Annotated Outlines and Reference Lists for Planned White Papers and Memos to Inform EPA Science Advisory Board Panel on Economy-Wide Modeling of the Benefits and Costs of Air Regulations

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U.S. EPA, Office of Policy and Office of Air and Radiation

Annotated Outlines and Citations for:

White Papers on

Memos on

Annotated Outline for White Paper on Using CGE Models to Estimate the Social Cost of an Air Regulation

I. Introduction

Model choice and the appropriateness of using an economy-wide approach to evaluate the economic effects of an air regulation are dependent on many factors. CGE models are of particular interest for applied welfare analysis of the economy-wide effects of an air regulation due to their strong foundation in micro-economic theory. This white paper will document the steps involved, key assumptions, and technical challenges that may arise when estimating social costs of an air regulation in a CGE model. As part of this exercise, the paper also will examine the sensitivity of social cost estimates to the treatment of issues identified in the charge (e.g., a small or sector specific rule).

II. Overview of Social Cost Framework in a Regulatory Setting

The paper begins by describing the BCA framework used to estimate costs of an air regulation, what is meant by social costs (vs. compliance costs), how social costs are typically analyzed at EPA, and characteristics used to evaluate the application of different modeling approaches for the analysis of air regulations, including when PE vs. GE models are recommended for use in the current version of EPA's Guidelines for Preparing Economic Analyses.

III. Overview of Air Regulations

This section briefly describes the range and heterogeneity of air regulations encountered at EPA to identify the set of issues relevant to the questions: what modeling tools may be best suited to estimate social costs? Since regulations are complex, what particular nuances matter when modeling the GE effects of regulation? In particular, this section discusses four basic categories of regulations and gives particular examples to illustrate differences in:

- Form of the standard: Is the regulation an emission rate or technology standard? Are limits applied at the sub-facility or facility level? Is trading/crediting allowed either within or across firms? Is the rule vintage based or differentiated along other attributes (e.g., plants, units, location)?
- Methods of compliance: Are the methods of compliance clearly identified? Is it expected that the methods of compliance will vary across units, firms, sectors, locations, etc.?
- Regulated sources: Is the regulated universe readily identified? In which sector(s) are the directly affected sources? How easy is it to map regulated sources to sectors?
- Unit compliance cost estimates: Are estimates of unit compliance costs available? Is the decomposition of compliance costs by input (e.g., capital, labor, intermediate inputs) available? Are some components of costs more uncertain or not available? Are some methods of compliance

expected to result in changes within a sector that are difficult to capture in a general equilibrium framework?

- Aggregate Compliance Costs: What is the expected magnitude of aggregate compliance costs? How does it compare to the size of the regulated sector?
- Implementation: Is implementation defined directly in the regulation or are key aspects left to the states or other government entities?
- Timeframe for compliance: What is the time period over which compliance occurs? What is assumed about technological innovation?

IV. Process of Representing an Air Regulation in a CGE Model

This section discusses the main challenges that analysts may encounter when attempting to represent an air regulation in a CGE model for the four categories of rules discussed in the previous section. For example, are certain representations simpler/more difficult in these contexts (e.g., there is more/less information available related to certain aspects of compliance costs or the affected universe, information maps more/less cleanly to the production function to particular industry sectors)? It is likely that there are instances where detailed information on who is affected and how they comply may not map well to a more aggregate representation in a CGE model.

V. Sensitivity of Social Costs to Air Regulation Attributes

Identifying appropriate modeling tools for conducting an analysis of social cost depends on the air regulation's details, as highlighted in the previous two sections of the paper, as well as data requirements, model availability, and constraints on time and budget. EPA's Guidelines for Preparing Economic Analyses also identify several technical factors to consider in model selection, including: "the types of costs being investigated, the geographic and sectoral scope of the likely impacts, and the expected magnitude of the impacts" (EPA 2010a).

