Memo on Using Other (Non-CGE) Economy-Wide Models to Estimate Social Cost of Air Regulation

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Prepared for the U.S. EPA Science Advisory Board Panel on Economy-Wide Modeling of the Benefits and Costs of Environmental Regulation

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1 Introduction

The white paper, Economy-wide Modeling: Social Cost and Welfare, (henceforth denoted as the social cost white paper) that accompanies this memo focuses on the technical merits and challenges of using computable general equilibrium (CGE) models to estimate the social cost of an air regulation based on EPA's experience with that class of models. In contrast, this memo takes a preliminary look of the potential use of other types of economy-wide models for estimating the social cost of air regulations. While EPA has limited experience utilizing these other economy-wide modeling approaches, they may hold promise for estimating certain aspects of social cost potentially missed by current CGE models.

As previously discussed in the social cost white paper, the concept of social cost encompasses direct, indirect, and transitional costs (EPA, 2010). Transitional costs are short term costs incurred while the economy is adjusting to a new equilibrium. Given that most state-of-the-art single-country CGE models for the U.S. economy are long-run models with instantaneous (or near-instantaneous) market adjustment in response to a policy shock, these models may miss transitional costs, and may therefore under-represent social cost. This leads to the question of whether other types of economy-wide models, aside from CGE models, could potentially add value with regard to the measurement of social cost by more completely capturing transitional costs. A related question is whether or in what circumstances transitional costs are expected to be substantial enough to potentially warrant investment in modeling tools that more fully capture them, in addition to those tools that capture the first order impacts associated with achieving the new equilibrium.

While these other (non-CGE) economy-wide models are used for a wide array of policy analysis, the focus of this memo is on their potential for estimating the social cost of an air regulation. In particular, we focus on the degree to which these models measure changes in consumer and producer surplus, the building blocks for estimating changes in economic welfare, both in equilibrium and transition, in response to a policy shock.[1] Several types of economy-wide models are discussed: input-output models, large-scale macro-econometric forecasting models, a hybrid between the two (input-output (I-O) macro-econometric models), and dynamic stochastic general equilibrium models (DSGE). It is our conclusion that, aside from CGE models, only DSGE models produce an estimate of changes in consumer and producer surplus required for benefit-cost analysis of policies. For this reason, the main portion of the memo discusses DSGE models while the other three types of economy-wide models are described in the appendix.

2 Measuring Welfare in Economy-Wide Models

There are a number of ways to characterize the main attributes of different types of economy-wide models. Arora (2013b) distinguishes between economy-wide models that are based on optimization by economic agents and those that are not. Optimization models build up to the macro-economy from microeconomic foundations: consumers are assumed to maximize utility and firms maximize profits

[1] Note that these other types of economy-wide models will also be discussed in the economic impacts white paper with regard to their ability to shed light on other economic measures aside from social cost that are of potential interest to policymakers.

subject to resource constraints, preferences, and production possibilities; the models also examine the ramifications of a policy shock in equilibrium (i.e., when supply re-equilibrates with demand in all markets). In contrast, non-optimized models, while potentially based on consumer and/or firm level data, are generally not predicated on the concept that economic agents optimize decisions. In addition to CGE models, only DSGE models can be classified as an optimization model, while the other types of economy-wide models discussed in this memo, input-output, macro-econometric, and I-O macro-econometric models, are all examples of non-optimized models.[2]

Which of these models can be used to derive a welfare measure follows directly from whether agents optimize. Optimization models, because of their microeconomic foundations and, in particular, their basis in utility theory, can calculate equivalent variation (EV) or compensating variation (CV) to capture welfare changes due to a policy shock. In the case of a more stringent regulation with positive net compliance costs, EV measures what a consumer would be willing to pay to avoid an increase in prices (and thus, a decline in real income) resulting from a regulation. CV measures how much a consumer would need to be compensated to accept changes in prices and income such that they achieve the same level of utility experienced prior to the policy shock (EPA 2010). In an economy-wide model that also includes benefits, net willingness to pay would also factor in changes in environmental quality as well as how these interact with price changes. Non-optimized models commonly report the effect of a policy shock on other aggregate economic measures of interest to policymakers such as changes in GDP, consumption, and employment, but as previously discussed in the social cost paper these may not correlate well with welfare measures appropriate for benefit-cost analysis.

