

**Summary Minutes of the
U.S. Environmental Protection Agency
Science Advisory Board
Economy-Wide Modeling Panel
Public Meeting
October 22 - 23, 2015**

Economy-Wide Modeling

Panel Members:

Dr. Peter Wilcoxen, Chair
Dr. Edward Balistreri
Dr. Richard Belzer
Dr. Linda Bui
Dr. Jared Carbone
Dr. Francisco de la Chesnaye
Dr. Karen Fisher-Vanden*
Dr. Alan Fox
Dr. Don Fullerton
Dr. Thomas Hertel
Dr. Edward Leamer*
Dr. Gilbert Metcalf
Dr. W. David Montgomery
Dr. Nick Muller
Dr. Sergey Paltsev
Mr. Richard Revesz
Dr. Lorenz Rhomberg
Dr. Adam Rose
Dr. Robert Shimer
Dr. V. Kerry Smith
Dr. Ian Sue Wing
Dr. Roberton Williams
* participated by teleconference

Purpose: The Economy-Wide Modeling Panel discussed charge questions from EPA's National Center for Environmental Economics.

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

Other EPA Staff: Allen Fawcett, Chris Zarba, Al McGartland, Ann Wolverton, Alex Marten, Richard Garbaccio, James McFarland, Jim DeMocker, Jared Creason, Michael Shelby, Darryl Weatherhead, Ann Ferris, Nathalie Simon, Linda Chappel, Carl Pasurka, David Evans, Iris Goodman, David LaRoss, Tom Carpenter

Public: Elaine Shen (South Coast Air Quality Management District); Bryan Zumwalt (American Chemistry Council); Mei Yuan (NERA Consulting); Amanda Thomas (Office of Management and Budget)

Webcast/Teleconference Attendance: Lauren Morris (Abt Associates); Charles Fulcher (EPA); Martha Moore (American Chemistry Council); Julie Hewitt (EPA); Wendy Hoffman (EPA); Kevin Swift (American Chemistry Council); Brett Snyder (EPA)

Meeting Materials and Meeting Webpage:

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

<http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/7f1209feb69099ec85257dfd00605b67!OpenDocument&Date=2015-10-22>

Agency Review Documents:

- Economy-Wide Modeling: Social Cost and Welfare White Paper by National Center for Environmental Economics and the Office of Air and Radiation, 9-22-15
- Economy-Wide Modeling: Benefits of Air Quality Improvements White Paper by the National Center for Environmental Economics and the Office of Air and Radiation, 9-22-15
- Memo on Using Other (Non-CGE) Economy-Wide Models to Estimate Social Cost of Air Regulation by the National Center for Environmental Economics and the Office of Air and Radiation, 9-22-15

Other Meeting Materials:

- Crosswalk Between Charge Questions and White Papers by EPA National Center for Environmental Economics, 9-22-15
- Glossary of Terms by EPA National Center for Environmental Economics, 9-22-15
- Guidelines for Preparing Economic Analyses -- Chapter 7 on Analyzing Benefits by EPA National Center for Environmental Economics, December 2010
- OMB Circular A4 on Regulatory Impact Analysis
- The Benefits and Costs of the Clean Air Act from 1990 - 2020 by EPA Office of Air and Radiation, April 2011
- Presentation from the National Center for Environmental Economics for the Oct. 22 - 23, 2015 meeting
- Discussion Material presented by David Montgomery
- Discussion Material presented by Don Fullerton
- Discussion Material presented by Kerry Smith
- Discussion Material presented by Nicholas Muller
- Discussion Material presented by Adam Rose
- Comments from Dr. Ed Leamer, Panelist, Economy-Wide Modeling Panel. 10-13-15
- Registered Public Speakers
- American Chemistry Council comments presented by Bryan Zumwal, 10-22-15
- Chamber of Commerce, American Chemistry Council, American Forests and Paper Association, American Petroleum Institute and American Wood Council comment submitted on 10-13-15
- South Coast Air Quality Management District comments presented by Elaine Shen, 10-22-15

October 22, 2015

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. At the request of Dr. Peter Wilcoxon, Panel Chair, panelists introduced themselves.

Dr. Al McGartland, Director of EPA's National Center for Environmental Economics, thanked the Panel for its efforts and noted that the topic of economy-wide modeling (rather than partial equilibrium modeling) was relatively new territory for the Agency. Dr. McGartland noted that although NCEE's white papers focused on air regulations, the Panel's deliberations would be of interest to all EPA offices.

Dr. Ann Wolverton of NCEE presented the slides posted on the meeting webpage. She explained EPA's interest in both cost-benefit analysis and economic impact analysis, noting that economic considerations were one of many decision criteria. Dr. Wolverton covered EPA's history with the use of computable general equilibrium (CGE) models and asked the Panel to think about advice that could be useful in the short-run as well as the long-run. Panelists questioned Dr. Wolverton and Dr. McGartland about the Agency's time constraints, the focus on non-CO₂ emissions for the white papers, the use of cost-benefit results, and other matters.

Public Comments

Elaine Shen of the South Coast Air Quality Management District (SCAQMD) in California described the need to balance legal requirements with policy relevance and academic rigor. She noted that California's Health & Safety Codes require that her agency analyze the employment impacts of proposed regulations and amendments, thus rendering any model that assumes full employment impractical. She urged the Panel to carefully consider how to do employment impacts analysis so that SCAQMD could benefit from its advice, and to avoid potential divergence between EPA's recommendations and SCAQMD's mandated practices.

Brian Zumwalt, on behalf of the American Chemistry Council, urged the Panel to focus on models that have sufficient industry and regional detail, including international trade flows, adjustment costs and impacts on competitiveness. Mr. Zumwalt also warned the Panel to beware of double and triple counting benefits as he said was done for the most recent regulatory impact analysis of the particular matter regulation.

When Mr. Zumwalt was asked about relaxing confidentiality requirements to facilitate access to detailed industry data so that effects of regulations could be more carefully considered, he said he would get back to the Panel on that. Dr. Williams said there is a tradeoff in CGE models between detail and transparency, noting it is difficult to have both, and asked Mr. Zumwalt how industry prioritizes these two objectives. Mr. Zumwalt indicated that he is not prepared to answer this question for industry at this time.

