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Comparing Policies to Combat Emissions Leakage: Border Tax Adjustments versus Rebates

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Abstract

We explore conditions determining which anti-leakage policies might be more effective complements to domestic GHG emissions regulation. We consider four policies that could be combined with unilateral emissions pricing to counter effects on international competitiveness: a border tax on imports, a border rebate for exports, full border adjustment, and a domestic production rebate. While all have the potential to support domestic production, none is necessarily effective at mitigating emissions leakage. Nor is it possible to rank order the options. In each case, the effectiveness depends on the relative emissions rates, elasticities of substitution, and consumption volumes.

Key Words: environmental tax, rebate, border tax adjustment, emissions leakage, climate

JEL Classification Numbers: Q2, Q43, H2, D61

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Introduction

A major stumbling block toward adopting significant policies for reducing greenhouse gas (GHG) emissions has been concern over the lack of emissions pricing on the part of key trade partners. If emissions regulation raises prices for domestic producers, the loss of competitive advantage would lead to the displacement of production and thereby emissions abroad. Currently, the United States, Japan, and the EU are significant net importers of embodied CO2 emissions, while China and India are significant net exporters (Peters and Hertwick, forthcoming), and fears are mounting that unilateral carbon pricing will exacerbate this situation. As a consequence, interest has been growing in policies that have the potential to combat leakage.

A popular option is border tax adjustment (BTA), which typically implies taxing imports according to the emissions associated with their production, at the same price as faced by domestic producers. This idea has support in the U.S. electricity industry (Morris and Hill 2007). For example, the Lieberman / Warner bill (S. 2191 "America's Climate Security Act")

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incorporates a requirement for purchasing “international reserve allowances” to cover goods imported from countries that have not undertaken adequate steps to mitigate GHG emissions (Section 1311). The allowance requirement is based on the national (foreign) energy intensity of production in that sector, but is reduced by the share of emissions for which the domestic U.S. sector receives free allocation of allowances. The Bingaman / Specter bill (S. 1766 “Low Carbon Economy Act”) includes a weak form of BTA, by requiring importers to have emissions permits when the emissions in the unregulated (or underregulated) producing country sector increase above a baseline level. The idea of border adjustment of carbon pricing is also gaining advocates in Europe (e.g., Godard 2007; Grubb and Neuhoff 2006), as the EU is preparing the next phase of the Emissions Trading System (ETS) and considering options in the absence of a major international agreement to cap greenhouse gas emissions.

However, many trade law experts have concerns that such import taxes may not be compatible with WTO obligations, since they attempt to regulate production processes rather than product qualities. Similarly, export rebates of emissions payments might be viewed as a subsidy, which can also be restricted by trade law. A large number of studies have focused on the interactions between domestic climate policy and WTO law, which the next section will review.

Still, few people have challenged the notion that such import taxes would, if allowed by international law, be appropriate and effective. Conceptually, however, there are several unilateral policy options for dealing with the relative price changes that cause leakage. Import taxes level the playing field for domestic consumption, but do nothing abroad. Border rebates for exports keep the playing field level abroad, but still give imports a competitive advantage at home. Full border adjustment policies combine these two measures, much like value-added taxes are implemented, such that only the emissions from domestic consumption are taxed.

A final option is to mitigate the impacts of emissions regulation on domestic production costs by offering rebates to all domestic production, not just exports; we will refer to this type of policy as the “home rebate.” Such a policy could equivalently be implemented using rate-based mechanisms for regulation or emissions permit allocation (e.g., tradable performance standards or output-based allocation with updating; Fischer 2001). The Lieberman / Warner bill variants have incorporated similar mechanisms by allocating emissions allowances among firms in energy-intensive sectors in proportion to their employment or according to electricity use. The home rebate keeps the playing field level at home and abroad, but at the expense of opportunities to reduce emissions by reducing consumption.

Indeed, while all these policies have the potential to mitigate leakage, it is not clear that they would necessarily be effective. This paper explores the conditions that determine which anti-leakage policies are most effective complements to domestic GHG emissions regulation. It reveals that none of these policies *necessarily* reduces leakage. Nor is it possible to rank order the options. In each case, the effectiveness depend on the relative emissions rates, elasticities of substitution, and consumption volumes.

