

The Impact of Border Carbon Adjustments under Alternative Producer Responses

Niven Winchester^{a,b}

^a *Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. Email: niven@mit.edu*

^b *Department of Economics, University of Otago, Dunedin 9054, New Zealand*

Abstract

Border carbon adjustments (BCAs) have been proposed to address leakage and competitiveness concerns. In traditional assessments, firms regard BCAs as output taxes rather than implicit emissions taxes. Using a stylized energy-economic model, we analyze the impact of BCAs for alternative producer responses. When firms view BCAs as an implicit emissions tax, the outcome depends on whether or not firms can differentiate production across destination markets. If firms are able to produce a low-emissions variety for regions imposing BCAs, results are similar to when firms regard BCAs as an output tax. If firms produce a single variety for all markets, BCAs result in larger leakage reductions than in standard approaches. We also find that BCAs are less effective at addressing competitive concerns in scenarios that result in larger leakage reductions.

JEL codes: F18, Q54.

Key words: Climate change, leakage.

1. INTRODUCTION

Greenhouse gas (GHG) restrictions implemented by some nations can increase emissions in nations without climate policies. Leakage of emissions can occur via at least two channels. First, climate policies reduce fossil fuel prices which result in increased energy consumption in countries without restrictions. Second, energy-intensive production can relocate from countries with GHG restrictions to countries without restrictions. The second form of leakage highlights competitiveness issues that arise when a subset of nations restricts emissions.

Border carbon adjustments (BCAs) – tariffs on emissions embodied in imports from nations without emissions restrictions – have been proposed to address leakage and competitiveness concerns. In the US, the House of Representatives recently passed the American Clean Energy and Security Act of 2009 (H.R. 2454), commonly known as the Waxman-Markey Bill (US Congress 2009). In addition to outlining emissions restrictions, H.R. 2454 details charges on emissions embodied in imports. In general, BCA provisions in the bill target energy-intensive imports from countries that do not have economy-wide GHG reduction programs at least as stringent as in the US. An important feature of BCAs yet to be detailed is how embodied emissions will be calculated. For example, H.R. 2454 requires that “a general methodology” is established to determine emissions embodied in imports (US Congress 2009, p.1123).

In economic analyses of BCAs (Felder and Rutherford 1993; Babiker and Rutherford 2005; Demailly and Quirion 2008; Ponssard and Walker 2008; Mattoo *et al.* 2009; Burniaux, Château and Duval 2010; and Winchester, Paltsev and Reilly 2010),

producers in nations without emissions restrictions regard BCAs as an output tax on goods shipped to countries with climate policies. An alternative assumption is that exporting firms view BCAs as an implicit tax on GHG emissions. In this regard, producer responses to BCAs will depend on embodied emissions legislation. If embodied emissions calculations are never or rarely updated, firms will view BCAs as a tax on exports. If embodied emissions calculations are frequently updated, producers will regard BCAs as an emissions tax and respond to BCAs by reducing the GHG intensity of production. In this situation, producer responses will further be influenced by the degree to which producers can operate separate production lines for different markets (and produce a low-GHG variety for some markets). This paper contributes to the BCA literature by examining the impact of BCAs for alternative firm responses to embodied emissions charges.

This paper has four further sections. Section 2 outlines our methodology and describes the scenarios we considered. Our results are presented and discussed in Section 3. The sensitivity of our results to key assumptions is examined in Section 4. Section 5 concludes.

2. METHODOLOGY

Modeling Framework

Our analysis employs a stylized energy-economic model, similar to the GTAP-EG model described by Rutherford and Paltsev (2000). The model is a static, multi-regional model of the global economy that determines the production and allocations of goods. The

model identifies two regions. One region (the Coalition) implements climate policies and the other region (the non-Coalition) does not. The model also distinguishes five energy sectors (Coal, Crude oil, Refined oil, Gas, and Electricity), two other sectors (Energy-intensive industry, EINT; and Other industry, OTHR), and five primary factors (capital, labor, coal resources, crude oil resources, and gas resources).