CGE and DSGE models are both built on micro-theoretic foundations so that behavioral responses in the models derive from the underlying structure of the models. These models also reduce the potential applicability of the Lucas critique since they do not assume that past behavioral relationships of consumers and firms govern future reactions.[3] Instead, consumer and firm behavior is modeled directly, which means that responses to policy shifts can be incorporated (Arora, 2013a; Arora, 2013b).

Another potentially useful distinction across model types is structural versus reduced-form specifications. Woodford (2009) distinguishes between reduced-form methods used to characterize data under a priori assumptions and structural models that explicitly specify underlying preferences, production, and

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[2] We do not discuss vector autoregressive (VAR) techniques separately. VAR econometric techniques specify multiple endogenous variables in terms of other endogenous variables and error terms (Sims introduced VAR in 1980 as an alternative to large-scale, macro-econometric models; he argued that all variables in these models could be potentially endogenous and therefore decisions about which are exogenous for purposes of solving the model are ad hoc and unjustified (Bjørnland, 2000)). VARs often are reduced-form approaches that strive to explain observed empirical phenomena and relationships, including sources of business cycles. Recently, some have been depicted VAR techniques as useful for describing data and for forecasting macroeconomic phenomena, but because they do not differentiate between correlation and causation that may prove less useful for structural inference and policy analysis unless explicitly derived from theory (Stock and Watson, 2001). See Arora (2013a) for further discussion.

[3] Because DSGE and CGE models are based in microeconomic theory, they potentially avoid the Lucas critique. Reduced-form macro-econometric models that rely on historical data cannot take into account the possibility that a firm or consumer may modify its behavior with changes in policy. The Lucas critique points out that the inability to account for this dependence invalidates these models for purposes of policy evaluation outside of short-term forecasting (Schmidt and Wieland, 2013; Arora, 2013a; Heutel and Fischer, 2013).

resource allocation in ways that are consistent with economic theory. The calibration of structural or behavioral model parameters with actual data ensures that the model represents important economic features while remaining in agreement with the underlying theory. In contrast, reduced-form models are principally data driven and based on empirical observation. For example, many equations in a macro-econometric model are specified in reduced form, and the parameters are econometrically estimated using time-series data. The equations in such models form a system of simultaneous equations that are then combined with national income account identities (Smith, 2012). Both CGE and DSGE models have been classified as structural models.[4] Input-output, macro-econometric, and I-O-macro-econometric models are typically empirically driven exercises and as such are largely reduced-form, though macro-econometric and I-O macro-econometric models are often described as guided by macroeconomic theory.

3 Dynamic Stochastic General Equilibrium Models

As only the DSGE model may potentially be used to estimate changes in consumer and producer surplus, in addition to CGE models, we provide an initial overview of its capabilities and limitations based on available assessments in the literature.

DSGE models are dynamic, inter-temporal models that attempt to explain aggregate macroeconomic phenomena but are based in micro-economic theory (e.g., households maximize utility and firms maximize profit subject to income constraints; prices are assumed to adjust until markets clear) (Woodford, 2009). Similar to a CGE model, DSGE models often assume a representative consumer that works, consumes, and saves (invests); a representative firm that hires labor, capital and other intermediate commodities to supply a final product; and a government sector that is tasked to design and implement monetary or fiscal policy, in addition to participating in the product and product markets (see Figure 1). By combining these basic ingredients, DSGE models describe the interrelated movement or evolution of basic macroeconomic variables.

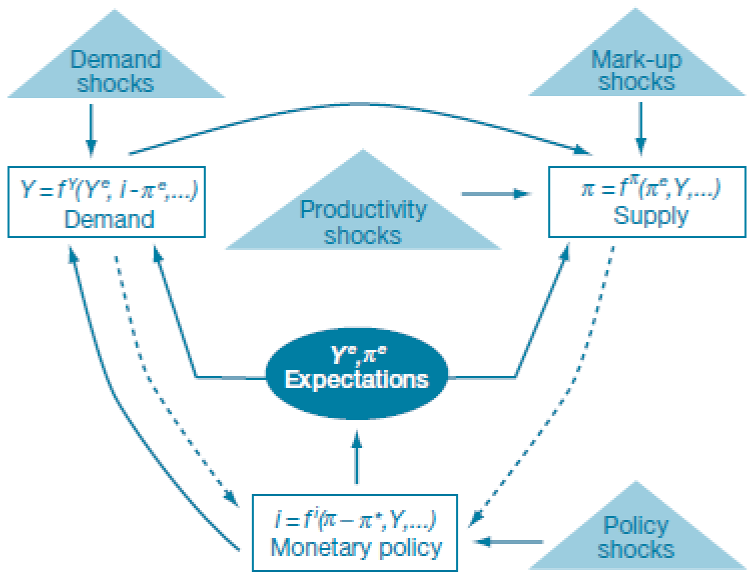
It is worth noting that, at a high level of abstraction, "DSGE models in principal are not different from CGE models" (Townsend, 2010). For instance, both types of models are built from microeconomic foundations and assume agents optimize and that markets clear in the long run. However, since these two economy-wide modeling approaches arise from different literatures, the specific implementations reflect different modeling priorities and tradeoffs. While the number of sectors represented in a DSGE model is typically

