models should be evaluated according to their suitability to answer the question at hand. He noted that if there is a limited body of evidence on the use of I-O macro-econometric models in an environmental context, then he would not recommend their use in this context. Dr. Carbone said he would favor a research design to produce short-run, medium-run and long-run results from a consistent CGE modeling framework that allows factor mobility as the time frame extends. He noted that Adkins, Garbaccio, Ho, Moore and Morgenstern (2012) is a good example of what can be done. Dr. Fullerton expressed a reservation about using economy-wide models to evaluate short run, disequilibrium, or sector specific effects; rather CGE models could provide directions of change for sectors. Dr. Smith noted that REMI employs a reduced-form representation of the effect of environmental regulations on employment and that a statistical representation of an equilibrium result is inappropriate in this context. Dr. Williams stated that use of large-scale macroeconometric models for policy analysis is not recommended because of the Lucas critique; interpreting statistical correlation from historical data as potentially causal is incorrect.

Dr. Leamer noted that these types of models are unlikely to pick up the effects of environmental regulations on employment: the experiment is too minor relative to everything else going on in the economy.

Comparability Question 1: Technical Merits and Challenges

This question asked about the technical merits and challenges of using economy-wide models to evaluate the social costs, benefits and economic impacts of air regulations. Dr. Balistreri said all of CGE modeling is an out-of-sample inference that moves us out of the realm of historical policies. Since most academic research dealt with questions of welfare (rather than job turnover), Dr. Balistreri said EPA should have a very simple structural CGE model built on micro-foundations that has the flexibility to add features depending on the question at hand as time allows. The interpretation of results becomes more difficult as features are added to the model. He noted that the asymmetric labor supply response during a recession is not something he would build into the simple model at this time. Dr. Balistreri said the non-separability between costs and benefits can interfere with our ability to blend CGE results with PE results. Dr. Fox noted that the model or tool chosen should line up with the problem being analyzed, both sectorally and spatially, and reminded the Panel of the potential pitfalls of geographic or sectoral aggregation. Dr. Montgomery said that although there are non-market externalities not estimated in a CGE model, the economy-wide approach would still yield useful information, particularly for cost-effectiveness analysis (i.e., comparing costs to achieve a given level of emission reductions). It would be possible to estimate non-market effects separately, but separability has been challenged by Dr. Smith. He suggested a paradigm of incorporating non-market effects for health which can be captured as the product of concentration levels and health care expenditures and embedded in the utility function. There may be ways to incorporate these, but Dr. Montgomery prefers using a CGE model to just capture the cost side than trying to embed everything in one model. Dr. Montgomery noted a package of regulations modeled together would solve the co-benefits problem. Dr. Hertel said PE models can be just as rigorous as GE models and may play a critical role in policy analysis. He did note the challenge of knowing where to draw the boundaries with PE models; what is important to have in the model is not always clear. Similarly, PE output can be used as an input in GE analysis. Dr. Hertel recalled the original analysis of ethanol conducted by engineers showing a host of benefits. Only later, when GE analysis was conducted, did other ramifications of ethanol become apparent. Dr. Hertel advocated for making models and data publicly available, and for standardizing practices such as verifying that Walras' Law holds. He also noted the importance of micro-economic foundations, peer review, thoughtful parameterization, and consistency with stylized facts. Dr. Williams also noted the importance of sensitivity analysis with respect to key assumptions. Dr. Smith again reminded the Panel of interactions between costs and benefits, i.e. non-separability, and the importance of trying to reflect it in the model in some way. Dr. Smith pointed out that a GE analysis of net benefits of the Clean Air Act yielded an estimate of 0.08% of GDP while a PE analysis yielded an estimate of 8.7% of GDP. A discussion ensued on how to parameterize non-separability. Dr. Williams noted that while separability is clearly incorrect, he questions whether there is a way to reasonably represent non-separability in CGE models. Dr. Metcalf reminded the Panel that it must provide near-term guidance to EPA, not just a long-term research agenda.

Comparability Question 2: Welfare Measures Versus GDP

This charge question asks how to approach potential discrepancies between welfare measures for the economy as a whole versus impacts on GDP. Dr. Smith objected to the framing of the question, which seemed to imply that GE analysis of net benefits could lead to inappropriate judgments. The circular flow diagram on which most CGE models are based omits non-market interactions with environmental systems that create important feedbacks. On this subject, Mr. Revesz expressed a concern about the reporting of quantitative estimates of costs but only qualitative information on benefits given that the harder number is likely to be taken more seriously. He urged the use of caveats expressed as prominently as possible. Dr. Belzer noted that, because costs are equivalent to benefits forgone, it is not clear than benefits are harder to quantify and monetize than costs. He also stated that EPA should communicate both PE and GE results when it has them, and clearly explain why they differ. He also noted that distributional analysis may be important for explaining key differences. He suggested that in the year of Big Data, which allows extraordinary product micro-targeting (e.g., “designer” pharmaceuticals), the public may now expect micro-targeting of regulations with compensation for adverse distributional impacts rather than accepting the Kaldor-Hicks rule. He also made the point that GE analysis is the only way to capture opportunity costs rather than just out-of-pocket compliance costs. Panelists discussed whether non-separabilities are driving differences between PE and GE results.

