Economy-Wide Modeling: Use of CGE Models to Evaluate the Competiveness Impacts of Air Regulations

DRAFT: June 17, 2016

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

Introduction

Jaffe, et al. (1995) note that coinciding trends of increasing costs for firms to meet environmental regulations and increasing trade deficits have led to concerns that regulation has "hinder[ed] the ability of U.S. firms to compete in international markets This loss in competitiveness is believed to be reflected in declining exports, increasing imports, and a long-term movement of manufacturing capacity from the United States to other countries [with more lax regulations], particularly in 'pollution-intensive' industries." In policy debates, competitiveness is often used as "a catch-all term to reflect an amalgam of concerns related to trade, profitability, employment, and welfare" and to refer to effects on an individual facility or firm, as well as broader sectoral or country-wide effects (Carbone and Rivers, 2014). In the context of unilateral climate policy, proposed legislation has focused on the potential that energy-intensive, trade-exposed (EITE) industries in the United States will not be able to pass the costs of regulation along to consumers via higher prices. This, in turn, may reduce their overall profitability and result in a loss in market share (i.e., reduced output) in international markets.[1]

Conceptually, it is possible that domestic air regulations may 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 the direction and magnitude of these effects can be complex and requires the use of general equilibrium economic models that have both breadth (multiple-countries) and depth (multiple sectors) to assess changes in the various components of supply and demand in the U.S. and abroad in response to an increase in production costs in regulated sectors.

This memo highlights some of the distinctive features of models used for competitiveness analyses. It is a companion to the white paper on the use of CGE models to evaluate economic impacts provided to the SAB. In this memo, we discuss the potential competitiveness effects of a domestic air regulation that is undertaken unilaterally, meaning without equivalent actions by trading partner nations. Following Carbone and Rivers (2014), we assume that the regulation increases production costs for affected industries in ways that correct a market failure (in this case, a pollution externality). In the following sections we discuss model requirements, model limitations, and summarize recent representative studies from the economics literature.

Defining Competitiveness

A number of studies note that it is challenging to define the concept of competitiveness in precise economic terms, particularly as it relates to changes in well-being or welfare (e.g., Carbone and Rivers, 2014; Metcalf, 2013). For instance, when measuring competitiveness effects for U.S. firms should one

[1] Shifts in economic activity can also result in "emissions leakage." This can occur due to the moving of production to regions or countries with laxer regulations or due to a price effect (reductions in demand for a good domestically may lower the global price, which then causes other regions/countries to consume more of it. This undermines the effectiveness of a standard that regulates emissions with transboundary effects (EPA 2010).

only focus on effects in EITE industries, or also include potential improvements in the competitiveness of relatively clean industries (Carbone and Rivers, 2014)? Jaffe, et al. (1995) emphasize the need for a general equilibrium approach to evaluate competitiveness effects due to the complexity of the issue.

Jaffe, et al. (1995) also note that the change in net exports, holding constant other factors such as exchange rates and real wages, is the theoretically consistent way of defining competitiveness:

> "We would wish to measure the reduction in net exports 'before' any adjustments in the exchange rate (and hence in net exports of other goods) have taken place, because other industries whose net exports increase to balance the fall in exports should not be thought of as having become more competitive if their exports increase is brought about solely by a fall in exchange rates. Similarly, we should not construe an increase in exports brought about solely by a fall in real wages as an increase in 'competitiveness'" (Jaffe, et al, 1995, p. 137).

Given the inability to hold all else constant, the economics literature has suggested and/or utilized various measures as proxies for competitiveness effects. Jaffe, et al. (1995) describe three classes of indicators: the change in net exports in a highly regulated sector versus those in a less regulated sector, the degree to which the production of highly-regulated goods has shifted overseas (also referred to as the pollution haven effect), and the relative change in investment in regulated industries to other countries.[2] Changes in sector-level production, the number and size of firms in a sector, and the domestic share of imports and exports have also been reported as measures of competitiveness, among others (Aldy and Pizer, 2015; Fischer and Fox, 2012; Rivers, 2010; Babiker, 2005).