[4] Recall that CGE models are built around the assumption that for some discrete period of time, an economy can be characterized by a set of conditions in which supply equals demand in all markets. When the imposition of a regulation alters conditions in one market, the model will determine a new set of relative prices that re-equilibrate supply and demand in all markets, accounting for interactions and feedbacks between commodity, input, household, and government sectors (EPA, 2010). CGE models examine the medium to long run effects of policy shocks, can be static or dynamic, are calibrated but may also rely on econometrically estimated behavioral parameters, and vary widely with regard to sectoral detail and representation of trade. For purposes of examining the effects of an air regulation, EPA has typically relied on single-country dynamic CGE models of the United States with a relatively simple representation of trade and a moderate level of sectoral detail (35 to 40 sectors).

small relative to a CGE model, they are able to model the dynamics of the economy over time in ways that a CGE model typically does not, making them well suited for studying the cyclical effects of policy.[5]

Figure 1 illustrates the emphasis in many DSGE models on forecasting macroeconomic aggregates. Demand is a function of expectations about uncertain future real economic activity (Y^e) and the nominal interest rate minus expected inflation ($i - \pi^e$). Supply is characterized with regard to key drivers of inflation. The government sector determines monetary policy through its setting of nominal interest rates.

Figure 1: A DSGE Model's Basic Structure



Source: Sbordone, et al., 2010

Another difference from CGE models is that, in addition to resource constraints, consumers in DSGE models maximize the present value of utility flows in the presence of processes and parameters that are subject to random, unexpected shocks in each period (e.g., in productivity, tastes, technology), as shown in Figure 1 (also see Romer, 2011; Faust and Gupta, 2012; De Grauwe, 2010; Heutel and Fischer, 2013). Consumers and firms typically are assumed to respond rationally to current and potential future cyclical changes when optimizing (i.e., on average, they correctly form expectations about the future). Since much DSGE work in macroeconomics has focused on explaining differences in growth across countries, the financial sector has often been less developed in these models, though this is an active area of current research (Townsend, 2010; Sbordone et al., 2010).

Similar to efforts to modify some CGE models (see the social cost white paper), short-run market rigidities may be introduced into DSGE models via a variety of mechanisms. For instance, some models assume

[5] "Roughly, the more the model incorporates dynamics and uncertainty, the less it is able to handle disaggregation" (Townsend, 2010).

monopolistically competitive firms that cannot instantaneously and costlessly adjust. Others assume production inputs are firm-specific (i.e., firms only accumulate capital for their own use), or only a certain proportion of households can reset their nominal wage in any particular time period (Sbordone, et al., 2010; Schmidt and Wieland, 2013).[6] It is through the introduction of some type of short-run rigidity that an analyst might capture transitional costs. We are unaware of any explicit comparisons of CGE and DSGE models in this capacity, however.

3.1 Environmental Policy Applications

While DSGE models are often used by central banks or in academic research (Woodford, 2009; Sbordone, et al., 2010), there are only a few applications of a DSGE model in an environmental policy context. One set of papers compares how different economic instruments perform in an economy that faces some pre-defined set of exogenous productivity, price, or wage markup shocks. For example, Fischer and Springborn (2011) explore the macroeconomic performance of an emissions tax, cap-and-trade, and intensity targets for an economy that faces uncertain future productivity. In their framework, a polluting input is a necessary part of production and any emission abatement requires reducing output. Heutel (2012) models emissions as a byproduct of production; firms are able to reduce emissions by installing a costly abatement technology. This framework is used to assess optimal environmental policy when economic fluctuations are caused by persistent productivity shocks. Another set of papers in the environmental economics literature combines aspects of DSGE models with highly stylized global integrated assessment models (IAMs) – Nordhaus' DICE or RICE model, in particular - for the analysis of climate policy (e.g., Hassler and Krussel, 2012; Cai et al., 2012; Lemoine and Traeger, 2014; and Barrage, 2014).[7]