Production technologies are represented by multi-level nests of constant elasticity of substitution (CES) functions. Production structures are outlined in panels (a), (b) and (c) of figure 1. Fossil fuel commodities are produced by a CES aggregate of a sector-specific resource and a composite of capital, labor and intermediate inputs. Important production features in other sectors include substitution between energy commodities, and substitution between aggregate energy and a capital-labor composite. Values assigned to elasticity parameters are detailed in the notes to figure 1. Elasticity values closely follow those used in the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev *et al.* 2005), which are drawn from an extensive literature review. Marginal abatement costs in the model are influenced by elasticities of substitution among commodities. Implied marginal abatement costs are increasing, convex functions of the quantity of emissions abated.

In each region, a representative agent derives income from factor income, tax revenue and an exogenous international net transfer (reflecting current account imbalances in the base period). Preferences are represented by nested CES functions, as outlined in panel (d) of figure 1. Consumption elasticity values also follow Paltsev *et al.*

(2005) and are detailed in the notes for figure 1. The specification allows greater substitution among energy commodities than among non-energy commodities.

Goods are traded internationally following an Armington approach. Imports by region of origin are aggregated using a CES function (as each region is an aggregate of many countries, each region imports from itself as well as the other region), and composite imports are combined with domestic production using an additional CES aggregator. Thus, goods purchased by firms and households are composites of domestic and imported varieties. Based on estimates from Hertel *et al.* (2007), the elasticity of substitution between imports from different regions is around 3 and the elasticity of substitution between composite imports and domestic production is around 6 for all products, except Gas and Crude oil. The corresponding elasticities for these commodities are around 15 and 35, reflecting less heterogeneity across varieties for Crude oil and Gas than for other products. A drawback of this treatment of trade flows is that, as demonstrated by Brown (1987), tariff changes can result in considerable terms-of-trade effects when goods are differentiated by country of origin.

Turning to closure, factor prices are endogenous and there is full employment; factors are immobile internationally, but capital and labor are mobile across sectors; and each region maintains a constant current account surplus.

The model is calibrated using version 7.1 of the Global Trade Analysis Project (GTAP) database (Narayanan and Walmsley 2008). The GTAP database includes economic data and carbon dioxide (CO₂) emissions from the combustion of fossil fuels for 113 regions and 57 sectors corresponding to 2004. In our model, the Coalition

includes Australia, New Zealand, Canada, Japan, the US, the EU 27, and the European Free Trade Association. Remaining regions form the non-Coalition. Energy-intensive industry includes paper products and publishing; ferrous metals (iron and steel); other metals; metal products; chemical, rubber and plastic products; and other mineral products (non-metallic minerals). Turning to energy sectors, the gas sector in our model is an aggregate of GTAP gas extraction and gas distribution sectors, and there is a one-to-one mapping between other energy sectors in our model and GTAP energy sectors. Remaining GTAP sectors are included in Other industry.

Embodied Emissions Calculations

As noted above, policy discussions do not detail how GHG emissions embodied in traded goods will be calculated. Our embodied emissions calculations consider CO₂ emissions from the combustion of fossil fuels. For each sector, we calculate embodied emissions as CO₂ emissions from direct fossil fuel use, plus CO₂ emissions from Electricity production used by that sector. An alternative method, following Rutherford and Babiker (1997), is to calculate embodied emissions as the sum of direct emissions (emissions from the combustion of fossil) and indirect emissions (emissions embodied in intermediate inputs). However, this method may be difficult to put into practice, as it requires detailed emissions input-output accounting.

Scenarios

We consider the impact of BCAs in 2020. We create a reference for this year by assuming capital and labor endowments grow at an annual rate of 2.5% in the Coalition and 7% in the non-Coalition. We also assume that there are annual autonomous energy efficiency improvements of 1% in the Coalition. Six climate policy scenarios are considered. In our first scenario (CAT-1), a cap-and-trade policy restricts Coalition 2020 emissions to 80% of 2004 emissions. Four scenarios consider BCAs under alternative producer responses to BCAs, in addition to the emissions constraint in the CAT-1 scenario. When firms regard BCAs as an output tax, the *ad valorem* tariff (τ) is selected so as to retrospectively apply the coalition CO₂ price (pc) to emission embodied in non-Coalition Energy-intensive production (x_N). That is, $\tau = (pcx_N)/pe_N$, where pe_N is the price of Energy-intensive production in the non-Coalition.