Potential 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 effects in the U.S. requires the use of an economy-wide model that can identify both domestic demand and net import responses. To understand which domestic industries may be negatively affected on net, a high level of detailed sectoral disaggregation also is required. To understand which industries in which countries may benefit from a change in a particular U.S. air regulation, detailed regional representation is needed. This section draws upon recent literature to summarize model requirements needed for an adequate representation of sectors and international regions for competitiveness analysis.

---

[2] Empirical evidence on the impact environmental regulations have had on the relocation of U.S plants abroad is mixed. Early studies found little evidence but relied on cross-sectional data, which cannot control for unobserved heterogeneity across countries and industries or help disentangle causal relationships between changes in environmental regulation and trade liberalization. Later studies are able to better account for both via panel data and instrumental variable approaches; they "find some evidence of a moderate pollution haven effect" (Shadbegian and Wolverton, 2010). Cole et al. (2005) argue that, because pollution-intensive industries also tend to be relatively capital-intensive, the attractiveness of lower regulatory stringency in a developing country is often outweighed by other factors such as lack of access to capital or a skilled workforce.

Evaluating competitiveness concerns requires a detailed sectoral representation to accurately identify and measure impacts. However, the data requirements impose a serious modeling constraint as sectoral disaggregation is often limited by the data available. Econometrically estimated parameters for demand systems, production functions and foreign trade are not generally available at high levels of disaggregation. Even when sectoral detail is possible, the relevant industry definitions for determining the impacts of a policy on particular regulated entities is often much finer. For example, proposed climate legislation (H.R.2454 or the American Clean Energy and Security Act of 2009) required that, to the extent feasible, eligibility for additional allowances to reduce the impacts of competitiveness effects on energy-intensive, trade exposed (EITE) industries be evaluated at the NAICS six-digit industry classification.[3] The Global Trade Analysis Project (GTAP) database, a common source of estimates for international economic models, aggregates economic activity into 57 sectors. EPA (2010) found that output of the EITE industries defined at the NAICS six-digit level constituted 23 percent of the nonferrous metals sector and 64 percent of the iron and steel sector in GTAP. Consequently, a CGE model with more aggregate sectors predicated on GTAP "may understate impacts on more narrowly-defined industries that are particularly emission intensive" (EPA, 2010).

Alexeeva-Talebi et al. (2012) and Caron (2012) found that estimated sectoral impacts can be quite sensitive to the level of aggregation. Caron (2012) disaggregates the 16 industrial sectors in the GTAP dataset into 51 sectors using data from the Department of Energy's Manufacturing Energy Consumption Survey (MECS) and finds that the additional detail leads the model to predict smaller output losses, but larger import competitiveness effects. Alexeeva-Talebi et al. (2012) use a similar methodology, with data from the European Union for a smaller number of sectors, and reach similar conclusions. Greater sectoral disaggregation means that outputs across closely related industries are more similar than they would be at a more aggregate level, which in turn can lead to greater import substitutability for domestic goods, and therefore greater competitiveness impacts.

When EPA analyzes the effects of an air regulation, it often relies on engineering or partial equilibrium approaches that do not account for impacts on trade. In cases where EPA has used CGE models to analyze economy-wide effects – for instance, of criteria air pollution limits – it has relied on models that offer more detail for the U.S. economy but limited consideration of trade. For example, both IGEM and EMPAX are one-country CGE models that do not explicitly model imports and exports for each commodity represented in the models. The exchange rate (or terms of trade) are often fixed; changes in

[3] "H.R.2454 considers an industry to be "presumptively eligible" for emission allowance allocations (or "rebates") to "trade-vulnerable" industries if the industry's energy intensity or its greenhouse gas intensity is at least 5 percent, and its trade intensity is at least 15 percent. In addition, H.R. 2454 considers an industry to be "presumptively eligible" if its energy or greenhouse gas intensity is at least 20 percent, regardless of its trade intensity. H.R. 2454 stipulates the specific data sources that should be relied on in assessing industry eligibility; these include the Census Bureau's Annual Survey of Manufactures and Economic Census, the Energy Information Administration's (EIA) Manufacturing Energy Consumption Survey, and data from the United States International Trade Commission. The bill also requires that, to the extent feasible, eligibility assessments should be conducted at the most disaggregated level for which the necessary public data are available — the six-digit industry classification under the North American Industry Classification System (NAICS). (EPA, 2010, p. 8).