Cost Question 1: Comparing CGE models to Partial Equilibrium (PE) models

On this charge question, Dr. Fullerton noted several key advantages of a CGE approach: it could capture interactions between sectors, factors of production, trade, etc. (e.g., through cross-price elasticities) while providing a consistent and comprehensive accounting framework for adding up all the effects of regulation, both the costs and benefits. Dr. Williams noted that an analyst could also achieve an internally consistent framework for benefit-cost analysis with an analytic GE model, not just a CGE model. Dr. Fullerton said he worried about the asymmetry between costs and benefits where costs can be captured more readily than benefits in a CGE model. At several points, panelists remarked on the importance of extending models to include more linkages between pollution and economic outcomes in order to improve modeling of benefits. While cautioning against an either/or choice of CGE versus PE models, Dr. Carbone said CGE models allow us to tease out key sensitivities of costs and benefits but were far less useful as precise forecasting tools. He encouraged a focus on simpler CGE models as a complement to established benefit-cost methods.

Both Dr. Metcalf and Dr. Shimer warned against generalizing about one approach or the other without specific context and a specific question to be answered. Dr. Smith noted that it would be useful to take several specific regulations and consider whether a CGE modeling approach is warranted in that context. Dr. Williams stated that given the heterogeneity across regulations it may be more useful to think about model features than model types when responding to the charge question. Dr. Shimer also noted that it may be more useful to think about what the regulation is going to change; some of these changes are well-handled in an engineering or PE approach while others are not. Dr. Sue Wing offered the analogy of an onion with four concentric rings to determine the type of analytic tool that may be needed for analysis, beginning with engineering costs in the center (building the abatement supply curve), followed by effects on the firm in the next ring (which could be met by an industry-focus economic model), followed by closely related market effects in the next ring (bringing in inputs and consumers via a multi-market approach), followed by general equilibrium effects (where a CGE model may be informative). He noted that the first three rings of the onion do not ensure consistency with respect to prices and incomes faced by firms or other sectors of the economy; this consistency is supplied by the last ring via the price mechanism in a CGE model. Dr. Sue Wing continued, what could be potentially useful to think about is a test EPA could perform at each stage to help determine the efficacy of going onto the next level of analysis.

Panelists debated whether modeling for insight or modeling for numbers (when capturing the details of a regulation would matter) was more important. Dr. Paltsev noted that CGE models such as EPPA are not precise enough to be a decision-making tool but are useful in a decision-support role. A key question is how well does the next best alternative to a CGE model do in capturing social cost. The answer to this question can help inform the relative advantages of using CGE models to analyze regulatory effects. Dr. Metcalf noted that the difficulty in capturing non-market benefits in a CGE framework means that results could give a sense of false precision; how the results are reported and discussed then becomes important. Dr. Wilcoxon warned that if the Panel says CGE models should be used primarily for insights, rather than numerical results, then EPA would not be able to use CGE models for rulemakings. He also

reminded the Panel that EPA is seeking advice on when CGE models might be appropriate in a regulatory context, which may require that the Panel be more specific in its advice.

Data quality evaluation and validation were discussed, with Dr. Hertel suggesting that confidence in a CGE model can be built over time, particularly if it is publically available and therefore subject to greater scrutiny. That said, validation often occurs for portions of the model but validating an entire model is rare and may not be possible to do in a meaningful way. Dr. Montgomery said that the inclusion of resource and budget constraints in a CGE model means it can provide a useful reality check in policy analysis (e.g., a CGE model specifies a labor endowment while non-GE models often assume an infinite supply of labor). A number of panelists discussed the data requirements of a CGE model, noting that some of the data are widely available while others are less so (elasticities were given as one example). Dr. Shimer worried that CGE models were so complicated that isolating a particular elasticity that might be driving the results would be too difficult.

Cost Question 2: Factors affecting model choice

Addressing factors that affect model choice, Dr. Balistreri stressed the context-dependency of all model choices. He also emphasized capacity-building and flexibility in model development, taking advantage of separabilities where possible, and the importance of structural uncertainty. He said the size of the shock alone would not be an important factor; sometimes relatively small shocks may be important to consider in a CGE model because of their general equilibrium effects. He noted that identifying separabilities (e.g., when spillovers or interactions between markets are limited) becomes important when determining where you stop with regard to the layers of Dr. Sue Wing's onion analogy (discussed under question #1); it allows you to determine when an analyst can sufficiently approximate the GE effects with a PE approach. With regard to structural uncertainty, Dr. Balistreri noted that it is likely to be a bigger issue than parameter uncertainty across models. Dr. Metcalf also stated that it is important to differentiate between parametric or structural uncertainty in the models and decision uncertainty.

Dr. Sue Wing warned that as you increase the granularity of the model (e.g., the more sectors built into it), the lower the elasticities of substitution in the economy. The implication is that an analyst will find larger impacts of a regulation with aggregation, all else equal, which leads to the question of how one determines if it is a real effect, thus highlighting the issue of structural uncertainty further. Dr. Sue Wing noted that a key consideration when determining the level of detail needed in a CGE model is whether representing specific control technologies and the substitution process between them matters. Can one impose an aggregate abatement supply curve on the model that is it roughly consistent with the more detailed information? He said it is time consuming to map engineering information to a CGE model, so one needs to evaluate what is "good enough." After complimenting the authors of the white papers, Dr. Paltsev reiterated the issue of aggregation/disaggregation because it involves reevaluating elasticity assumptions in the model. He also emphasized the importance of the representation of distortions in specific sectors. Dr. Sue Wing also noted that interdependence across sectors in a CGE model makes it very difficult to shut off specific components of the model to identify how different aspects/assumptions contribute to the outcome.

Dr. Balistreri noted that with regard to the treatment of international trade across models, sometimes it is acceptable to assume that the United States is a small open economy; in other contexts this would be less acceptable as an assumption. Dr. Sue Wing noted that the way capital vintaging is treated in the model is much more important than the trade closure utilized.