When firms view BCAs as an output tax, we implement separate scenarios for exogenous and endogenous embodied emissions calculations. In one scenario (TRF-EXG), embodied emissions are calculated exogenously using the reference data, as is standard in the BCA literature. In another scenario (TRF-END), embodied emissions are calculated endogenously to account for the effect of BCAs on energy prices and ultimately energy use. Our TRF-END scenario mimics a case where embodied emissions calculations are regularly updated, but firms do not realize that they can reduce BCA charges by reducing emissions.

In two other BCA scenarios (TAX-DIF and TAX-AGR), firms view BCAs as an implicit tax on CO₂ emissions. Under this assumption, a key question is the extent to

which non-Coalition firms can use different production lines for goods shipped to different markets. We consider two cases. In our TAX-DIF scenario, non-Coalition firms use the same technology for all production lines, but can use different factor employment shares when producing for each market. In this case, BCAs (with endogenous embodied emissions calculations) effectively apply the Coalition CO₂ price to emissions from non-Coalition export production. As such, in response to BCAs, firms are able to substitute among energy commodities (including Electricity) and between aggregate energy and other inputs. In our analysis, implied emissions charges on direct fossil fuel use are directly related to CO₂ emissions from each fuel, and we calculate the BCA-implicit charge on Electricity use based on emissions embodied in Electricity. As such, BCAs do not influence the composition of fossil fuel use in Electricity generation. An alternative assumption is that Energy-intensive producers are able to influence electricity generation choices. In this situation, BCAs would directly influence Electricity generation choices. We do not consider this alternative.

Non-Coalition firms use one (aggregate) production line for goods shipped to all markets in our TAX-AGR scenario. Under this assumption, BCAs effectively apply a carbon price equal to αpc (where α is the share of non-Coalition Energy-intensive production exported to the Coalition) to emissions from non-Coalition Energy-intensive production. Embodied emissions calculations and α are determined endogenously in our TAX-AGR scenario. Like in our TAX-DIF scenario, the BCA-implicit charge on Electricity use is based on emissions embodied in Electricity.

Our final scenario (CAT-2) implements a non-Coalition cap-and-trade policy that includes all sectors (in addition to a Coalition cap-and-trade policy). The non-Coalition emissions cap is set so as to eliminate leakage. Although it is unlikely that such a policy will be implemented by the non-Coalition in the near future, this scenario provides a useful yardstick for our BCA simulations. In the CAT-2 scenario, the non-Coalition is able to take advantage of cheap abatement options in all sectors, not just those in Energy-intensive industry.

3. RESULTS

Table 1 presents welfare changes (without accounting for climate benefits from reduced GHG emissions), CO₂ prices, output changes and leakage rates for each scenario. Welfare changes, measured as annual equivalent variation incomes changes, and output changes are expressed as proportional changes relative to our 2020 reference. In the CAT-1 scenario, an emissions price of \$112 per metric ton of CO₂ (tCO₂) is required to reduce emissions to 20% below 2004 levels. The emissions constraint reduces welfare by 0.59% in the Coalition and 0.19% in the non-Coalition. Energy-intensive output decreases by 4% in the Coalition and increases by 7% in the non-Coalition. The leakage rate indicates that non-Coalition CO₂ emissions increase by 25 tons for every 100 tons of CO₂ abated in the Coalition.

In the TRF-EXG scenario, based on reference embodied emissions, the Coalition imposes a 12.5% tariff on Energy-intensive imports from the non-Coalition. The increase in Coalition welfare and decrease in non-Coalition welfare in this scenario, relative to the

CAT-1 scenario, is driven by a large movement in the terms-of-trade in favor of the Coalition. As the tariff encourages Energy-intensive production in the Coalition, the Coalition emissions price increases to \$116/tCO₂. Relative to the reference scenario, the tariff induces a 1% increase in Energy-intensive output in the Coalition and a 3% decrease in the non-Coalition. As a result, leakage decreases to 16% (from 25% in the CAT-1 scenario). The tariff on Energy-intensive imports in our TRF-END scenario (13.5%) is similar to that in the TRF-EXG scenario, as carbon tariffs cause only a small decrease in non-Coalition energy prices. Consequently, results are similar across the two tariff scenarios.