U.S. demand are not viewed as large enough to affect world prices. While these models use Armington elasticities to account for imperfect substitution between domestic goods and imports, this is done at an aggregate level (EPA, 2008; Goettle, 2009).

To fully understand the interaction between an air regulation and competitiveness effects, a model must be international in scope with the ability to analyze trade flows between regions. In contrast to one-country models, Armington elasticities are specified for multiple sectors and the terms of trade are not necessarily fixed. Moreover, models must have sufficient granularity in regional definitions to distinguish between trading partner countries across economic and policy spectra. In practice, most studies of economic competitiveness effects in the environmental context have focused on the implications of policies that limit carbon emissions, which often utilize models with at least three regions (e.g., U.S., rest of Annex 1 except the Russian Federation, and Non-Annex 1 regions).

Model Limitations

The additional capability described above can generally only be achieved at some cost in the model. This section highlights the limitations of the class of models used for competitiveness analysis. Typically, these include restrictive assumptions about the behavior of agents.

Models with a great deal of regional and sectoral disaggregation often restrict behavioral responses of agents by abstracting from the time dimension (i.e., they are static models instead of dynamic) to keep computational and data requirements manageable. For example, EPA (2010) utilized a static modeling framework to examine the competitiveness effects of proposed climate legislation. More recently, of 12 models participating in a model comparison exercise focused on border measures, EMF29 (Bohringer, et al. 2012), only three were dynamic. Furthermore, all three dynamic models are recursive in nature whereby foresight of agents is myopic; in other words, none of the 12 models are inter-temporal CGE models. This may be necessary to gain tractability but contrasts with many one-country CGE models that are dynamic and inter-temporal in nature with perfect foresight.

Another limitation is that representation of environmental policy may not be explicit. For example, EPA (2010) relied on a fixed $20 per ton carbon price as a proxy for H.R. 2454, an amount that was "representative of the near- to medium-term allowance prices." In EMF29, a greenhouse gas emissions reduction target was exogenously imposed on the model. Given that most EPA air regulations are not market-based instruments but technology or emissions-rate performance standards with many nuances regarding who is affected and what is required to comply, their representation in a CGE model is potentially more challenging. In particular, the analysis could miss some aspects of an air regulation that are important for accurately predicting competitiveness effects.[4]

Lastly, as previously mentioned most CGE models utilize the Armington specification of trade, which effectively limits the range of potential competitiveness impacts by imposing a particular structure on

[4] For more on rule representation, see the social cost white paper.

trade. Firms and the goods they produce within a particular sector are identical. However domestic and foreign produced goods are imperfect substitutes because consumers care about their origin; this is represented in a CGE model by a fixed taste parameter calibrated to pre-existing trade patterns (i.e. an Armington elasticity). Models that rely on Armington elasticities cannot capture changes in the overall number and kinds of goods traded, particularly those that have historically seen little or no trade (Zhai, 2008). Balistreri and Rutherford (2012) and Balistreri et al. (2014) explore how much of an impact an Armington specification has on predictions of trade flows for EITE sectors by exploring an alternative, the Melitz specification.[5] The Melitz specification allows firm heterogeneity; trade patterns are no longer dictated by an exogenous taste parameter but by factors such as market size, technology and trade barriers. They find that using a Melitz specification almost doubles the negative effect on output in EITE sectors compared to the same scenario using an Armington specification (see BBR in Figure 1). However, while results from models that rely on a Melitz specification are intriguing, data availability and computational requirements have limited widespread use in applied work to date.[6]