Dr. Sue Wing noted that one needs to evaluate what is gained from using a dynamic model: can you get close with a comparative static evaluation or a dynamic approximation using a static model? He said the degree of foresight might be determined by computational constraints, with more detailed models requiring shorter time horizons or a dynamic recursive approach. Dr. Paltsev said he favored the use of recursive-dynamic models over intertemporal perfect foresight models because of the sensitivity he has observed with respect to transversality conditions (i.e., what happens after the last period in a forward looking model) in the latter. Dr. Rhomberg wondered about the appropriate treatment of technological change over time given the choice of time horizon. He pondered how CGE models might treat feedback effects over time as technology improved, as well as how to account for transitional costs if you are only looking at the beginning and end points of a policy change in a comparative static exercise. Dr. Montgomery said there are three attributes of a policy related to dynamics that make it difficult to get producer and consumer surplus right in a static model. If the policy being analyzed occurs in a future year, anticipatory effects of a large change in requirements could matter. Two additional problems include the possibility of guarding against a policymaker assuming they know more than the actors in the model (i.e., strategically manipulating the outcome); and transversality conditions distorting model results relative to the base case if they are not carefully specified. Dr. Hertel noted that intertemporal dynamics matter but said that static models could be useful for capturing near-term responses and discussed recent work on modeling historical shocks in agriculture. He also mentioned that it would be useful to have a set of stylized facts in air regulation that could be used for a similar validation exercise. Dr. Sue Wing said that one needs to understand how much is missed with regard to transition costs if you don't use a fully detailed dynamic model since there are different analytic costs and benefits associated with different techniques. Dr. Shimer also stated that while it may be easy to write down a fully dynamic, rational expectations model with adjustment costs and uncertainty they are difficult to solve, so one needs to make compromises. Dr. Williams said there were two factors that would support the use of a CGE model: how tightly linked the markets are and whether there are distortions in related markets. With regard to dynamics, he noted that a model without perfect foresight introduces distortions itself that may be important, and that while one can pick up short run effects in a comparative static model, transitional effects are inherently dynamic. Dr. Balistreri offered a warning about distortions in intertemporal markets that would affect calculations of equivalent variation (EV); adding a distortion could cause EV to go up because of other offsetting distortions.

Dr. Paltsev noted that with respect to time and resource requirements, CGE models are expensive to maintain. They need continual improvement and maintenance to retain quality.

Cost Question 3: Other factors to consider

Other issues raised include model validation issues, the adequacy of reduced form representations, what is known about behavioral parameters, the difficulty of solving perfect foresight models, the assumption of investment displacement, assumptions about competitive or monopolistic structures, the representation of endogenous technology, international flows of labor and capital, structural shifts stemming from international trade, the difficulty of historical validation (particularly for models with foresight), the public availability of the model, the quality of the underlying SAM (some noted issues with IMPLAN data); whether the model assumes full employment, geographic/spatial resolution, and whether a model assumes a representative agent (which may matter for distributional impacts). Dr. Shimer said the question wasn't the choice of model so much as it was whether the policy analyst was capturing the relevant impacts. Dr. Montgomery noted that it is much harder to get the welfare results right in a CGE model than the prices and quantities. Dr. Williams noted it is much harder to conduct welfare analysis when people move; their movement across space doesn't matter for aggregate benefit-cost analysis, though it may matter for evaluating economic impacts. Dr. Wilcoxon referred panelists to Dr. Leamer's written comments on the parameterization of models.

Cost Question 4: Non-Price regulations

Dr. Fisher-Vanden presented the following points in relation to representing emissions-based or technology-based regulations in an economy-wide framework.

- The more spatially, sectorally, and/or temporally detailed the regulation is, the more challenging it is to represent in an economy-wide modeling framework.
- Models that assume least-cost compliance strategies do not typically account for real-world rigidities.
- Decision-making by regulated entities rarely strictly follows the economic model of cost-minimization; imperfect information and industry norms may be important.
- Technology-based or performance-based standards could lead to market power issues that are difficult to represent in models.

Dr. Muller added that the degree of compliance and the potential importance of over-compliance may matter given non-linearities in abatement cost functions, making it more difficult to model. Dr. Fisher-Vanden also pointed out the potential for non-compliance, citing the example of the NAAQS where states are trying to get close to the standard but can't actually reach it. Dr. Fullerton suggested most non-price regulations could be modelled as their price-equivalents, using tax and subsidy combinations. He specifically referenced a forthcoming paper in *AEJ-Policy* by Goulder, Haefsted, and Williams as instructive in this regard. Several panelists noted the potential challenges of implementing Dr. Fullerton's suggested approach; for instance, how to identify what you would actually tax when analyzing a regulation when you are not sure which sectors will make changes and by how much; how to implement when there may be changes in the input process in response to the regulation; how to treat the timing of shifts in input responses missed by a price representation. Dr. Montgomery noted that in order to capture the margins on which the policy is likely to produce a wedge in prices you need a detailed representation in the model, as detailed as the regulation itself. This raises the question of how many margins you can actually fit into the model and which matters most with respect to their representation. Dr. Williams noted that some of these difficulties are true regardless of the type

of model utilized; they are not CGE specific challenges but more general data challenges. Dr. Wilcoxon asked panelists to refer to EPA's examples of specific regulations in the white paper in their draft responses to charge questions.

Dr. Balistreri suggested that EPA could invest in a set of "toy" models to explore the implications of a given regulatory approach in a GE context. Dr. Smith noted, however, that EPA has already estimated the specific technology they expect industry will need to comply and its associated costs, so why not use that information instead of coming up with an alternative approach. Dr. Wilcoxon raised the question of how to credibly introduce this information into a CGE model when it doesn't have the same industry structure or representation. Dr. Montgomery reminded the Panel that for the CAFE standard, the engineering analysis never contemplated the cross-elasticity of substitution between light trucks and passenger cars. CGE models would be more advantageous in picking up these elasticities if only because they remind the analyst that such elasticities are needed.