Background

Stiglitz (2006) has argued that not pricing the global external costs of carbon emissions is a *de facto* domestic subsidy that should allow for countervailing duties. While this argument may make economic sense, global trade law is unlikely to accept that absence of regulation would be an actionable subsidy under the SCM Agreement governing Subsidies and Countervailing Measures (see, e.g., Bagwati and Mavroidis 2007; Green 2006). Still, no clear opinion exists on the use of trade measures to support the integrity of climate policies, as they have neither been explicitly negotiated nor tested in the dispute settlement process.

Fischer et al. (2004) note that the legal institutions for international trade do not formally recognize certain fundamentals of environmental economics. One is the polluter pays principle, by which the efficient allocation of resources in the long run is achieved by ensuring the polluting party bears the economic burden of the environmental costs. A sovereign nation cannot be forced to incorporate the global environmental costs of its activities. Nor can one country necessarily incorporate those costs into its imports from another country; agreements to limit tariffs have been designed with the goal of reducing protectionism, and they are wary of allowing exceptions tantamount to regulating production processes in other countries. A second overlooked principle is the economic equivalence of emission tax and permit regimes. Both introduce an emissions price as a market mechanism for incentivizing pollution reduction; however, one is a tax while the other is a regulation, and they have different legal implications.

As a result, for global pollution problems, the GATT may create some barriers to implementing economically justified policies to prevent emissions leakage from more stringently regulated countries. On the other hand, if that is so, some design options might pass legal muster.

Legal analysis of BTA

There are several good reviews of the compatibility of GATT/WTO law with climate policy in general and border adjustment options in particular. Pauwelyn (2007), Brewer (2008), Kommerskollegium (2004), Zhang and Assuncao (2001), Sampson (1998), and Esty (1994) take a primarily legal view. Hoerner and Muller (1997), Fischer et al. (2004), Ismer and Neuhoff (2004) add an economic perspective. de Cendra (2006) and van Asselt and Biermann (2007) focus on options for incorporating BTA into the EU ETS in a manner that could be WTO-compatible.

The law on border tax adjustment has evolved with major consumption taxes in mind. For example, governments include imports in and exempt exported goods from indirect taxes, such as a value-added tax (VAT) or sales tax, which are designed to be paid by consumers in the country of destination. The GATT permits adjustment at the border for indirect taxes on "like" products, but not for direct taxes, such as income tax or emissions tax, which are imposed on factors of production in the country of origin. The issue becomes murkier looking at taxes on products used in the production process. The GATT Subsidies Code initially specified that taxes on inputs to production are border-adjustable only when the goods are "physically incorporated" into the exported products. A revision in the Uruguay Round broadened the category of adjustable taxes to allow export rebates for indirect taxes on goods and services if they are "consumed" in the production of the exported product: "in addition to physically incorporated inputs, export rebates are permitted on "energy, fuels and oil used in the production process." Thus, for example, a gasoline tax that may have environmental purposes would be adjustable, because energy is a qualifying material input in the exported products. But an environmental tax on noxious emissions would not be adjustable because pollution is a "disincorporated material output." However, for policies concerning energy or greenhouse gas emissions, it is still unclear whether specific taxes on energy are adjustable, and if so, whether adjustments may only be applied to exports and not to imports. Furthermore, any adjustment that would be allowed would be limited by the taxes imposed on domestic products.

Even if they were ruled to be discriminatory, an argument could be made for justifying border adjustments on imports under Article XX, the general exceptions clause (Kommerskollegium 2004, Pauwelyn 2007, Sampson 1998). Three exceptions in that clause may be relevant for building that case: "(b) necessary to protect human, animal or plant life or health;… (d) necessary to secure compliance with laws or regulations which are not inconsistent with the provisions of this Agreement...; (g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption." The latter exception may be particularly relevant for energy products and for the climate. Still, acceptance of such arguments is not assured.