Select Studies

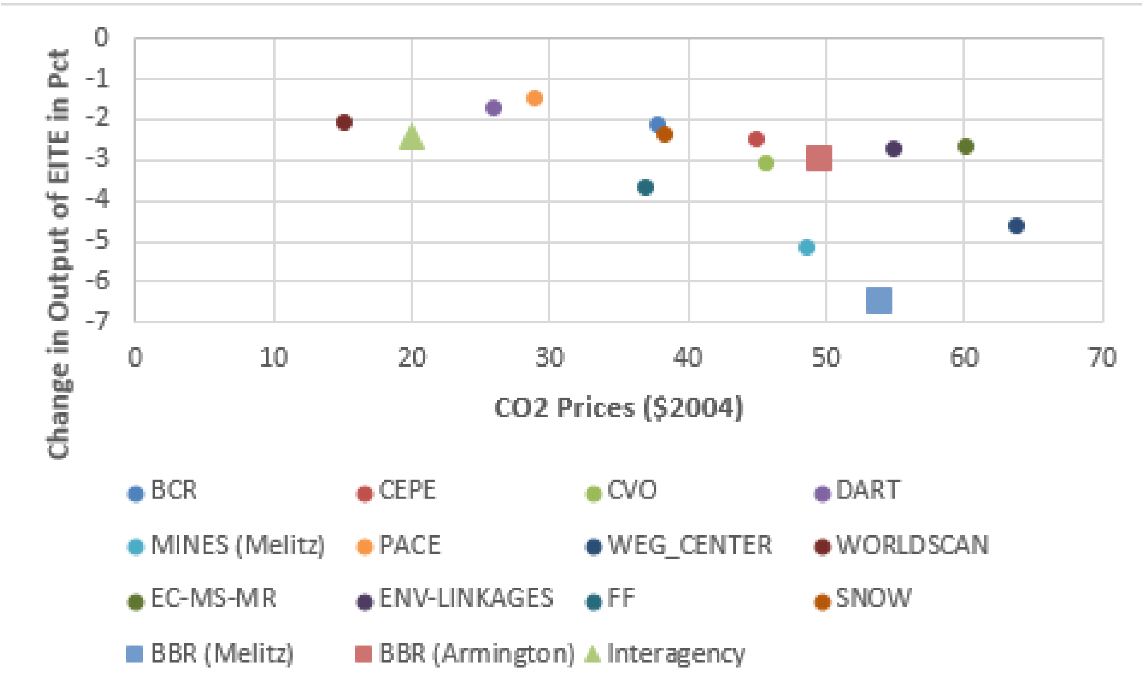
In 2009, EPA participated in an interagency report evaluating the competitiveness impacts of proposed economy-wide cap-and-trade legislation, H.R. 2454 (Interagency, 2009). This effort brought together economists from across the Federal government, notably the Departments of Treasury, Energy, and Commerce in addition to EPA and the U.S. International Trade Commission. It relied on several multi-country CGE models, many of which had not been previously used by EPA to analyze the effect of environmental regulations. This broad approach was required to undertake a comprehensive analysis of the competitiveness impacts of the GHG cap-and-trade and allowance allocation provisions of H.R. 2454, with special focus on the trade measures (import tariffs and export subsidies for EITE goods).

In the last 5 years, other studies have been published examining the effects of climate policy on EITE industries. Overall, a robust conclusion emerges that competitiveness impacts are relatively modest. Figure 1 summarizes the results from 14 different studies, showing the impact of CO_2 reductions with no border carbon adjustments on production of EITE industries. In addition to the 2009 Interagency Report we include results from the recent Stanford Energy Modeling Forum working group (EMF29) exercise on the role of border carbon adjustments in unilateral carbon policy (Bohringer, et al., 2012). Using standardized base data and assumptions, 12 models were used to analyze a range of border tax scenarios for the EMF 29 exercise.[7] The domestic output effects from these models, measured by a percentage change in output from EITE industries for a stylized climate change policy, range from -1.46 percent to -5.17 percent, with a mean of -2.84 percent. The Interagency Report, using assumptions

[5] Dixon, et al. (2015) have shown that Armington models, as well as the more general Krugman and Melitz formulations can be derived from a single encompassing model and that under some circumstances it is possible to compile and run a global trade model based on any of the formulations.
[6] See the sectoral impacts section of the economic impacts white paper for further discussion.
[7] For our purposes, the reference scenarios provide estimates of the competitiveness impacts of a domestic energy price increase unaccompanied by comparable measures in trading partner nations.

specific to H.R. 2454 arrived at an estimate of -2.5 percent, after adjusting for sectoral coverage to make it more comparable to the EMF analyses.[8] Balistreri, et al. (BBR in Figure 1) report values of -3.0 percent for the Armington model, and -6.5 percent for the Melitz model formulation. Over all 14 studies the average production impact is -3.07 percent.