Cost Question 5: Metrics to measure social costs

Dr. Metcalf said EV or compensation variation (CV) would be the appropriate metrics to use when capturing welfare changes. He noted that EV and CV are comprehensive welfare measures but the "devil is in the details" with regard to how to operationalize them (e.g., the specification of the utility function, assumptions about separability). Dr. Metcalf noted that a disadvantage of these measures was that policymakers don't understand these concepts. However, he did not view GDP or consumption as alternatives to a welfare measure (though consumption is certainly better than GDP) because they cannot account for non-market goods, do not include the value of leisure, and GDP includes investment. After seconding Dr. Metcalf's comments, Dr. Carbone said one benefit of a CGE approach is that it forces you to write down the utility function and where non-market goods enter. Dr. Fullerton agreed that social costs/externalities are not in a GDP or consumption measure so you cannot use them by definition to measure net social costs. Dr. Shimer stated that the answer to this question is obvious – an EV or CV measure - and it does not change with the type of model used. Dr. Wilcoxon pointed out, however, that CGE models provide an approach to calculating social costs that engineering approaches do not, though it is possible to approximate social costs in PE models under some circumstances. Dr. Smith noted that there is an unobservable component to social costs that a CGE model helps to track and make observable (e.g., averting behavior in consumption), though differences between engineering and social costs may vary over time (as in Hazilla and Kopp, 1990) and we need a way to judge the plausibility of social cost estimates from CGE models.

Dr. Fox mentioned that sometimes legislation mandates the reporting of GDP and while he is not suggesting this as a metric of social cost, it would be useful for the Panel to be specific in its response about how a more appropriate metric maps or does not map to GDP. He stated it would be useful to be explicit in the Panel's response about why GDP is not a sufficient measure of social cost. Dr. Balistreri noted that GDP was not a measure of welfare and that it was potentially problematic as, unlike for EV, the modeled change in GDP was dependent upon the choice of numeraire in the model and the numeraire is often not reported. He suggested that one could use a true cost of living index as the numeraire, though it is still not a replacement for an EV measure because of what is left out of GDP [namely, leisure and nonmarket goods]. Dr. Williams

discussed items left out of GDP but that are important in understanding the impact of policies for society, and would be included in appropriate welfare measures.

Cost Question 6: Linking PE Models to CGE models

Dr. Hertel delineated several possible approaches to linking CGE and detailed sector models. He spoke about the “soft link” option for linking a PE model to a CGE model whereby a result from one model is passed to the next model. He characterized this approach as a “one-off” approach that comes with many challenges and probably would not stand up to regulatory scrutiny. A second approach is to incorporate a step function of abatement into the model but the disadvantage of this approach is that it does not capture many of the details of the regulation. A more sophisticated approach is iterative or sequential calibration in which supply functions (through the price response) are incorporated iteratively. He highly recommended this approach to linking models. Finally, he discussed a “full handshake” between the two models in which detailed electricity/engineering data could be used to break out the information in the SAM in the CGE model. He noted that this type of full integration is probably out of reach. Dr. Hertel noted that disaggregating the CGE model to represent specific technologies may make sense in cases where a model is used again and again to analyze the same sector, and mentioned the development of a power sector database by the GTAP project.

Dr. Fox noted that the electricity sector is one place where additional detail would likely add value; he recommended a direct swap out of the sector in the CGE model in this case, noting that while it is expensive computationally it can really affect the results. That said, Dr. Fox stated that the challenges of linking models should not be underestimated because engineering data do not necessarily have the right kind of “hooks” to match up to CGE models (e.g. differences in granularity geographically or temporally). There are also dimensionality challenges when incorporating sectoral detail into a CGE model. Dr. Fox also noted that there are challenges to linking models when either only a small fraction of the sector is broken out in a CGE model (e.g., specific chemicals, cement) or compliance costs are spread across many goods or service sectors (e.g., in the case of the boiler MACT rule). Dr. de la Chesnaye noted challenges related to consistency in assumptions and time periods between PE and CGE models when linking and noted that linking multiple sector models to a CGE model is even more complicated (e.g., transportation and electricity). Dr. Rose said a lot of demand side management needs to be incorporated and household behaviors were important for the power sector.

Dr. Sue Wing noted that given resource constraints, it may be worth considering another class of linkages via emulators in which you derive the GE analogue of the bottom up engineering approach to come up with an aggregate abatement supply function that can then be integrated directly into the CGE model. He noted that it does not need to be univariate: what one is really interested in is the process engineers use to derive compliance costs, not the answers, so you could map inputs to abatement, though abatement itself is not a good. Another complicating factor is the dynamics in the model. If both the electricity model and the CGE model are fully dynamic than it may be difficult to do the linking between them. Dr. Montgomery and Dr. de la Chesnaye noted, however, that both the EPRI and NERA models that link with the energy sector have accomplished this; that convergence issues are manageable. Dr. Montgomery elaborated that the difficulty in linking a dynamic sector model to a dynamic CGE model came in how to

transfer labor, capital, and materials from one model to the other properly; they do not always line up as Rutherford's Mixed Complementarity Problems (MCP) approach only applies to the energy sector. He also noted that if they had more convergence criteria in the model (for example, for capital) then linking the models may be more difficult.

Dr. Montgomery described another challenge of how to handle marginal abatement cost curves with negative costs in them (e.g., MARKAL). He noted that if you construct your own dispatch model, this allows you to be consistent with the CGE model, but if you use other people's models, it can be difficult to match them up appropriately. Dr. Rose also defended the possibility of negative marginal abatement cost curves. Dr. Balistreri questioned the use of some types of bottoms up information in a CGE model. He noted that while we know quite a lot about the power sector, for other sectors there are likely to be inconsistencies between the engineering approach and basic economic assumptions that make it difficult to directly adopt marginal abatement curves in the CGE model (e.g., engineers often make questionable assumptions regarding prices when generating estimates).

Cost Question 7: Other economy-wide approaches

Dr. Shimer cited a Congressional Budget Office (CBO) effort to move from static to dynamic scoring in which economy wide effects of public finance policies are considered, while satisfying the criteria of transparency, reproducibility and forecast ability. He said it was important to think about equilibrium effects that are missing from a static picture of the economy. The CBO approach is to use a Solow growth model and an overlapping generations model to identify what might be missing from the static scoring approach. Based on what they identify, they then do more work on those specific items to understand the likely impacts (as opposed to using the economy-wide models to derive the final answer). In this vein, Dr. Shimer noted that building labor adjustment costs into a dynamic CGE model would likely be a nightmare, so instead it might make sense to draw on other literature related to displacement in different industries to add this effect to estimated PE effects. He is more comfortable with this approach than trying to build it into a full blown CGE model.