This section considers the sensitivity of social costs estimation in a CGE framework to a number of key characteristics associated with the structure of air regulations. In particular, each factor is discussed with regard to how it may affect the technical merits of using a CGE model for estimating the social costs of a regulation. The intention of this section is not to ask panelists to review/critique past modeling approaches used by EPA or outside groups, but rather to set the stage for a broader discussion of these issues as laid out in the charge. The specific factors are:

- Magnitude of expected compliance costs.
- Time horizon for implementation.
- How compliance costs are entered into a CGE model, and
- Number and types of sector(s) directly and/or indirectly affected, and magnitude of potential market effects.

Since air regulations are complex and vary widely in their attributes, it is likely that the modeling tools deemed most appropriate for social cost estimation will be regulation-specific. For some regulations, an engineering or partial equilibrium approach may be adequate to capture expected social costs. For other regulations, compliance costs or partial equilibrium welfare measures may be inadequate estimates of overall social costs. In these cases, a general equilibrium approach may add value over an engineering or partial equilibrium approach.

Evidence of the particular sensitivity of social cost estimation to these factors has been gathered from the existing literature, though a few papers look specifically at the effects of regulation; EPA's experience using CGE models to analyze regulations; and, at times, results from a limited set of illustrative runs using the EMPAX static CGE model.

VI. Sensitivity of Social Cost to Model Structure

This section considers the sensitivity of social cost estimation in a CGE framework to a number of key issues associated with the structure of CGE models. Each factor is evaluated with regard to how it may affect the technical merits of using a CGE model for estimating the social cost of a regulation. The specific factors examined are:

- Degree of foresight (e.g., when is it appropriate to use a recursive dynamic model or an intertemporally optimizing model? If only one type is available, to what degree can alternative foresight assumptions be approximated?);
- Static versus dynamic model structure;
- The rules used to close a model (i.e., government revenue-expenditure, savings-investment, current account);
- How international trade is represented (e.g. when is a detailed representation of the rest of the world important for estimates of social costs?);
- Technological change;
- Whether adjustment costs are incorporated into the model for some input markets (e.g., technological constraints or worker training);
- Considerations relevant to the availability and cost of an economy-wide model versus alternative modeling approaches (i.e., to inform analytic choices that weigh the value of information obtained against analytic expenditures when resources are constrained); and
- Ability to incorporate and appropriately characterize uncertainty in key parameters and inputs (e.g., engineering costs).

Evidence on the sensitivity of social cost estimates to these factors is gathered mainly from the existing literature. Given that most of the relevant literature in this area is not specific to the analysis of environmental regulation due to the dearth of papers focusing on that topic in a CGE context, this section draws from a broader array of CGE modeling experience (e.g. in international trade settings).

VII. Characterizing Social Cost and Overview of Key Attributes of CGE Models

This section discusses and compares the types of outputs that are sometimes used to characterize economy-wide costs (e.g., equivalent valuation, household consumption, GDP, etc.) and their potential advantages or limitations with respect to characterizing changes in economic welfare. The treatment of employment impacts in a benefit cost analysis is a matter of ongoing debate. We opt to address a regulation's effects on employment in the economic impacts white paper. This section will also briefly describe the main characteristics of widely-applied CGE models of the U.S. as they pertain to the estimation of social costs.

VIII. Linking CGE and Detailed Sector Models

A partial equilibrium sector model may capture many compliance details that matter for accurately estimating the method and associated cost of compliance with an air regulation. CGE models are, by design, more aggregate representations of the economy that generally do not include these details. Various methods of linking models have been proposed and to some extent can be found in the existing literature. "Soft linking" refers to passing outputs from one separate model to another and may or may not include a two-way exchange. "Hard linking" refers to two models that are run together and actively pass outputs back and forth with the goal of consistency between the solutions of both models. In reality, true hard linking may be difficult between models that differ greatly in structure and dimensionality. For this reason, some modelers have moved toward a hybrid approach that includes elements of both. Two applications of linked models of particular interest to EPA that are discussed in this section are energy-CGE and transportation-CGE models. Finally, this section discusses the applicability and challenges of linking models in the context of the regulatory process at EPA.