Figure 1: Change in Output of EITE Industries from 14 models (Interagency, 2009; Bohringer, et al., 2012; and Balistreri, et al., 2014)



Notes: Interagency Report modeled a $20/ton CO_2 price and achieved a 13% economy-wide reduction in CO_2 emissions. All other analyses modeled a 20% emissions reduction at CO_2 prices shown.

For comparison, Carbone and Rivers (2014) provide a recent survey and meta-analysis of 54 studies published in the last decade that examined climate policy and competitiveness impacts on EITE sectors. They find that, "for a 20 percent reduction in coalition emission levels from the pre-policy baseline, the models predict approximately a 5 percent reduction in EITE output in the region." However, in addition to CGE model studies, Carbone and Rivers include sub-global (typically national-level) models and partial equilibrium estimates in their analysis.[9] They also included models that involve coalitions of nations in addition to those assuming unilateral action. Despite these differences, the estimates of domestic production effects are similar to the present analysis.

[8] Specifically, the Interagency Report included the pulp and paper sector in addition to four sectors included in EMF29 and BBR - iron and steel, nonferrous metals, chemicals, nonmetallic minerals.
[9] The 12 EMF studies are also included in Carbone and Rivers (2014).

The output effects in Figure 1 include both domestic demand reductions and substitution of imported goods. Aldy and Pizer (2015) argue that what is most relevant from the perspective of the public debate over competiveness is the latter effect. This is consistent with the view in Jaffe, et al. (1995) that effects driven by changes in real exchange rates or wages should not be included when measuring competitiveness effects. Relying on econometric approaches, Aldy and Pizer (2015) find that import substitution effects were responsible for about 15 percent of the total change in output of energy-intensive industries between 1979 and 2005. The upper bound of the 95th percentile confidence interval is about 16.5 percent. Import substitution effects are slightly negative for the median industry. It is important to note that this effect is never statistically significant.

Combining the domestic production results in Figure 1 with the decomposition results from Aldy and Pizer (2015), we calculate a comparable competitiveness effect (i.e., the change in sector output attributable to competition from import substitution, as opposed to domestic demand reductions) for the studies included in Figure 1. Using an average value from the 14 studies of the production impact of -3.07 percent, and an average value of import substitutability of 15 percent (from Aldy and Pizer), the competitiveness effect due to import substitution is approximately 0.5 percent. Using the high and low values from the 14 studies, we find a range of about 0.2 percent to -1 percent. (If we instead use the upper bound of the 95th percentile confidence interval from Aldy and Pizer (2015) the range increases slightly to between -.24 percent and -1.1 percent.)

Conclusion

During debates surrounding potential U.S. environmental policy actions, concerns have been raised that in response to a change in U.S. environmental policy domestic production may shift to countries that do not yet have comparable policies, negatively affecting the international competitiveness of energy-intensive trade-exposed industries. This memo briefly describes CGE model requirements and limitations with regard to evaluating effects on competitiveness and summarizes recent studies from the literature in order to inform SAB discussion of whether a CGE model can shed light on the international competitiveness effects of air regulations, the types of CGE models that would be needed to evaluate its effects; and whether accounting for international competitiveness effects in a CGE model necessitate compromises in other modeling dimensions that may be important when evaluating the effects of air regulations.

References

Aldy, J., and Pizer, W. 2015. "The Competitiveness Impacts of Climate Change Mitigation Policies." *Journal of the Association of Environmental and Resource Economists* 2(4): 565-595.

Alexeeva-Talebi, V., Böhringer, C., Löschel, A., and Voigt, S. 2012. "The value-added of sectoral disaggregation: Implications on competitive consequences of climate change policies." *Energy Economics* 34 (S2): S127–S142

Babiker, M. 2005. "Climate change policy, market structure, and carbon leakage." *Journal of International Economics* 65(2): 421–445.