Firms view the carbon tariff as a CO₂ tax and operate a separate production line for goods shipped to the Coalition in our TAX-DIF scenario. Under these assumptions, non-Coalition producers reduce the CO₂ intensity of exports, in addition to reducing exports to the Coalition. As a result, there is a small reduction in the leakage rate in the TAX-DIF scenario relative to the two tariff scenarios. Also relative to our tariff scenarios, Coalition welfare deteriorates and non-Coalition welfare improves, as terms-of-trade movements are smaller in the TAX-DIF scenarios than in the tariff scenarios.

The lowest BCA leakage rate (5.1%) is observed for the TAX-AGR scenario. In this scenario, as noted above, αpc is effectively applied to non-Coalition Energy intensive production for all markets. The lower leakage rate for TAX-AGR compared to TAX-DIF is driven by the convexity of implied marginal abatement cost functions. To see this, let $f(A)$ denote marginal abatement cost as a function of the quantity of emissions abated per unit of Energy-intensive output, where $f'(A) > 0$ and $f''(A) > 0$. It follows that $g'(pc) > 0$

and $g''(pc) < 0$, where $g = f^{-1}$. The quantity of emissions abated in the TAX-DIF scenario, A^{DIF} , is $g(pc)y_{NC}$, where y_{NC} is the quantity of non-Coalition Energy intensive exports shipped to the Coalition. The quantity of emissions abated in the TAX-AGR scenario, A^{AGR} , is $g(apc)(y_{NC} + y_{NN})$, where y_{NN} is the quantity of non-Coalition Energy-intensive production sold in the non-Coalition. Noting that $\alpha = y_{NC}/(y_{NC} + y_{NN})$, $A^{AGR} = \frac{1}{\alpha}g(apc)y_{NC}$. From $g'(pc) > 0$ and $g''(pc) < 0$, it follows that $g(\alpha) > \alpha g(1) + (1 - \alpha)g(0)$. Further noting that $g(0) = 0$ (i.e., if the emissions price is zero, abatement will also be zero) yields $A^{AGR} = \frac{1}{\alpha}g(apc)y_{NC} > A^{DIF} = g(pc)y_{NC}$. Put simply, when marginal abatement cost curves are convex, a small carbon price applied to multiple processes induces a larger decrease in emissions than a large carbon price applied to a single process.

Non-Coalition welfare is lower in the TAX-AGR scenario than in the TAX-DIF simulation, as the TAX-AGR scenario places an additional constraint on non-Coalition producers. Conversely, Coalition welfare is higher in the TAX-AGR scenario than under the TAX-DIF assumptions, as Coalition exports to the non-Coalition increase. Although the reduction in leakage is largest in the TAX-AGR scenario, this scenario also results in the lowest level of Energy-intensive industry production in the Coalition across all BCA scenarios.

In our final scenario, CAT-2, a non-Coalition emissions price of \$2/tCO₂ is required to eliminate leakage, and there are only small changes in welfare and Energy-intensive output compared to the CAT-1 scenario. These results reflect the fact that leakage is a very small proportion of global emissions – in the CAT-1 scenario, leakage to the Coalition represents 2% of global emissions. Consequently, while BCAs can

significantly reduce leakage they have a minor impact on global emissions, and leakage can be eliminated by modest non-coalition mitigation measures.

Sensitivity Analysis

Key parameters in our analysis include elasticities of substitution in the Armington specification. We examine the sensitivity of our results to these parameters by multiplying Armington elasticities by 0.5 and 2 (except Armington elasticities for Crude oil and Gas). We also report results when the Armington multiplier is 1, to facilitate comparison with our base results. Leakage rates for alternative Armington multipliers are presented in figure 2. Larger Armington elasticities result in larger leakage rates, as Coalition climate policy induces a larger shift in demand toward non-Coalition production when substitution possibilities are greater. For all elasticity specifications, the leakage rate is lowest in the TAX-AGR scenario, and the leakage rate is negative in this scenario when the Armington multiplier is 0.5.