In comparison to CGE models, the DSGE models used in environmental applications are highly aggregate, stylized representations of the economy. Arora (2013a) points out that this is in part due to the incorporation of uncertainty. For instance, Fischer and Springborn (2011), Heutel (2012), and Angelopoulos et al. (2010) model a single representative consumer and a single representative firm. Dissou and Karnizova (2012) model six production sectors (coal, electricity, natural, gas, services, energy-intensive goods, and non-energy-intensive goods) and allow for more than one source of an exogenous shock in the economy: each sector experiences its own autocorrelated production shock, which means that contrary to previous studies they find that the performance of the economic instrument varies with the source of the shock. Of the four papers that compare instruments for environmental policy, only Fischer and Springborn (2011) and Dissou and Karnizova (2012) include labor as an input into production.

[6] Arora (2013a) notes another difference in the calibration process for CGE and DSGE models. CGE models typically calibrate structural or behavioral parameters so that the model is able to reproduce the social accounting matrix (SAM), which "records all the transactions and transfers between production activities, factors of production, and agents in an economy." DSGE models do not rely on a base year SAM to calibrate parameter values. Instead they combine commonly accepted values from the literature with calibration of certain ratios to long run averages in the macro data. DSGE parameters can also be estimated using historical data.

[7] DICE "is an optimal growth model based on a global production function with an extra stock variable (atmospheric carbon dioxide concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions— implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased (Interagency Working Group, 2010).

3.2 Potential Advantages and Limitations

Bukowski (2014) identifies two possible advantages that DSGE models bring to policy analysis that are not afforded by static or recursively dynamic CGE models. First, DSGE models are fully dynamic such that investment and saving decisions are interdependent and endogenously determined by the future path of the economy. The second advantage of DSGE models over CGE models lies in their ability to explicitly model decision-making under uncertainty (also Arora, 2013a). While both types of models assume rational expectations, forward-looking CGE models typically assume perfect foresight, while DSGE models allow for imperfect foresight when forming expectations about the future. An analyst has the ability to vary stochastic processes and agent's information sets within the model to explore the dynamic properties of the model. For instance, in contrast to most CGE models, "not only long but also short to medium term policy implications can differ depending on whether economic agents perceive a given policy as transitional or permanent" (Bukowski, 2014). See the uncertainty white paper for more discussion.

When using DSGE models to analyze environmental policy, researchers have noted a further appeal over CGE models in their ability to model the short- to medium-run within a tractable and consistent economic framework (Heutel and Fischer, 2013; Woodford, 2009). For instance, DSGE models can potentially be used to analyze the short run effects of policies under assumptions other than perfectly competitive markets and fully flexible wages and prices (e.g., one could model imperfect competition in labor or product markets, assume wages or prices that are fixed for some period of time before adjusting to reflect current market conditions, or build in search and matching frictions that result in underutilized resources (Woodford, 2009)). While CGE models also can accommodate some market rigidities and economies of scale, they do not typically explicitly model the transition period as the economy moves from one equilibria to another.

Despite their popularity with central banks, economists appear to disagree on the extent to which applying DSGE models to policy making is practical.[8] Cogley and Yagihashi (2010) caution that if a DSGE model is misspecified (i.e., it fails to predict the "true" correctly specified model parameters), it may not be policy invariant. While this is true of any model, the introduction of random, exogenous shocks may complicate matters. For instance, correlated structural shocks are a potential indicator of misspecification (Andrle, 2014). In an ideal setting, structural shocks are uncorrelated with the policy intervention (Faust, 2009). However, some of the shocks most commonly evaluated in DSGE models - for instance, wage and price markup shocks or government spending shocks - may fail to meet this criterion (Chari, et al., 2008; Faust, 2009). This concern may be less immediate when evaluating the effects of environmental policies that do not explicitly raise government revenues or vary over time to mitigate exogenous fiscal or monetary shocks (e.g., Heutel (2012) discusses the possibility of a carbon tax being pro-cyclical).