Dr. Bui noted that one problem is that there are no models that look over both time and space, which can also be important for transition costs. Dr. Bui then asked how the numbers were going to be used and whether they were being used only to rank different policy options or as quantitative estimates of the policy impact. Would a PE model yield a different ordinal ranking of policy instruments as compared to a CGE model? If that was the central question, then it might not matter which model was used. Dr. McGartland said some legislation requires that benefits justify costs while other legislation prohibits such a consideration in the setting of environmental standards.

Dr. Williams said Question 7 created artificial distinctions between models that do not exist and that it was more useful to think about model features that might be needed (static models, dynamic models, representative agent models, models with uncertainty, etc.). He strongly advised against large-scale macro-econometric models for virtually any purpose other than forecasting because they are remarkably opaque, but also noted the danger of pulling numbers out of the literature and attempting to transfer them to other contexts (e.g., reduced form

empirical estimates without a model attached may or may not be consistent with the CGE model). Dr. Rose presented a slide (posted on the meeting webpage) on alternative modeling approaches. Dr. Rose suggested input-output models should not be used for analysis of environmental policies. He also noted that conjoined input-output macro-econometric models such as the Regional Economic Models Inc. (REMI) have been pieced together over time and are therefore inconsistent between modules. The model would need a full scale upgrade or would need to be built up again from scratch before it could be used to evaluate national policy; it is most widely used at the state and local level. Dr. Smith voiced opposition to the use of REMI for national level analysis of the kind conducted by EPA. Dr. Williams supported Dr. Smith's position that REMI was not appropriate for this context.

Dr. Sue Wing asked whether the objective is to explicitly model the transition process or whether one can credibly capture economic effects with a constant elasticity of substitution (CES) function in a CGE model in a relatively simple way. Another key consideration is whether a model is policy invariant (i.e., stands up to the Lucas critique). Dr. Shimer noted that it is important to get the elasticities right in a CGE model if there are more general effects and that if you find a policy is mostly related to the core of the onion (using the analogy discussed in the response to question #1), then a PE model may be appropriate, perhaps supplemented with borrowing from the literature to account for transition effects. He finds it "crazy" that EPA would have to explicitly identify and model what is causing labor displacement in the economy to answer a question with respect to the effect of a regulation on the labor market. Instead, he recommends a simpler approach informed by the literature or ignoring the effect altogether instead of using an ill-considered approach to try to directly incorporate labor effects into a CGE model. Dr. Williams noted, however, that the explanation for why displacement occurs could be important if they have different model implications. In addition, a panelist mentioned the symposium on unemployment recently sponsored by EPA that covered multiple models and could be useful in formulating the Panel's response.

Before concluding the day, Dr. Wilcoxon said he wanted the Panel to avoid advice to EPA that would have them solve today's problems with tomorrow's models.

October 23, 2015

The Panel reconvened and turned its attention to discussion of the charge questions on benefits.

Benefits Question 1: Conceptual and technical hurdles to representing benefits

Dr. Muller presented the slides posted on the meeting webpage, covering firm response to policy and incorporating the tradeoff between firms' response to policy and the spatial tradeoffs. Dr. Muller showed the spatial dispersion of PM_{2.5} from a coal-fired power plant in Ohio. Such dispersion would imply benefits/ton varying greatly by location. Another slide showed the spatial dispersion from a coal-fired power plant in Louisiana with a very different spatial pattern based on wind patterns. Dr. Muller showed a map of damages from SO₂ pollution spanning two orders of magnitude and a map of damages from PM_{2.5} showing even greater spatial heterogeneity. He also noted that effects are distributed spatially with respect to population density and demographics (e.g., age) and that damages will vary by pollutant and plant

characteristics such as stack height. In addition to the other hurdles to representing benefits, Dr. Muller said that this raises the question of how to couple CGE models with spatially explicit benefits information. Also the spatial aspects of benefits complicates accounting for adaptive responses to policy on the part of firms or households. In addition, since there are potential biases in underlying risk estimates which are not unique to CGE modeling, it is important to have a model that is nimble enough to explore these key sensitivities. Dr. Muller identified coupling a CGE model with a downstream benefits model as one potential solution, but noted that BENMAP alone won't work because you still need the link between emissions and concentrations, i.e. some sort of dispersion or transport model.

Dr. Fisher-Vanden asked about the potential role of sorting models to get at migration issues. Dr. de la Chesnaye said the level of regional disaggregation varies across CGE models but they are all still fairly aggregate, which is a problem when modeling pollutants with specific localized effects in a national analysis. He said that for both PM_{2.5} and mercury, a model broken down to the state level would not be sufficiently detailed to capture effects. This raises a key question of what is missed when linking pollution information to a CGE model and how do you make sure that you don't end up with a misleading result. The answer to this question is going to depend on how you aggregate in the model, Dr. Hertel said. He questioned whether the relevant aggregation unit should be airsheds rather than administrative boundaries. Dr. Rhomberg asked if we should instead be focusing on the spatial implications of related sectors on the benefits side, for example the geographically dispersed effects on the health care sector.

Dr. Smith raised the issue of EPA's estimate of the benefits of the Clean Air Act equaling 17% of wage income and noted that whether one agrees with that exact quantitative estimate, the magnitude is likely large enough to have GE effects. Dr. Sue Wing raised the issue of whether you need to understand the GE effects on the benefits side or whether it is okay to use to separate techniques, one for costs and another for benefits. Because the links on the benefits side are indirect (e.g., through labor supply), we don't necessarily know much about these relationships/effects. Dr. Muller raised the possibility on a one-way link at the intermediate level for capturing benefits in a CGE model. Dr. Shimer was not an advocate of this approach, instead arguing for using different approaches to address costs and benefits. Dr. Smith then questioned this assumption of separability between costs and benefits: when trying to determine whether they are worth including you need to know whether behavior changes the emissions profile, which then may change costs. He also raised the need to assess the relative size of the change in behavior in response to change in air quality to determine when it is big enough to warrant inclusion in the CGE model.