Welfare changes for alternative Armington elasticities (which are not reported due to space constraints), indicated that, in general, larger Armington elasticities decrease Coalition welfare and increase non-Coalition welfare. These results are driven by terms-of-trade movements that favor the Coalition, which are a decreasing function of Armington elasticity values. In all Armington specifications, as in our base scenarios, global welfare is higher in the TAX-AGR scenario than in other BCA scenarios, but global welfare is highest in the CAT-2 simulation. In general, the ordering of scenarios in

terms of leakage and welfare costs is unaffected by alternative Armington elasticity values.

5. Conclusions

Leakage and competitiveness concerns arising from climate policies implemented by a subset of nations have been the source of a considerable political debate. BCAs have emerged as a likely remedial measure. However, despite discussion of BCAs in policy circles, details concerning the operation of BCAs are vague.

An important feature of BCAs is the calculation of emissions embodied in imports, and how firms might respond to BCAs. We assumed that embodied emissions were calculated as the sum of direct emissions and indirect emissions from electricity, and considered the impact of BCAs on energy-intensive imports under alternative responses by non-Coalition firms. Our analysis showed that the impact of BCAs on leakage and production varied significantly for different assumptions. When firms viewed BCAs as an emission tax and operated a separate production line for each market, BCAs reduced leakage by about one-third. When non-Coalition firms operated a single production line for all markets, firms utilized low-cost abatement options in all Energy-intensive production and leakage fell by 80%.

Simulations that generated the lowest leakage rates also resulted in the lowest increase in Coalition energy-intensive production, relative to a scenario with a Coalition cap-and-trade policy without BCAs. As the response of non-Coalition producers to BCAs will be influenced by embodied emissions legislation, these results indicate that

policymakers face a tradeoff between leakage and competitiveness concerns. To the extent that terms-of-trade changes simulated in our model are plausible, the results also suggest the specifics of BCA legislation will have a large influence on welfare impacts.

We also considered a case where leakage was eliminated by a cap-and-trade policy in the Coalition. As leakage from the Coalition to the non-Coalition represents a small proportion of global emissions, the CO₂ price in this scenario was around \$2/tCO₂. This result indicates that leakage could be eliminated by modest emissions mitigation measures by the non-Coalition. As near-term emissions constraints in the non-Coalition are unlikely, modest efficiency improvements in this region may be a more practical way to offset leakage. A global agreement binding the non-Coalition to such measures would encourage non-Coalition producers to take advantage of low-cost mitigation options in all sectors, and avoid inefficiencies associated with border measures. In this regard, BCAs may serve as a coercion device in global climate policy negotiations.

A caveat to our analysis is that we did not consider legal issues surrounding BCAs. The consensus in the literature examining the legality of BCAs is that tariffs on embodied emissions may be permissible under World Trade Organization (WTO) provisions for border tax adjustments (Goh 2004, Bhagwati and Mavroidis 2007, Ismer and Neuhoﬀ 2007, and Green and Epps 2008). However, as a BCA complaint has yet to be lodged with the WTO's Dispute Settlement Body, the legality of alternative embodied emissions regulations is unclear.