[8] DSGE models have been criticized for assuming rational expectations. De Grauwe (2010) states that it imposes higher level "cognitive capabilities on individuals" than they actually have. (Many CGE models are subject to the same criticism.) DSGE models also are sometimes criticized for their parameter estimation approach. Tovar (2008), for example, notes that maximum likelihood methods in DSGE models leads to "stochastic singularity" problems.

A second recent criticism of DSGE models relates to their overall forecasting performance. De Grauwe (2010) points out that the validity of a model is usually judged by its ability to make empirical predictions that are supported by the data. In this regard, Morely (2010) points out that “just as older versions of large-scale macro-econometric models failed to predict or even explain the ‘stagflation’ of the 1970s, micro-founded ‘dynamic stochastic general equilibrium’ (DSGE) models inspired by the Lucas critique have failed with the Great Recession of 2007–2009.” Caballero (2010) echoes this sentiment: “macroeconomics—by which I mainly mean the so-called dynamic stochastic general equilibrium approach—has become so mesmerized with its own internal logic that it has begun to confuse the precision it has achieved about its own world with the precision that it has about the real one.” (See also Robert Solow’s 2010 testimony regarding DSGE models’ predicative abilities to the House Committee on Science and Technology.) Woodward (2009) points out that the macroeconomics literature offer little in the way of guidance or agreement on how to best specify an empirical DSGE model. That said, it remains an open question – to our knowledge, undiscussed in the literature – to what extent this criticism applies when DSGE models are used to assess the potential welfare effects of a policy ex-ante rather than for forecasting purposes. When conducting benefit-cost analysis of air regulations, the EPA focuses on estimating changes in welfare relative to a baseline rather than correcting predicting any particular future.

4 Concluding Remarks

Given EPA’s relative lack of experience with DSGE and other types of economy-wide modeling approaches aside from CGE models, this memo should be viewed as an initial foray into characterizing the potential value added of other economy-wide models for estimating the social cost of an air regulation. In particular, this memo is designed to aid the SAB Panel in addressing the charge questions:

- Are there other economy-wide modeling approaches beside CGE that EPA should consider for estimating the social cost of air regulations?
- What are the potential strengths and weaknesses of these alternative approaches in the environmental regulatory context compared to using a CGE approach?

As in the social cost white paper, we have left aside the question of whether benefits should also be included in an economy-wide model to fully characterize changes in economic welfare.

DSGE models are particularly intriguing to the EPA because of their ability to potentially characterize the short-run implications of unexpected policy shocks, which could allow an analyst to characterize the transition between the baseline and new equilibria or to formally characterize uncertainty in an economy-wide framework. However, since the application of DSGE models to environmental policy questions in the published literature is relatively recent, it is unclear how or to what extent this class of models could be applied to the analysis of an air regulation, what features of a DSGE model would be particularly important in a regulatory context, or how results from a DSGE model compare to those of a CGE model when used to evaluate the same environmental policy. In addition, the relative high level of sector aggregation in most DSGE models raises similar issues to those discussed in the social cost paper: when using CGE models to measure social costs, there is the potential for missing heterogeneity in compliance technologies and costs that may matter when estimating aggregate social cost.

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5 Appendix

As previously mentioned, the main limitation of input-output (I-O) models, macro-econometric models, and hybrid I-O macro-econometric models for social cost estimation is that they are non-optimizing models. Since they are not based on micro-economic foundations, they cannot be used to directly estimate changes in consumer and producer surplus resulting from the introduction of a new policy. However, because these types of models may be of interest for estimating economic impacts of air regulations on affected input or goods markets in the short or longer-run, we briefly describe each of these three economy-wide models and then summarize their main advantages and limitations compared to a CGE model. Whether these models are potentially useful for estimating economic impacts will be discussed in detail in the economic impacts white paper.

Similar to CGE models, **input-output models** are based on highly disaggregated national level input-output tables that describes the interrelated flows of good and factors of production (in terms of values of purchases) for a particular year. However, while the information base is similar, input-output models differ from CGE models in that they impose a simple linear model that relates changes in final demand to changes in the total amount of goods and services, including intermediate inputs, required to meet that demand. Input-output models are static and assume fixed prices and technology. Thus, while they can capture immediate-term direct and indirect effects of a new policy, they do not model interactions between sectors or feedback effects that normally occur in response to price changes (EPA, 2010). Given this description, it is not surprising that input-output models are sometimes used to characterize the very short run effects (before prices can adjust) of national policy (e.g., Morgenstern, Ho, and Shih, 2008).[9] They are also often used to examine local or regional policies that are anticipated to have relatively small effects relative to the national economy.