Dr. Sue Wing expressed some optimism that a national model could be disaggregated within the energy sector using non-proprietary data to estimate changes based on the relevant spatial detail in a static setting, but also noted that if benefits are not expected to affect macroeconomic aggregates or there are not many feedbacks, then it doesn't need to be included in the CGE model; it can be calculated separately. If there are feedbacks, then you need to understand whether they vary spatially. If they do not, then you can use an aggregate specification; if they do, then there is a question of how to match up or be faithful to the underlying spatially disaggregated information. Dr. Sue Wing advocated for picking and choosing where you disaggregate in the CGE model and ignoring the rest (keeping it aggregate). Dr. Williams noted

that if benefits affect the time endowment then you may need to link a benefits and CGE model but it is not clear whether disaggregation is warranted given the quality of the data. He disagreed that disaggregate benefits implies you need a disaggregate CGE model. Dr. Montgomery stated that there are things we can learn from including benefits in the CGE model at some level of disaggregation (he noted the GE nature of time endowment effects, incorporating income constraints when attempting to apply WTP measures and effects on the health care sector). While he is sympathetic to the notion that introducing too much disaggregation goes beyond the level of precision available in the CGE model, he thinks one could handle benefits in a relatively simple way by having a good detailed outside model to test the more aggregate CGE model with benefits incorporated into it to see how well it performs. Dr. Montgomery noted that if the time endowment is the main spillover or you are focused mainly on mortality effects, then you do not need spatial disaggregation in the CGE model. If upwind facilities are affecting downwind facilities, then maybe some regional disaggregation is warranted. Dr. Fox agreed that one does not need a highly disaggregated CGE model to capture these effects. Dr. Sue Wing also agreed that if labor supply is sufficiently mobile and effects are mainly through mortality, and production-consumption links are sufficiently low you do not need disaggregation in the CGE model. Dr. Metcalf called attention to the need to capture important spillovers across markets but agreed that if the only impact of air pollution is through mortality, a CGE model would not be needed.

Dr. Paltsev noted that incorporating some level of spatial disaggregation becomes difficult in a dynamic setting where there is a need to determine the spatial location of new or retired facilities in the future. Dr. Williams said if something doesn't affect national aggregates, it would be more appropriate to link a sector model to a CGE model rather than building it into a national model. Dr. Montgomery said he thought spatial disaggregation could be accomplished within a CGE model. Dr. Wilcoxon suggested that if disaggregation satisfies conditions for exact aggregation, then disaggregation would not be necessary at the general equilibrium level. Dr. Williams noted that even if it satisfies the conditions for approximate aggregation then it would not be necessary.

Benefits Question 2: Willingness to pay vs. equivalent variation

On the topic of Willingness to Pay (WTP) for risk reductions versus measure of welfare like equivalent variation (EV), Dr. Carbone said WTP measures benefits of risk reduction while EV yields a measure of social costs, but if relevant benefits are included in a CGE model then it becomes a measure of net welfare change. Dr. Carbone said he favored including more comprehensive measurements of benefits directly in CGE models, e.g. WTP for mortality risk reduction, but that there are choices to be made about how changes in environmental quality affect wellbeing. He noted that it is worth exploring how sensitive CGE results are to the mapping of these different channels. Drs. Carbone and Smith both noted that the incorporation of benefits into CGE models could be calibrated to match willingness to pay estimates. Dr. Fullerton presented the slides (posted on the meeting webpage) that displayed an equation from Harberger's 1964 article showing the change in welfare. Dr. Fullerton pointed to terms in the equation that showed a general equilibrium model would be needed when there are interactions between sectors (non-separability, no cross-price elasticity) or distortions in other markets (e.g. tax wedges). Dr. Fullerton advocated putting all benefits in a CGE model, in at least a separable form at first even if the prior was that they were not, so it could serve as a consistent accounting

framework. Dr. Metcalf noted that CGE estimates of benefits were several orders of magnitude smaller than benefits stemming from WTP studies and that this seems like a big issue to resolve. If benefits are really this large, then there must be spillovers we are not capturing when we assume separability. Dr. Smith advocated for capturing non-separabilities and other benefit categories in CGE models.

Benefits Question 3: Relationship between public health and economic activity

Alex Marten of EPA NCEE was asked to clarify charge question 3 on the relationship between public health and economic activity. Dr. Marten, joined by Dr. Wolverton, said the question was alluding to uncertainties about modeling the linkage between air pollution and health at the individual level. Panelists noted this topic overlapped with question 6 and other questions. Dr. Wilcoxon suggested the Panel wait until it could be clarified by EPA before discussing it further.

Benefits Question 4: Change in household time endowment

Dr. Sue Wing stated that it is appropriate but not sufficient to reflect the changes in mortality and morbidity in the time endowment. If there is non-separability, he said, then in addition to the time endowment effect you need to account for changes in what is consumed (e.g. averting behavioral changes and health service demand changes). Drs. Balistreri and Williams agreed that changes in mortality and morbidity should be incorporated as changes in the household time endowment but that other impacts needed to be modeled as well. After offering praise for the EPA white papers, Dr. Paltsev said using the wage profile to value time leaves open the question of how to value the time of children and elderly. Dr. Paltsev also advocated capturing changes in productivity and visibility. Dr. Rhomberg pointed to inter-individual variability in baselines health and health responses to air pollution. He also pointed out that pollutant concentrations, rather than emissions per se, are important for health, and that modeling concentrations would thus be important. Dr. Rhomberg described multiple points of uncertainty in estimating health effects going from emissions to health impacts, especially in dose-response functions, which may be biased due to imprecision in estimates. Dr. Williams noted that in a static model one is probably limited to evaluating the change in the time endowment but in a dynamic model there may be other effects on retirement, savings and discount rates – though he stated that this is an area for future research. Dr. Balistreri disagreed with only modeling the effects on the working population as the willingness to pay measure includes other members of the household. A panelist also expressed concern about the large gap between WTP and human capital estimates of benefits.