Dr. Montgomery thinks there is value in a CGE analysis of costs even if benefits cannot be incorporated. However, he noted the importance of reporting results on the cost and benefit side in equivalent terms so that a comparison is possible, even if they are derived using different models (whether reported in percentage or absolute terms). Dr. Balistreri noted the incorporation of benefits into a CGE model with separability should not change the rank ordering of options. However, he and Dr. Smith emphasized the importance of paying attention to the denominator (which should include virtual or imputed income from non-market goods) when reporting results in percentage change instead of absolute terms.

The Panel then discussed the role of heterogeneity. Dr. Williams reminded the Panel that impacts can vary at small spatial scales – e.g., changes in beaches visited or local variations in air quality. Dr. Rhomberg observed that such heterogeneity may drive some regulations: worse problems may be addressed first. Dr. Montgomery mentioned that inter-firm heterogeneity in emissions factors is large and difficult to model. Dr. Smith noted that the impacts of pollution depend on conditions where it is emitted and that the response across individuals to a given concentration can vary.

Comparability Question 3: Presenting Results

This charge question asks for the SAB’s thoughts on the information that needs to be presented to the public and policymakers from CGE analysis. Dr. Bui advised that EPA present a large table with initial conditions, elasticities (and where they came from), sectors and interactions being considered. She also noted the importance of a written description of key take-aways and how to interpret the main results as well as a description of the main sensitivity analyses that have been conducted and how they affect the main results. Dr. Bui also urged EPA to correct the public’s misinterpretation of CGE results as a forecast by explaining to the non-modelers what a CGE model can and cannot do. Dr. Leamer said he would prefer an emphasis on *why*

things happen rather than the numbers. Dr. Sue Wing advised EPA to have a public, stripped down simple model to screen whether effects are big or small, local or national, etc. such as a DICE type version of a CGE model with no more than 10 sectors. Dr. Williams expressed reservations about trying to provide a model that the public can run given the potential for misuse and misinterpretation but he did say the simplest possible model that can answer questions is best. Dr. Belzer raised his concern that public confidence in CGE modeling would be greatly damaged, and possibly destroyed, if the public were denied access, noting that no one was recommending restricted access to statistical software despite the actual (not potential) extent of misuse and misinterpretation. He noted that the discussion accompanying results may be more important than the results themselves, particularly with regard to their sensitivity to key parameters and alternative assumptions. Dr. Fullerton agreed that EPA should select the simplest model for the problem at hand and advised the use of a suite of models with different relative comparative advantages. Dr. Smith reiterated the importance of transparency with regard to presentation of results and the way in which the model is characterized. Mr. Revesz noted that any criteria for transparency should also apply to models used by outside organizations.

Dr. Williams expressed the opinion that, whatever model EPA uses, the source code and data should be publicly available. Several other panel members agreed. Dr. Belzer said that EPA published information quality guidance in 2002 requiring that model results be capable of being reproduced by qualified independent analysts, and this would be difficult with proprietary (i.e., not publicly available) models. Dr. Leamer mentioned that reproducibility is a broad problem in social science and suggested that the Berkeley Initiative for Transparency in the Social Sciences may provide some useful guidance. Dr. Paltsev noted that data are often commercial products so free public access is not always possible. Dr. Metcalf advised caution with regard to a strong statement against use of proprietary models. He also suggested that transparency standards should be the same across all models: PE and engineering models as well. Dr. Smith noted that General Algebraic Modeling System (GAMS) software is also often required, which can be an additional hurdle to public access. In addition, he noted that a large amount of information is produced for a regulatory analysis, so it may not be feasible to make it all publicly available. Dr. Smith also suggested that the common practice of presenting results by calendar year may contribute to the misimpression that CGE models produce forecasts; just presenting results by year since the start of the analysis may be clearer. Mr. Revesz noted that charge questions I3 and C3 are closely related and suggested that the Panel's responses be linked.

The Panel ended with a discussion of the potential usefulness of conducting a model comparison exercise. Dr. Montgomery suggested the need to create a forum to organize review and critique and discuss key models and analyses. One would need a particular application in order to conduct such an exercise, but once selected this type of forum would provide an organized opportunity to ask questions, identify differences in assumptions, and identify potential errors.