Pauwelyn (2007) also argues that an expansion of the law to allow for border adjustability for carbon taxes does not necessarily imply that regulations are adjustable: "Indeed, The Agreement on Subsidies and Countervailing Measures only allows adjustment upon exportation (i.e. rebates) for taxes or duties, not for regulations" (p27). Thus, it may be difficult to use a tax to adjust a cap-and-trade system at the border, particularly for rebates. However, one might still be able to extend carbon regulation to imports. Some case law indicates that if the regulations are deemed to be sufficiently product-related, an argument for comparable requirements for imports could be made. Morris and Hill (2007) make a similar point, that while a border adjustment tax would likely not be WTO compatible, an emissions permit requirement for imports should be. Brewer (2008) concurs that an emissions permit purchase requirement for imports is more likely to qualify as an environmental regulation allowable under the Article XX(g) exception.

Scholars raise other complications for what level of BTA might be allowed. One challenge is calculating the carbon content of imports in a way that does not discriminate against them. The National Treatment principle embedded in Article III requires that the tax burden on imports not be heavier than that on like domestic products (Kommerskollegium 2004). Thus, without clear and comparable metrics, it may be difficult to require payments for actual embodied emissions if they exceed the payments made for like domestic products. Pauwelyn (2007) proposes the option of using the emissions associated with the predominant method of production in the U.S. Alternatively, one might use a benchmark of the best available technology (BAT); Pauwelyn (2007), Godard (2007) and Ismer and Neuhoff (2004) argue that this metric is likely to be allowed, but it is a weaker adjustment factor and would therefore be less effective. Indeed, from an economic perspective, one would *want* to discriminate against more emissions-intensive imports.

Another challenge is permit allocation. de Cendra (2006) and Hepburn (2006) argue that auctioning may be a prerequisite for BTA, since the free allocation of permits through grandfathering might then appear to be an unfair subsidy. Similarly, Pauwelyn (2007) points out that adjustment taxes on imports would likely have to be reduced in proportion to the free allocation of emissions permits to comparable sectors in the U.S. These legal arguments run counter to the fact that grandfathering permits has little economic incentive effect, being a transfer.

Most of the restrictions that multilateral trade agreements pose for market-based climate policies remain speculative at this point. As Fischer et al. (2004) summarize, a confluence of several events must occur for these speculations even to be tested. Emissions taxes and tradable permit systems must be sufficiently widespread and/or stringent as to have significant effects on export industries for offsetting policies to be called for. For those aspects of climate policy to be challenged under the GATT, a member country must show not only inconsistency with some rule but also harm from the resulting trade impacts. Furthermore, to prove that the policy is not worthy of exception under Article XX, the complainant must show that a less trade-restrictive policy option is available and effective, or possibly even that the policy does not contribute toward achieving a reasonable climate goal at all.

Even if some measures would be considered illegal under WTO law, Sampson (1998) notes that future climate agreements can still provide for them without problem, as long as Parties to the Agreement voluntarily agree to forgo their WTO rights. Still, this former Director of the Trade and Environment Division of the WTO calls for revisiting of key WTO provisions for clarification.

Economic Analysis of BTA

Economic analysis of border adjustment policies is rooted in the effects of climate policy on “competitiveness,” a broad term that can encompass changes in trade flows, terms of trade, carbon leakage, and domestic economic indicators like employment or production. Reinaud

(2005), in a review of the potential competitiveness impacts of the EU ETS on energy intensive industries, defines competitiveness for her purposes as “the firm’s ability to maintain and/or expand market position based on its cost structure.”[1] We will similarly focus on changes in production in this study. However, Aldy and Pizer (2008) find that only a portion of the production loss is due to changes in international competitiveness; the majority of the production response to energy price increases reflects reduced consumption.

Grubb and Neuhoff (2006) review issues in the design of the first phase of the EU ETS and, looking toward future phases, they raise three options to address competitiveness issues and protect the security of low-carbon investments. The first is to negotiate international agreements for all major competitors to engage in similar carbon-reducing efforts in their mobile, energy intensive sectors. Second, in the absence of such agreements, they propose the use of border tax adjustments. The third option is to employ output-indexed allocation of emissions allowances.