Benefits Question 5: Representations of mortality and morbidity impacts

Dr. Montgomery presented a tree diagram in the slides posted on the meeting webpage to describe the elements of a utility function in a CGE model based on labor supply. Consistent with comments from Drs. Sue Wing and Smith, he expressed skepticism about the magnitude of the labor/leisure effect as a reasonable estimate of benefits (it is likely overstated due to changes in responses to improved health). He expressed skepticism that WTP studies were consistent with the conditions for revealed preference such as: (1) WTP must be increasing in the supply of non-use or non-market goods; (2) marginal WTP is decreasing (quasi-concavity); and (3) total

WTP must be bounded by income. Dr. Smith addressed the question of whether there was sufficient research to incorporate other representations of mortality and morbidity impacts and pointed to hedonic property value studies on the relationships between housing prices and air pollution, though he noted that these studies are not sufficiently pollution specific and not at a national scale nor can they be separated from other explanations apart from regulatory changes. He said he did not think the other approaches could be substituted for the damage function approach but could offer supporting evidence and still be fit into the framework suggested by Dr. Montgomery. Dr. Smith noted that going beyond what EPA currently does requires making assumptions about substitutabilities and complementarities for which we have very little empirical evidence, so then the question becomes how sensitive are the results to their inclusion.

After praising the EPA white papers, Mr. Revesz said he was skeptical of some alternative to WTP to value premature mortality. He noted that EPA's reliance on new tools that have not been sufficiently researched or established in the literature could possibly be subject to legal challenges after rulemakings and encouraged the panelists to distinguish between research and what can be done in a regulatory impact analysis. Dr. Shimer noted that many effects seem very hard to quantify but one seems relatively easy to add, i.e. people not working due to morbidity effects. He also said that estimates of reduced income and reduced tax revenues could be derived from estimates of mortality and morbidity. Dr. Smith noted that Dr. Shimer's suggestion of using CBO's approach to dynamic scoring could be a useful experiment in this context as a way of getting feedback but should not be viewed as a substitute for what EPA already does. Dr. Belzer noted that most of the substances regulated by EPA were substances for which safety assessments rather than risk assessments were done, thus rendering it very difficult to measure benefits. Dr. Williams said the Panel should be focusing on spillover effects of benefits, as opposed to estimating benefits, since the Panel's job was to focus on economy-wide effects. Dr. Smith suggested the Panel think about finding a "moment" associated with a virtual price of environmental quality--whether it comes from a human capital approach or a WTP approach or a hedonic property approach—and that the virtual price multiplied by the quantity of environmental quality should equal virtual expenditure on environmental quality. He said any of these prices could represent the appropriate marginal rate of substitution. He noted that the literature on price index construction is relevant in this context when trying to represent tradeoffs in a CGE model.

Benefits Question 6: Incorporating employment shifts in a CGE model

Dr. Williams said that employment effects of environmental regulations on health and crime rates would be both difficult to estimate and not very important at an economy-wide level. He suggested that linking environmental policy to employment to health/crime to social welfare was beyond current abilities and empirical evidence. He said existing general equilibrium models estimate the effect of environmental regulations on unemployment. Some models measure the effect on hours worked, but this was different from estimating effects on unemployment. Dr. Bui agreed the linkages from unemployment to health and crime were very tenuous. She noted that a line needs to be drawn regarding what benefits to include or not include and that this seems like a category that can be credibly excluded. She also noted that changes in eligibility for quality health care may be a better way to try to characterize secondary effects than through unemployment, but even here the literature is fairly sparse. Dr. Shimer said the effects are too far

down the line to be very large (e.g. knock-on effects about the ability of displaced workers to buy medications) and that causality would be very difficult, if not impossible, to show. He noted that there is a large literature on the health-wealth tradeoff but that causal links are not well established. He noted that this does not seem like a good place for EPA to invest its resources; that it would be better to leave this effect out. Dr. Smith agreed that this should be kept out of the benefit-cost analysis for now. Dr. Belzer said he thought this question suggested EPA had unlimited resources. Dr. Wilcoxon said he was surprised this question was filed under the Benefits section rather than the Cost section, but Dr. Fullerton clarified that the question was really alluding to a potential negative effect on benefits. Dr. Shimer agreed that based on the white paper discussion, it is clear that it is a benefits question, though he noted that the cost side with respect to unemployment is also important to consider.

Clarification on Question 3

After lunch, Dr. Marten took the opportunity to clarify question 3. He said it referred to the conceptual and technical challenges in constructing a relationship between public health and the economy and how uncertainty might influence choices in constructing that relationship within a modeling framework.

Dr. Leamer's Comments

On the phone, Dr. Leamer said he submitted written comments on the reliability issues with CGE models. He said there was a big gap between the treatment of uncertainty in econometrics versus the treatment of uncertainty in CGE modeling. Dr. Leamer noted that there are systematic non-linearities and interactions built into CGE models that differentiate them from an econometric approach but questioned the reliability of the data for adequately capturing these non-linearities (e.g. diffusing data over too many parameters might yield standard errors that are too big; sensitivity to functional form). He suggested that analysts begin with a list of items for which there are feedback (endogeneity) effects. He said leisure activities will vary greatly with air quality as well as location. He expressed skepticism that air quality was having an effect on wage rates. He expressed great skepticism with using consumer surveys to estimate WTP for air quality improvements, including hypothetical bias and the failure to capture the distinction between private goods and public goods.

*Benefits Question 8: Incorporating productivity gains**

On the subject of incorporating productivity gains, Dr. Williams said the hard part was calibrating the changes given that most empirical estimates were focused on a particular pollutant's effects of specific workers in a particular industry. Going from effects on migrant workers to a general equilibrium framework was difficult and therefore not recommended at this time. Dr. Bui and Dr. Shimer echoed Dr. Williams' point, noting that we would need to know more before we could include them in a CGE model. Dr. Shimer noted that the hard issues are not the economy-wide modeling but the underlying estimates with respect to the effects themselves (i.e., the productivity gains). Dr. Williams disagreed to some extent, noting that this

* Note to the Reader: To accommodate a panelist's travel schedule, the Panel took up question 8 before taking up question 7.

effect could be a potentially big deal and thus it may be worth investigating to get an approximately right answer. However, he acknowledged that it is hard to generalize from the specific instances where it has been estimated. Dr. Montgomery noted that he is suspicious of attempts to identify how environmental quality changes labor productivity because it is hard enough to do so in response to much larger macroeconomic effects. Dr. Leamer agreed that it is pretty difficult to pick up on the long run effects of environmental quality over time on labor productivity except in the extreme cases where it has already been studied. However, he agreed that it was a potentially important effect. Dr. Smith agreed that the Panel should not advocate for its inclusion in benefit-cost analysis or a CGE model now but access to data could move the research a few steps forward and therefore they might recommend it as an area that merits more research.