Macro-econometric models are large-scale, highly detailed systems of equations designed to predict quarterly or annual effects of mainly fiscal or monetary policy changes on macroeconomic aggregates (e.g. GDP, interest rates, net employment growth).[10] While not explicitly derived from microeconomic theory, they are designed to be consistent with macroeconomic theory: the short-run structure is commonly based in Keynesian theory such that variable outcomes are demand determined. In the long run, macro-econometric models are consistent with neoclassical growth theory in that supply side effects dominate model outcomes (Arora, 2013a). These models combine a series of accounting relationships (e.g., savings equal investment) with econometrically estimated relationships that are based on historical time-series data (Hahn and Hird, 1991). The validity of their predictions is premised on the assumption that historical relations (as reflected in the data) are valid predictors of future effects (European Commission, 2015).

I-O macro-econometric models are hybrid models that integrate the high level of detail from an input-output model with the forecasting properties of an econometrically estimated macroeconomic model

[9] Morgenstern et al. (2008) go further by characterizing the very short–run response to a national carbon price based on an input-output model as "a partial equilibrium view of the effects."

[10] These models provide the level of detail encompassed in the National Income and Product Accounts (e.g. U.S. GDP and its components) (Portney, 1981).

(EPA, 2010). Unlike I-O models, this hybrid approach closes the model using a system of endogenous econometric relationships between primary factors and final demand (West, 1995). By combining the two model types, it is possible to examine the broader macroeconomic implications of industry-specific policies. However, an I-O macro-econometric model may have less sectoral resolution than an input-output model by itself and is still not derived from microeconomic theory.

Table A-1 summarizes the types of costs (beyond direct effects on the regulated sector) typically captured by the three types of economy-wide models discussed in the appendix in comparison to CGE and DSGE models.

Table A-1: Types of Costs Captured by Economy-Wide Models

Attributes	**Input-Output**	**Macro-Econometric**	**I-O Econometric**	**DSGE**	**CGE**
Can estimate welfare effects				√	√
Can be used to measure transitional costs	√	√	√	√	
Can capture indirect effects	√	√	√	√	√
Can capture feedback and interaction effects			Some	√	√

Advantages and Limitations

We now turn to a discussion of the key advantages and limitations of these three types of economy-wide models based on available literature.

Input-output models are described as transparent and relatively easy to use and interpret (EPA 2010, West, 1995). These models are capable of having a high level of sectoral disaggregation. If used in the appropriate context, they can also provide "considerable insight into short term supply chain issues and how industries are related" (European Commission, 2015). As previously mentioned, fixed prices may be a valid assumption when evaluating a policy in a local or regional context when local producers are not expected to greatly affect supply or prices outside the region (West, 1995).

The limitations of input-output models are particularly relevant when contemplating their use for analyzing the effects of national policy. I-O models are static and described as lacking realistic behavioral reactions by producers and consumers. For example, they do not include supply constraints (which are usually transmitted via price increases) (West, 1995; Dwyer et al., 2006). I-O models also assume linearity in the production system (i.e., a fixed, strictly proportional relationship between input coefficients and output). This assumption is unrealistic if changes in relative prices cause firms to substitute away from more expensive inputs (Dwyer et al., 2005). In addition, the model does not account for feedback effects between final demand and input markets (EPA, 2010; Dwyer et al., 2006; West, 1995). The government sector is also not explicitly modeled.

As previously mentioned, I-O models are not based in micro-economic theory and do not estimate changes in consumer or producer surplus. The lack of resource constraints mean that I-O models frequently overestimate the economic effects of a policy. While the degree of overestimation is likely not too large when assessing local impacts, it may be of significant size when analyzing larger regions or the national economy (Dwyer et al., 2005; Dwyer et al., 2006; West, 1995).

Macro-econometric models are recognized as having a number of appealing features. First, they are comprehensive, and identify effects of policy on important aggregate measures "as well as price and output effects for at least some individual economic sectors." In addition, the "predictions they generate are integrated and simultaneously determined….price increases in one sector are translated into cost and price increases in other sectors" (Portney, 1981). This is a key advantage over I-O models that assume away these effects.