IX. Concluding Remarks

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Annotated Outline for White Paper on Integrating Benefits into CGE Models

I. Introduction

This paper presents a basic introduction to the benefits associated with air quality regulations, discusses previous work that has attempted to incorporate some types of benefits into CGE models, describes benefits that result from pollution mitigation that have not yet been included in most CGE models, and briefly considers the potential for including additional types of benefits in future CGE modeling studies. The paper also discusses relevant topics related to spatial issues associated with benefits that may affect their incorporation into CGE modeling and potential interpretation of the results.

II. Air Quality Benefits

This section provides a basic overview of the traditional methods used to calculate the benefits of improvements in air quality for regulatory analyses. It begins by summarizing the general categories of benefits associated with improving air quality, including effects that are typically quantified by EPA and those that are not, but potentially could be quantified if improved data and methods were available. Human health benefits have traditionally been more easily quantified and monetized due to the availability of concentration-response functions relating health outcomes to ambient pollution concentrations and estimates of the monetized value for marginal changes in health outcomes. This section describes the approaches traditionally used by EPA to monetize these and other types of health and non-health benefits. This includes a description of the “damage-function” or “effect-by-effect” approach typically used by EPA to estimate total benefits of modeled changes in air quality. This section ends with an illustrative example of the presentation of results, including the characterization of uncertainties.

III. Incorporating Direct Air Quality Benefits in CGE Models

This section provides an overview of how some categories of benefits from air quality improvements have been incorporated into CGE models and other relevant topics in the literature associated with modeling benefits in a CGE context. This includes previous studies conducted by the EPA and outside researchers as well as studies that have looked at both human health related benefits and other categories of benefits. The discussion begins with a brief review of how some limited health benefits were included in the CGE analysis for the EPA’s Second Prospective Study of the Clean Air Act Amendments (CAAA) and the importance of including those benefits for assessing the economic impact of CAAA. In addition, this section also discusses several limitations associated with incorporating beneficial impacts of the CAAA into a CGE framework.

This section also reviews academic studies have modeled direct health impacts and non-health environmental feedbacks of air pollution in CGE models. While the number of applications that have attempted to incorporate environmental quality in a CGE model beyond a separable component of the utility function is small, there are some studies that have attempted to improve the representation of benefits in applied settings and this section briefly reviews the specific approaches adopted. This section ends with a discussion of academic literature on the role of interactions between pre-existing market distortions and the benefits of improved environmental quality that may be captured in a general equilibrium framework.

IV. Moving Forward with Incorporating Benefits in CGE Models

The previous studies reviewed in Section 3 highlighted the potential economy-wide effects of beneficial impacts associated with air quality improvements and made strides in developing new tools for this purpose. This section builds off of that review and considers potential benefits categories yet to be fully captured, if at all, in previous CGE analyses of air quality improvements. The discussions includes a basic review of the methods and the relevant papers that lay out different approaches for capturing such impacts along with a brief discussion of the potential merits and challenges of incorporating those approaches into a CGE model. These topics include options for valuing mortality risk reductions and health risks to children, state-dependent utility functions, labor and agricultural productivity effects, and material damages from atmospheric and deposition effects.

V. Spatial Challenges in Benefits Assessment

The heterogeneous impact of air quality improvements across space presents unique challenges for assessing the benefits of environmental policy in general, and potentially the use and/or interpretation of CGE-based benefits assessments in particular. This section focuses on the degree of spatial heterogeneity in the benefits of air quality improvements relative to the spatial resolution of typical CGE models, and the potential first order welfare effects associated with resorting in housing markets in response to exogenous changes in the provision of public goods such as air quality.

VI. Concluding Remarks

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Annotated Outline for White Paper on Using CGE Models to Evaluate Economic Impacts of Air Regulations

I. Introduction

This paper serves two purposes. The first half of the paper describes the types of economic impacts from air regulations that are typically of interest to policymakers and examples of the ways in which CGE models have - or have not - been used by EPA to evaluate them. It also describes the main economy-wide approaches used by outside organizations to analyze EPA air regulations (e.g., input-output approaches, CGE), with a particular emphasis on labor market impacts, and similarities and differences in the metrics used to present this information.