Balistreri, E., and Rutherford,T. 2012. "Sub-global carbon policy and the competitive selection of heterogeneous firms." *Energy Economics* 34 (S2) S190–S197

Bednar-Friedl, B., Schinko, T., andSteininger, K. 2012. "The relevance of process emissions for carbon leakage: A comparison of unilateral climate policy options with and without border carbon adjustment." *Energy Economics* 34 (S2): S168–S180

Boeters, S., and Bollen, J. 2012. "Fossil fuel supply, leakage and the effectiveness of border measures in climate policy." *Energy Economics* 34 (S2): S181–S189

Böhringer, C., Bye, B., Faehn, T., and Rosendahl, K. 2012. "Alternative designs for tariffs on embodied carbon: A global cost-effectiveness analysis." *Energy Economics* 34 (S2): S143–S153

Böhringer, C., Carbone, J., and Rutherford, T. 2012. "Unilateral climate policy design: Efficiency and equity implications of alternative instruments to reduce carbon leakage." *Energy Economics* 34 (S2): S208–S217

Böhringer, C., and Rutherford, T. 2002. "Carbon abatement and international spillovers." *Environmental and Resource Economics* 22 (3) 391–417.

Carbone, J., and Rivers, N. 2014. "Climate Policy and competitiveness: Policy guidance and quantitative evidence." Colorado School of Mines Division of Economics and Business. Working Paper 2014-05

Caron, J. 2012. "Estimating carbon leakage and the efficiency of border adjustments in general equilibrium — does sectoral aggregation matter?" *Energy Economics* 34 (S2): S111–S126

Cole, M., Elliott, R., and Shimashoto, K. 2005. "Why the Grass is not Always Greener: The Competing Effects of Environmental Regulations and Factor Intensities on U.S. Specialization." *Ecological Economics* 54: 95–109.

Dixon, P., Jerie, M., and Rimmer, M. 2015. "Modern Trade Theory for CGE Modelling: the Armington, Krugman, and Melitz Models." Purdue University. GTAP Technical Paper No 36.

Fischer, C., and Fox, A. 2012. "Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates." *Journal of Environmental Economics and Management* 64(2): 199–216.

Goettle, R., Ho, M., Jorgenson, D., Slesnick, D., and Wilcoxen, P. 2009. "Analyzing Environmental Policies with IGEM, an Intertemporal General Equilibrium Model of U.S. Growth and the Environment." Report to U.S. EPA, Office of Atmospheric Programs. Available at: http://www.igem.insightworks.com/docs/236/part1_toc.pdf

Interagency Report. 2009. "The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries." Response to Request from Senators Bayh, Specter, Stabenow, McCaskill and Brown. Available at: https://www3.epa.gov/climatechange/Downloads/EPAactivities/InteragencyReport_Competitiveness-EmissionLeakage.pdf

Jaffe, A., Peterson, S., Portney, P., and Stavins, R. 1995. "Environmental Regulation and Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?" *Journal of Economic Literature* 33: 132-163.

Rivers, N. 2010. "Impacts of climate policy on the competitiveness of Canadian industry: How big and how to mitigate?" *Energy Economics* 32(5): 1092–1104.

Shadbegian, R., and Wolverton, A. 2010. "Location Decisions of U.S. Polluting Plants: Theory, Empirical Evidence, and Consequences." *International Review of Environmental and Resource Economics* 4: 1- 49.

U.S. EPA. 2008. "EMPAX-CGE Model Documentation. Interim Report." Available at: https://www3.epa.gov/ttnecas1/models/empax_model_documentation.pdf

U.S. EPA. 2010. "Estimation of eligible sectors and emissions under H.R.2454." Memorandum in Data Annex for Interagency Report on International Competitiveness and Emissions Leakage. February. Available at: https://www3.epa.gov/climatechange/EPAactivities/economics/legislativeanalyses.html

Zhai, F. 2008. "Armington Meets Melitz: Introducing Firm Heterogeneity in a Global CGE Model of Trade." Asian Development Bank Working Paper. No. 108.