Each of these options has been explored individually by economists, many using similar multi-country, multi-sector static general equilibrium models based on GTAP-E. For example, Babiker and Rutherford (2005) compare a reference case of Kyoto-style emissions targets without border adjustment to adjustment measures including import tariffs, export rebates, exemption of energy-intensive industries, and voluntary export restraints on the part of noncoalition countries. They focus on the impacts by country (rather than by sector) and find that the exemptions produce the least leakage overall but are associated with higher carbon

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[1] p. 17

prices, while from a welfare perspective, most countries prefer tariffs. Peterson and Schleich (2007) investigate border tax adjustment options for the EU ETS, concentrating on the calculation of the carbon content for imports, which affects the stringency of the border tax. Fischer and Fox (2007a, 2007b) investigate designs for domestic rebate programs, combining output-based allocation of emissions permits (revenues) with an emissions pricing program. Their model also considers interactions with labor tax distortions, and they show that output-based rebating (designed appropriately) can generate lower leakage and higher welfare than grandfathering and even than auctioning in some circumstances.

Other papers have analyzed leakage in specific sectors. Demailly & Quirion (2008) use a detailed spatial model of the cement industry to compare two combinations of a CO2 tax with BTA. In the first case, the BTA is based on actual emissions intensities, both for export rebates and for import taxes. In the second scenario, the BTA corresponds to the best-available technology, with rebates given according to the least CO2-intensive technology available at a large scale, and imports are taxed to the same level. They find that carbon leakage decreases in both cases and foreign emissions even decrease in the first case. However, BTA also causes the cement price in the regulated countries to increase, further impacting their cement consumers. Demailly & Quirion (2006) perform some similar analysis for the iron and steel industry and include updating allocation options; they find little competitiveness effect from the EU ETS. Gielen and Moriguchi (2002) simulate the effects of carbon pricing on the Japanese iron and steel industry, finding leakage rates of 70% and calculating the import tariffs needed to balance that.

While economic modelers have addressed particular trade-related and allocation-related options for addressing leakage individually, no one has compared them comprehensively. The goal of this paper is to do this in an intuitive and transparent fashion. The next section introduces a simple two-country partial equilibrium model to illustrate the incentive effects of the different policies. The subsequent section parameterizes that model for the key sectors likely to be covered by a carbon policy. Results are presented for the U.S. and Canada, with some sensitivity analysis using alternate scenarios, followed by discussion, caveats, and directions for further research.

Model

The basic issues of international emissions leakage can be addressed with a partial-equilibrium model. We evaluate some proposed border-adjustment policies for their ability to enhance the global effectiveness of a domestic emissions pricing policy. We also assess the extent to which the policy options change domestic production, as an indicator both of the cost of the regulation and of pressures for protection. Incentives to manipulate terms of trade will be left for future research.

Consider two countries, Home and Foreign. Home produces good H at a per-unit cost $c_H(r_H)$ that rises with reductions r_H from its baseline emissions rate e_H^0. Foreign produces good F at a per-unit cost c_F, which does not depend on its emission rate, since it does not have an incentive to reduce emissions. Producers are perfectly competitive. Global emissions are $E = (e_H^0 - r_H)H + e_F F$.

Each country has a representative consumer that demands some of each good. Let home and foreign consumption of good *H* and be *h* and *x* (exports), respectively, and let home and foreign consumption of good *F* be *m* (imports) and *f*. Demand for each good depends on the consumer prices of each good in the country of consumption: $h(p_H, p_M)$, $m(p_H, p_M)$, $x(p_X, p_F)$, and $f(p_X, p_F)$.