The second half of the paper reviews the academic literature with regard to key features and current practices in U.S. CGE models for evaluating impacts of a policy shock on labor and capital markets, sectors, energy prices, and income distribution. When available, the paper also discusses what features or attributes – which may not be present in any model - may offer potential for analyzing these economic impacts for an air regulation going forward. Also considered are the technical merits and challenges of using economy-wide modeling approaches such as macro-econometric and dynamic stochastic general equilibrium models for analyzing labor market impacts in the short run or to evaluate market responses when the labor market is not at full employment.

II. Analysis of EPA Regulations and Policy

Context

This section defines economic impacts as distinct from social cost, briefly describes the main types of economic impacts that are typically discussed by EPA when analyzing the expected effects of a proposed regulation, and summarizes guidance on how to evaluate economic impacts, from the EPA's Guidelines for Preparing Economic Analyses, particularly as it pertains to the possible role of CGE models.

Summary of EPA evaluation of economic impacts

As a starting point, this section describes current practice at EPA when analyzing economic impacts for air quality regulations. It then discusses examples of how EPA has evaluated the economic impacts in the charge (i.e., energy prices, sectoral impacts, transition costs in capital or labor markets, equilibrium impacts on labor productivity, supply or demand, and income distribution) for recent air regulations. After describing the few examples where CGE models have been used to analyze economic impacts of regulations, the section briefly describes other non-general equilibrium approaches utilized, noting when quantification of certain types of economic impacts is not possible.

Economy-wide approaches to analyzing economic impacts of EPA air regulations by outside organizations

This section briefly describes CGE analyses conducted by outside groups of the economic impacts of EPA regulations and, to the extent possible, identifies key questions that arise, the potential merit of applying these approaches to future EPA analyses, and potential limitations of these modeling approaches. The focus is on use/applicability of these economy-wide approaches, not on differing assumptions about the regulation itself. This section also describes the metrics used to report labor market impacts by EPA and outside analyses.

III. Economy-Wide Approaches to Estimating Economic Impacts in the Literature

Labor markets in CGE models

Given interest in understanding labor market effects related to long-run structural and shorter run transitional unemployment, this section reviews the literature to assess whether CGE models offer additional insight over other modeling approaches, and, if not, whether alternative economy-wide approaches may offer potential for use in regulatory analysis. The overall effects of environmental regulation on employment are difficult to disentangle from other economic changes and business decisions that affect employment. Moreover, labor markets respond to air regulations in complex ways. Net employment impacts are composed of a mix of potential declines and gains in different areas of the economy (i.e. the directly regulated sector, upstream and downstream sectors, and pollution abatement sector) and over time. In light of these difficulties, this section begins with a theoretic framework for characterizing labor market effects of air regulations.

This section then describes the standard specification of the labor market in CGE models, including labor supply elasticity assumptions. CGE models generally assume labor supply is fixed, and a uniform, flexible, market-clearing wage balances labor supply and demand. Workers may move from one sector to another following a policy shock, but the economy remains at full employment. The models typically do not distinguish transition dynamics from one equilibrium to another. This section next examines the literature on alternative specifications for the demand and supply of labor in CGE models. It is not EPA's intention that the panel review these applications - to our knowledge none are used to examine labor market implications of air quality regulations - but rather set the stage for a broader discussion regarding approaches in the literature to-date. Finally, this section reviews other economy-wide modeling approaches (e.g., input-output, macro-econometric, dynamic stochastic general equilibrium models) to evaluate their technical merits and challenges for estimating labor market effects in the short run or when the economy is at less than full employment.

Capital markets

This section discusses the treatment of capital in CGE models with separate discussions of long run equilibrium effects, and ability- or inability – of CGE models to identify short run impacts on capital. The treatment of capital markets in CGE models plays a central role in capturing the behavioral response of markets to regulation and the economic impacts that are implied by them. Many factors affect the formation and evolution of capital in CGE models in response to regulation. This section examines these factors through the treatment of capital in three areas: the degree of foresight, capital vintaging, and short-run adjustment costs.