References

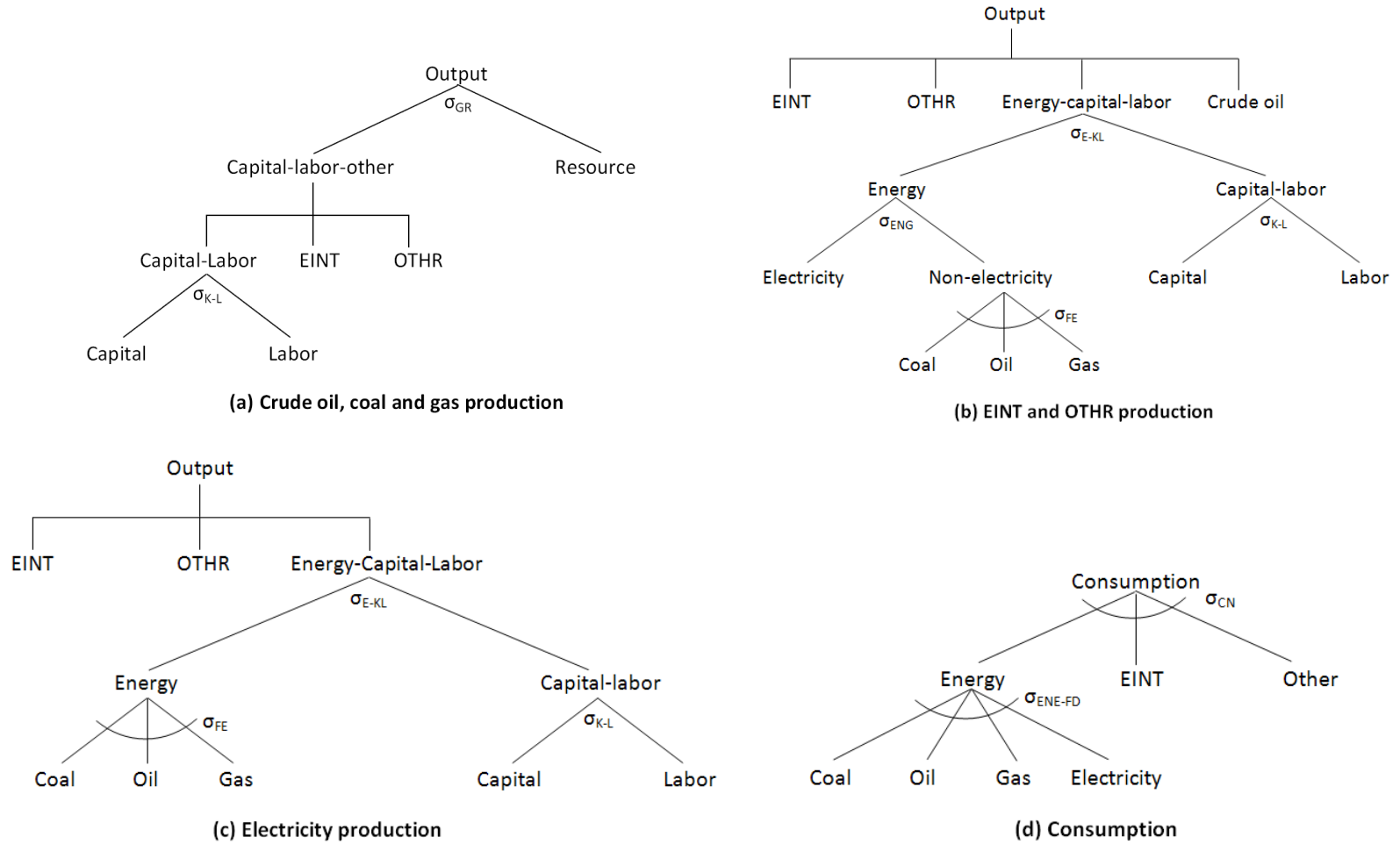
- Babiker, M.H. and T.F. Rutherford, 2005. "The Economic Effects of Border Measures in Subglobal Climate Agreements." *The Energy Journal* 26(4):99-125.
- Brown, D., 1987. "Tariffs, the Terms of Trade, and National Product Differentiation." *Journal of Policy Modeling* 9(3):503-26.
- Bhagwati, J. and P.C. Mavroidis, 2007. Is Action Against US Exports for Failure to Sign the Kyoto Protocol WTO Legal? *World Trade Review*, 6:299–310.
- Burniaux, J-M, J. Chateau, and R. Duval, 2010. "Is there a Case for Carbon-Based Border Tax Adjustments? An Applied General Equilibrium Analysis." Economics Department Working Paper No. 794, OECD.
- Demailly, D., and P. Quirion, 2008. "European Emissions Trading Scheme and Competitiveness: A Case Study on the Iron and Steel Industry." *Energy Economics* 30(4):2009-27.
- Felder, S. and T.F. Rutherford, 1993. "Unilateral CO₂ Reduction and Carbon Leakage." *Journal of Environmental Economics and Management* 25(2):163-176.
- Goh, G., 2004. "The World Trade Organization, Kyoto and Energy Tax Adjustments at the Border." *Journal of World Trade* 38(3):395–423.
- Green, A., and T. Epps, 2008. "Is there a Role for Trade Measures in Addressing Climate Change?" *UC Davis Journal of International Law and Policy* 15(1):1-31.
- Hertel, T., D. Hummels, M. Ivanic and R. Keeney, 2007. "How Confident can we be of CGE-Based Assessments of Free Trade Agreements?" *Economic Modelling* 24(4):611-635.