Benefits Question 7: Changes in consumer preferences

Dr. Belzer presented the slides posted on the meeting webpage focusing on income effects from reduced medical expenditures. Dr. Belzer covered price signal issues, the dominance of 3rd-party payment regimes, distinguishing income effects from noise, the confounding of price signals by secular changes in technology, delivery systems and expectations. Dr. Montgomery said he interpreted the question differently, as referring to a changing marginal rate of substitution when health status changes which was a property of the utility function. He noted that this may be important at the individual level but is not sure it matters at an aggregate level, though he noted one could calculate the income shares to get a sense of how important it might be. Dr. Smith referred to studies showing people spend less time outside during period of high air pollution, but noted that these are not the types of studies you would include in a CGE model. Dr. Smith stated that the Panel should support the notion of encouraging more research in this area but there is not enough evidence now to incorporate it into a CGE model. Dr. Balistreri said the Panel needed to be clear that “changes in preferences” was not necessarily equivalent to changes in choices or changes in marginal rates of substitution. Dr. Williams noted that short run changes are relatively easy to identify but they are not necessarily indicative of the long run relationship (for instance, in the short run you could just be shifting activity form one day to the next). He continued that medical care is a highly distorted sector (why it has a weak price signal) so it could be potentially important to characterize; leisure is also an activity expected to change with changes in environmental quality and also has large distortions, but not clear there is enough good information available to be able to pin these effects down. Dr. Fisher-Vanden wondered if the question included averting expenditures. Dr. Marten of EPA clarified that the question refers broadly to reduction in demand for health care expenditures that might be associated with health improvements as well as the potential for changes in the marginal utility of consumption for particular goods being contingent on health status. Dr. Marten said the question referred to state-dependent utility functions and Dr. Wilcoxon clarified that health status would be an argument in the utility function.

Benefits Question 9: Impacts on non-market resources

Dr. Smith offered a resounding endorsement of incorporating impacts on non-market resources in economy-wide modeling. He said if changes in non-use benefits were additively separable with no behavioral trail, then they don't need to be in CGE models but if non-use values were

really deep in preferences trees, then there was a real challenge in identifying these relationships. Dr. Leamer asked the Panel to distinguish between non-market and non-use benefits. Dr. Montgomery noted that unless contingent valuation could distinguish between WTP for 5 wilderness areas versus 4 wilderness areas, then it would not be possible to squeeze such preferences in the utility function because it would violate the restrictions on preferences discussed earlier. Dr. Montgomery stated he agreed with Dr. Smith but thinks an effect should only be included in a CGE model if a WTP has been expressed for it. Panelists debated the merits of contingent valuation with Dr. Williams asserting that non-use values would be a separable term in the utility function by definition. Objecting to the notion that incorporating non-use benefits implied non-separability, Dr. Fullerton again advocated the use of a CGE model as an organizing framework that incorporated all costs and benefits in a consistent way, even if some are modeled separately, because the GE framework has an overall resource constraint, which has the advantage of adding all the effects up subject to a consistent budget constraint, which is needed to calculate EV. Dr. Williams pointed out that *feedbacks* from non-market resources are not typically incorporated; these are difficult to include.

Benefits Question 10: Interpreting CGE results when only some benefits can be modeled

Dr. Montgomery said that the insights from a CGE model are no different from any other modeling approach except that a CGE model affords “adding up” and integration of various economic phenomena. He also noted that you can include things in a CGE model even when you cannot value their benefits. He further suggested that net benefits from CGE models could be treated as a conservative estimate. In the case where you can only partially include benefits, Dr. Montgomery noted the importance of avoiding confusion by being specific about what we cannot include and then identifying what we can say about those excluded effects, short of valuation. Dr. Smith added that CGE models had the potential to bound estimates and allow us to think about the plausibility of non-use benefit estimates for which we have no other source of information. Dr. Carbone added that CGE models can provide a check on other methods we have for quantifying these effects.

Benefits Question 11: Spatial distribution of environmental benefits

In addressing the question of whether the spatial distribution of benefits should be modeled in CGE models, Dr. Hertel referred to a global river basin model designed to analyze water scarcity and wondered whether river basins needed to be broken out into grid cells. For questions about sub-national impacts, spatial heterogeneity is needed but for questions about aggregate welfare impacts, spatial heterogeneity might not be needed. He noted that cross-price elasticities in the power sector influenced the whole economy and thus were important for aggregate measures. Dr. Hertel said comparing the PE demand elasticity to the GE demand elasticity and if the difference was under, say, 10%, then PE modeling might be sufficient for that sector. Dr. Hertel said EPA might take a CGE model and perform a similar analysis to compare PE results to CGE results, comparing welfare results from a unified airshed to a disaggregated airshed. Dr. de la Chesnaye expressed interest in developing a rule of thumb that would allow EPA to choose whether to use a PE model or a CGE model. Dr. Fullerton noted that non-linear damages would affect aggregate damages and hence required spatial modeling. Dr. Williams said comparing PE demand elasticity with GE demand elasticity was not a sufficient rule of thumb but that other

metrics might be developed to determine when welfare effects in other markets were important. He noted that a threshold is going to mean something different for a quantity measure than a welfare measure because of distortions. Dr. Hertel responded that with a case where there are almost no interactions, then PE is good enough, but agreed it is unclear where the threshold should be (as opposed to his earlier suggestion of 10%). Dr. Metcalfe noted that there are cases where spatial disaggregation will matter more or less, so guidance from the Panel on when it may matter seems useful. Dr. Balistreri noted that while there is value in using spatial information to shock the CGE model, regions in a CGE model are often created by sharing out the national data, which would obscure some of the spatial heterogeneity. Dr. Smith said he could think of a number of CGE model runs that would shed light on this question and Dr. Wilcoxon said such a request could be transmitted to EPA through Dr. Stallworth.

Finally, Dr. Wilcoxon covered a draft schedule of deadlines and meetings that included a December 1, 2015 deadline for panelists to provide draft responses to charge questions, following by scheduling two teleconferences and a face-to-face meeting in the winter and spring of 2016.

Dr. Wilcoxon thanked the Panel for their time and Dr. Stallworth adjourned the meeting.

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.