Sectoral impacts

This section discusses a key model feature that may determine the ability of a model to capture the effects of an environmental regulation on economic activity: the degree of sectoral aggregation. Many economy-wide models are highly aggregated and the regulated sector or sectors may not appear separately. In addition, highly aggregated models may not include separate sectors for secondary market impacts of interest. This section also describes how alternative model structures aside from perfect competition and constant returns to scale could affect sectoral impacts. The section ends with a discussion of possible solutions to address data limitations or lack of sectoral disaggregation in CGE models when conducting sectoral analysis.

Impacts of energy prices

Some economy-wide effects of regulatory actions are manifested through changes in energy prices, which can be captured to varying degrees in a CGE framework. This section discusses how an air regulation might be expected to manifest as a change in energy prices, how CGE models typically characterize energy markets, recent methodological work on representing fossil fuel supply in economy-wide models, and the ability of CGE models to capture short versus long run impacts on energy prices.

Income distribution

Questions of how the costs and benefits of U.S. environmental policy are distributed across households have been explored in the economics literature since the 1970s. The use of CGE models to analyze distributional consequences is more recent and mainly concentrate on analyzing the effects of market-based instruments such as environmental taxes or cap-and-trade policies; they also almost exclusively focus on the distribution of costs. (This is not surprising given that most CGE models do not incorporate societal benefits.)

The ability to drill down – particularly with respect to how different types of households are affected by a given policy – is limited in many CGE models of the U.S. economy due to the assumption of a representative household. Some CGE models include more detailed representations of the household sector, though the degree of disaggregation varies by model. This section discusses two main approaches used to evaluate the distributional consequences of environmental policies in the academic literature: linking the results of a CGE model to a separate household incidence model, and using a CGE model that explicitly integrates the behavior of different types of households into the model itself.

IV. Concluding Remarks

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Annotated Outline for White Paper on Uncertainty and Economy-Wide Modeling

I. Introduction

This white paper provides a general discussion about the types of uncertainties that analysts may be concerned with when estimating the costs, benefits, or economic impacts of air regulations, particularly when a CGE model is used to examine economy-wide effects. The paper also discusses different approaches for analyzing the impact of uncertainty on modeling results, and approaches for verifying and validating modeling results.

II. Sensitivity and Uncertainty Analysis

Uncertainty in model structure, calibration, and representation of air regulations and compliance may motivate additional analysis to study the robustness of results. This section of the paper presents different approaches that have been used in the economics literature to study the results of CGE modeling under uncertainty. The discussion will also consider the resource requirements for the various approaches in the context of a typical regulatory analysis.

Comparative Statics

This section discusses the most basic method of considering the responsiveness of relevant state variables to changes in key input parameters. The discussion focuses on the common types of variables/parameters that studies using CGE models have considered worthy of examining in such sensitivity analyses.

Probabilistic Analysis

This section introduces more formal approaches to including uncertainty in sensitivity analysis. Specifically, it discusses approaches used in the literature to develop probability distributions for key input parameters or stochastic paths for exogenous variables and then integrate over those distributions. This includes a discussion of the use of Gaussian Quadrature approaches to integrate over uncertain parameters to obtain estimates of the moments for key outputs. It also considers Monte Carlo simulations designed to develop distributions of CGE model outputs given specific input distributions.

Inter-Model Comparisons

This section discusses the use of inter-model comparisons as an approach to assessing the effect of more structural model uncertainty. This section will also include a presentation of the relevant limitations that have been discussed in the literature, such as over-sampling of the peak.

III. Validation Exercises

This section describes various procedures that have been proposed for CGE model validation exercises that could increase the credibility of modeling results. It covers topics including statistical validation, historical simulation, and baseline back-testing. The section considers both short-term exercises that may be considered in the context of preparing a regulatory impact analysis and longer-term exercises associated with on-going model development.

IV. Uncertainty in Benefits Estimates

This section briefly discusses the uncertainty associated with the estimates of benefits traditionally assessed in regulatory analyses of air regulations and based on the epidemiological literature and discusses the implications of such uncertainties for their potential inclusion in a CGE modeling framework.