Comparability Question 4: Uncertainty

This charge question asks for the SAB's thoughts on how uncertainty can be addressed in an economy-wide modeling framework. While the charge question asked specifically whether one

type of uncertainty was more of a concern than others (e.g. statistical variability versus parameter uncertainty), Dr. Webster said all types of uncertainty are a concern. He said the challenges for GE and PE are the same. He noted that there are credible approaches for addressing statistical variability and heterogeneity, acceptable approaches for characterizing parameter uncertainty, but no approaches to describe deep uncertainty. He described three approaches for incorporating uncertainty into a CGE model: sensitivity analysis, scenario analysis, and formal uncertainty analysis. A Monte Carlo analysis would provide the richest characterization of uncertainty, but it is also the hardest to do and the most expensive. Dr. Webster noted that, when multiple models are used for an analysis, care should be taken in how results are characterized, as they do not represent a full range of uncertainty. Instead, one would want to subject multiple models to similar sensitivity models and report the information in a way that conveys probabilities of outcomes (e.g., histograms or confidence intervals around a median). Dr. Balistreri was not supportive of constructing confidence intervals around a CGE model outcome when there is no underlying econometric structure. He thought it more constructive to explore the structural components of the model in a systematic way. Dr. Paltsev agreed that EPA should pursue formal sensitivity analysis.

Dr. Rhomberg agreed that uncertainties were the same, whether from a GE or PE analysis. Dr. Rhomberg harkened back to his original comments on problem formulation to encourage analysts to first know what they were trying to derive before addressing uncertainty about the results, and encouraged analysts to evaluate model performance against real data/stylized facts. Dr. Paltsev talked about a herd mentality, where results from different models often converge over time, which can result from inter-model comparison type of exercises. He referenced the confusing nature of the Intergovernmental Panel on Climate Change's uncertainty categories: "likely" "more likely than not," etc. to emphasize that figuring out a clear way to convey uncertainty to the public is important. Dr. Metcalf said the characterization of uncertainty was context-specific and stressed the use of sensitivity analysis to determine which parameters are important. Dr. Leamer noted that significant sources of uncertainty are doubtful variables: those that are neither clearly appropriate nor clearly inappropriate to include in a regression. He suggested that CGE modeling needs an analogy to maximum likelihood for measuring the closeness between a model and data. A discussion ensued on how to avoid the problem of policymakers preferring the middle number between a high and low estimate. Dr. Metcalf questioned whether to use a CGE model to evaluate a small policy. Dr. Paltsev noted that it has sometimes been difficult to represent a very small policy in the Emissions Prediction and Policy Analysis (EPPA) model. Several panelists noted the potential pitfalls in using parameters estimated in other literatures in CGE models.

Comparability Question 5: Research Priorities

This charge question asked for the SAB's recommendations on long-term research priorities for EPA. All panelists were invited to comment. Dr. Wilcoxon opened the session by noting that previous discussion had clearly shown the need for research on labor markets and non-separability. Dr. Hertel said it would be important to extend the Williams-Hafstead work to structural unemployment. In addition, there was a need to compare results from open economy models to global trade (multi-region) models. He also called for research on characterizing heterogeneity in emissions intensities across firms in an industry, and for examining the importance of oligopoly effects. Dr. Williams emphasized the importance of unemployment,

and of modeling non-market effects more broadly than just non-separability. Several panelists voiced support for resurrecting STAR grants for the development of economic tools. Dr. Fox called on EPA to build a reference database of CGE data with open source code to be available as a public good. Dr. Hertel agreed and mentioned that he would use an open-source process for the Global Trade Analysis Project (GTAP) if he were to do it over. Dr. Rose suggested further work on closure rules, including the fiscal and trade deficits. He also argued for disaggregating household income classifications more finely; for exercising care in modeling cross-jurisdictional ownership of capital; for developing the ability of CGE models to examine the impacts of disasters (and disaster preparedness); and for further enhancing the ability to link top-down and bottom-up models. Dr. Belzer argued that the most important consideration is to focus on what the models do most poorly, or not at all – not just adding significant figures to estimates of the portion of the result that is comparably well-understood. Dr. Muller also emphasized the need for coupled models.

Next Steps

In closing the meeting, Dr. Wilcoxon and Dr. Stallworth presented a draft timeline to the Panel that included further edits on Parts I and II (social costs and social benefits) in response to NCEE's comments; a deadline for lead writers to submit responses to charge questions on Parts III (Impacts) and IV (uncertainty); a subsequent deadline for the Panel to see a full draft of responses to all charge questions and tentative plans for a fall teleconference to be scheduled in late November 2016 or early December 2016.

Dr. Stallworth adjourned the meeting.

Submitted by:

Holly Stallworth, Ph.D. /s/
Designated Federal Officer

Certified as Accurate:

Peter Wilcoxon, Ph.D. /s/
Chair, SAB Economy-Wide Modeling Panel

NOTE AND DISCLAIMER: The minutes of this public meeting reflect diverse ideas and suggestions offered by committee members during the course of deliberations within the meeting. Such ideas, suggestions, and deliberations do not necessarily reflect definitive consensus advice from the panel members. The reader is cautioned to not rely on the minutes to represent final, approved, consensus advice and recommendations offered to the Agency. Such advice and recommendations may be found in the final advisories, commentaries, letters, or reports prepared and transmitted to the EPA Administrator following the public meetings.