- Ismer, R. and K. Neuhoﬀ, 2007. “Border Tax Adjustment: A Feasible Way to Support Stringent Emissions Trading.” *European Journal of Law and Economics* 24(2):137-164.
- Mattoo, A., A. Subramanian, D. van der Mensbrugghe and J. He, 2009. “Reconciling Climate Change and Policy,” World Bank Policy Research Working Paper no. WPS 5123.
- Narayanan, B.G. and T.L. Walmsley, eds. 2008. *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. Center for Global Trade Analysis, Purdue University.
- Paltsev, S., J. Reilly, H.D. Jacoby, R.S. Eckaus, J. McFarland, M. Sarofim, M. Asadooria and M. Babiker, 2005. “The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4.” Joint Program on the Science and Policy of Global Change, Report No. 125, Massachusetts Institute of Technology.
- Ponssard, J-P. and N. Walker, 2008. “EU Emissions Trading and the Cement Sector: A Spatial Competition Analysis.” *Climate Policy* 8(5):467-93.
- Rutherford, T.F. and M. Babiker, 1997. “Input-Output and General Equilibrium Estimates of Embodied Carbon: A Dataset and Static Framework for Assessment.” Economics Discussion Paper 97-02, University of Colorado, Boulder.
- Rutherford, T.F. and S. Paltsev, 2000. “GTAP-Energy in GAMS: The Dataset and Static Model.” Economics Discussion Paper 00-02, University of Colorado, Boulder.

Winchester, N., S. Paltsev and J.M. Reilly, 2010. “Will Border Carbon Adjustments work?” Joint Program on the Science and Policy of Global Change, Report 184, Massachusetts Institute of Technology.

US Congress, 2009. “The American Clean Energy and Security Act of 2009 (H.R. 2454)”
US House of Representative, Washington, DC.

Figure 1. Production and consumption nesting structures



Note: Vertical lines signify a Leontief structure where the elasticity of substitution is zero. $\sigma_{GR} = 0.6$, $\sigma_{K-L} = 1$, $\sigma_{E-KL} = 0.5$, $\sigma_{ENG} = 0.5$, $\sigma_{FE} = 1$, $\sigma_{CN} = 0.25$ and $\sigma_{ENE-FD} = 0.5$.

Table 1. Welfare, CO₂ prices, Output and Leakage

	CAT-1	TRF-EXG	TRF-END	TAX-DIF	TAX-AGR	CAT-2
<i>Welfare change relative to reference (EV, %):</i>						
Coalition	-0.59	-0.48	-0.47	-0.52	-0.40	-0.59
Non-Coalition	-0.19	-0.50	-0.52	-0.41	-0.57	-0.22
Global	-0.44	-0.49	-0.49	-0.48	-0.46	-0.45
<i>CO₂ price (2004\$/tCO₂):</i>						
Coalition	112.33	115.59	115.80	114.67	113.76	113.09
Non-Coalition	-	-	-	-	-	2.36
<i>Energy-intensive output change relative to reference (%):</i>						
Coalition	-4.1	1.1	1.5	-0.4	-3.2	-3.8
Non-Coalition	7.4	-3.8	-4.6	-0.8	4.7	6.4
<i>Leakage (%):</i>						
Global	24.8	16.3	15.7	15.1	5.1	0.0

Figure 2. Leakage rates for alternative Armington elasticity multipliers (%)