V. Concluding Remarks

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Annotated Outline for Memo on Using Other (Non-CGE) Economy-Wide Models to Estimate Social Cost of Air Regulations

I. Introduction

This memo reviews information available on the potential use of other types of economy-wide models, aside from computable general equilibrium models, to estimate the social cost of air regulations. It is a companion to the white paper on estimating social cost in a standard CGE framework or using a model that links CGE and sector models. The main focus of this memo is macroeconomic models, of which there are two common types: large scale macro-econometric forecasting models and models that focus on macroeconomic aggregate variables but have micro-foundations (e.g., dynamic stochastic general equilibrium models). Other economy-wide approaches such as input-output approaches and vector autoregressive approaches are discussed briefly in the last section of the memo. Technical merits and challenges of using these types of models to evaluate economic impacts of air regulations are discussed in the economic impacts white paper.

II. Use of Macroeconomic Models to Evaluate Regulatory Policy

This section discusses guidance on when and in what capacity macroeconomic models are used by U.S. Federal agencies. For instance, the Office of Management and Budget, in guidance for evaluating effects of regulations on State, local, and tribal governments, notes that macroeconomic effects tend to show up in national level macro-econometric models only when their economic impact reaches 0.25 percent to 0.5 percent of Gross Domestic Product. The guidance also notes that a regulation with a smaller aggregate effect is "highly unlikely to have any measurable impact in macro-economic terms unless it is highly focused on a particular geographic region or economic sector."

After comparing the costs of air regulations to this threshold to characterize the types of rules for which effects could be discernible in a macroeconomic model, this section briefly describes the use of macroeconomic models by other agencies to produce forecasts and to evaluate the effects of Federal policies and regulations, with a particular emphasis on social cost estimation.

III. What Macroeconomic Models Measure

This section briefly describes two main classes of macro-economic models and their main advantages and limitations in comparison to CGE models for estimating social cost of regulation, including the degree to which these models measure changes in consumer and producer surplus (or changes in economic welfare) in response to a policy shock.

IV. Other Types of Economy-Wide Models

This section briefly discusses economy-wide approaches such as input-output and vector autoregressive methods and the degree to which they may or may not be appropriate for estimating social cost.

V. Concluding Remarks

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Annotated Outline of Memo on Using CGE Models in the Literature to Evaluate Competitiveness Impacts

I. Introduction

Conceptually, it is possible that domestic air regulations can have global economic implications due to their effects on relative prices of inputs and/or goods and services produced domestically relative to those produced abroad (absent corresponding regulations in other countries that are major U.S. trading partners). Quantifying competitiveness requires the use of economic models that assess the various components of supply and demand responses, for example, to an increase in factor prices. This memo highlights some of the distinctive features of CGE models for competitiveness analyses.

II. Model Requirements

The empirical questions at the heart of the competitiveness issue require modeling tools with particular attributes, which may differ from the typical CGE model used for analysis of the domestic effects of air regulations. For instance, quantifying competitiveness requires the use of an economy-wide model that can identify both the domestic demand and import responses. To understand which industries in which countries may benefit from a change in regulatory requirements relative to their own, detailed regional representation is needed. To understand which particular domestic industries may be negatively affected on net, a high level of detailed sector disaggregation also is required. This section draws upon recent literature to summarize model requirements needed for an adequate representation of sectors and international regions for competitiveness analysis.

III. Model Limitations

This section highlights some of the main limitations of the class of CGE models used for competitiveness analysis including restrictive assumptions about the behavior of agents, ability to represent environmental policy in the model, and an Armington specification of trade, which limits the range of potential competitiveness impacts by imposing a particular structure on trade.

IV. Select Studies

This section discusses findings from a 2009 interagency report evaluating the competitiveness impacts of proposed economy-wide cap-and-trade legislation and several recent academic studies of the effects of climate policy on energy-intensive, trade-exposed industries. Many of the academic studies are drawn from a Stanford Energy Modeling Forum exercise on the effects of border restrictions. Overall, a robust conclusion emerges that competitiveness impacts are relatively modest.

V. Concluding Remarks

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