However, macro-econometric models are described as having a number of limitations compared to CGE models. First, they are often subject to the Lucas critique. Model predictions are based on observed historic correlations between macroeconomic variables. However, consumer and firm responses are not policy invariant and may change when a new policy is introduced (EU Commission, 2015; Arora, 2013). Thus, while these models may capture short-term responses, they are less likely to capture longer run changes. Second, while the many "feedbacks inherent in econometric models ensure at least a crude approximation to the simultaneous and interdependent decision-making characterizing a market economy" (Portney, 1981), macro-econometric models are still based on a top-down approach. As such, they are frequently unable to account for interactions between different sectors as the model does not specify how the input of one sector might be related to the output of another sector (Arora, 2013).

Third, environmental regulations may be too small to have a notable effect in these models. While environmental control expenditures "are large in absolute terms, [they] still account for a fairly small fraction of gross national product" (Portney, 1981). The Office of Management and Budget (OMB, 1995) notes that macroeconomic effects tend to show up in national level macro-econometric models "only if the economic impact of the regulation reaches 0.25 percent to 0.5 percent of Gross Domestic Product … 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."

To put this in perspective, in 2014 U.S. GDP was about $17 trillion, so a regulation would have to reach $43 billion to $85 billion in effects to show up in a macro-econometric model. There were 24 major air regulations promulgated by EPA between fiscal years 2003 and 2013 with total annual costs of $41 billion to $49 billion (in 2014 dollars) (OMB, 2014). Thus, if EPA had reason to examine the effects of its air regulations in aggregate it is possible that a macro-economic approach may prove useful. However, the most expensive individual air regulation during this time period, the Utility MACT, had annualized costs of about $11 billion (2014$), well below the OMB threshold for use of a macro-economic model.

Portney (1981) notes that macro-econometric models rely on pollution control expenditure (versus pollution control cost) data as an input into analyses of policy effects on macroeconomic aggregates. This raises two potential issues: Expenditures include transfers between sectors or economic agents (e.g., sales taxes on equipment purchased or payroll taxes firms pay to government), which are not included in a measure of social cost; and they do not reflect foregone opportunities – alternative uses of resources besides pollution control.[11] This leads Portney (1981) to conclude that these models may only "determine roughly how the costs of regulation may manifest themselves in the economy" but they are "no more than suggestive, and at times they may even fall short of even this modest goal."

I-O macro-econometric models gain several advantages over each model type used separately. Unlike input-output models, they account for supply-demand conditions in the economy, including resource constraints due to coupling with a macroeconomic framework. Feedbacks between supply and demand occur in I-O macro-econometric models via econometric equations (in contrast, CGE models accomplish this via a price mechanism and market clearing assumptions) (West, 1995). In addition, the hybrid model provides a dynamic structure for the static I-O model. Finally, the hybrid approach can estimate changes in demand for and production of intermediate goods due to their coupling with a detailed input-output model while relaxing the linearity assumption in I-O models.

While CGEs assume full market clearing, I-O macro-econometric models assume imperfect knowledge of product and factor markets, with an emphasis on tracking short run disequilibrium adjustments over time (West, 1995). Thus, these models can account for non-equilibrium phenomena such as less than full employment and business cycles (EPA, 2010). That said, I-O macro-econometric models still retain some of the same limitations as I-O and macro-econometric models. Key among them is the fact that since the models use econometrically estimated relationships to predict economy wide aggregates, they are still often subject to the Lucas critique. The lack of a micro-theoretic foundation and inability to reflect behavioral responses may also limit their potential for examining long run policy implications; the additional sectoral detail from the I-O component "does not alleviate [the model's] shortcomings for the purpose of long term forecasting" (White House Climate Change Task Force, 1997).

While West (1995) notes that the distinction between I-O macro-econometric and CGE models has blurred over time as hybrid models incorporate price responses into product and factor demands, several other differences are worth emphasizing. First, I-O macro-econometric models have been criticized for their lack of adequate supply-side specification (West, 1995). Second, the hybrid model is more complicated than either an I-O or macro-econometric model alone; it can be difficult to disentangle the mechanisms driving model results (EPA, 2010). Third, as previously mentioned, they do not directly estimate consumer and producer surplus.

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[11] When firms increase prices to offset new expenditures, consumers may postpone or forgo purchases they would have made at lower prices; this loss in consumer surplus (because consumers are generally willing to spend more for goods they buy than the prices they actually pay) are not included in expenditures (Portney, 1981).