In the market equilibrium,

$$\begin{aligned} H &= h(p_H, p_M) + x(p_X, p_F) \\ F &= f(p_H, p_M) + m(p_X, p_F) \end{aligned}$$

Furthermore, in the absence of any emissions policy,

$$\begin{aligned} p_H &= p_X = c_H^0 \\ p_F &= p_M = c_F \end{aligned}$$

Let us assume constant elasticity of demand functions, so

$$\begin{aligned} h &= \alpha_h {p_H}^{\eta_{hH}} {p_M}^{\eta_{hM}} \\ m &= \alpha_m {p_H}^{\eta_{mH}} {p_M}^{\eta_{mM}} \\ x &= \alpha_x {p_X}^{\eta_{xX}} {p_F}^{\eta_{xF}} \\ f &= \alpha_f {p_X}^{\eta_{fX}} {p_F}^{\eta_{fF}} \end{aligned}$$

Own-price elasticities are negative, while cross-price elasticities are assumed to be positive. With this formulation, $dh = \eta_{hH} h \frac{dp_H}{p_H} + \eta_{hM} h \frac{dp_M}{p_M}$, etc.

Our metric of home competitiveness is the change in domestic production. Simplifying, we get

$$dH = h\left(\eta_{hH}\frac{dp_H}{p_H} + \eta_{hM}\frac{dp_M}{p_M}\right) + x\left(\eta_{xX}\frac{dp_X}{p_X} + \eta_{xF}\frac{dp_F}{p_F}\right)$$

From a policy effectiveness point of view, however, the change in global emissions is what matters, and

$$dE = (e_H^0 - r_H)\left(h\left(\eta_{hH}\frac{dp_H}{p_H} + \eta_{hM}\frac{dp_M}{p_M}\right) + x\left(\eta_{xX}\frac{dp_X}{p_X} + \eta_{xF}\frac{dp_F}{p_F}\right)\right) + e_F\left(m\left(\eta_{mH}\frac{dp_H}{p_H} + \eta_{mM}\frac{dp_M}{p_M}\right) + f\left(\eta_{fX}\frac{dp_X}{p_X} + \eta_{fF}\frac{dp_F}{p_F}\right)\right) - dr_H H$$

Policy Options

Next, let us evaluate different policies for controlling emissions leakage from a domestic emissions pricing program. In each case, an emissions price t will be imposed, so the baseline scenario will be a policy that uses that price alone. Furthermore, since we are evaluating the imposition of the full policies, rather than a marginal increase in the rate, we assume $dt = t$ and $dr_H = r_H$.

Emissions Price Alone

In principle, an emissions price can be implemented either by a tax or a cap-and-trade program. For our purposes, let us model the policy as a carbon tax (“Ctax”), to operate with a consistent price across scenarios.

With an emissions price *t* in the home country,

$$\begin{aligned} p_H &= p_X = c_H(r_H) + t(e_H^0 - r_H) \\ p_F &= p_M = c_F \end{aligned}$$

In other words, domestically produced goods see their prices rise not only due to changes in their production costs, but also due to the additional emissions payments associated with each unit of output. Prices of foreign produced goods remain unchanged.

The change in global emissions is

$$\begin{aligned} dE_{\text{Ctax}} &= (e_H^0 - r_H)\left(h\left(\eta_{hH} \frac{dp_H}{p_H} \right) + x\left(\eta_{xX} \frac{dp_H}{p_H} \right) \right) + e_F\left(m\left(\eta_{mH} \frac{dp_H}{p_H} \right) + f\left(\eta_{fX} \frac{dp_H}{p_H} \right) \right) - r_H H \\ &= \frac{c_H - c_H^0 + te_H}{c_H^0}\left(e_H\left(\eta_{hH} h + \eta_{xX} x \right) + e_F\left(\eta_{mH} m + \eta_{fX} f \right) \right) - r_H H \end{aligned}$$

where $e_H = (e_H^0 - r_H)$ is shorthand for the home emissions rate in the presence of the emissions price. Thus, the home good price increase causes substitution effects across all goods, with corresponding emissions changes.

The change in domestic production is

$$dH_{\text{Ctax}} = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\eta_{hH} h + \eta_{xX} x \right)$$

Border Adjustment for Imports

This policy attempts to level the playing field between the home good and imports for domestic consumption, by ensuring that imports are equally penalized for the emissions associated with their production. Let this import tax policy be denoted by the subscript "ImpTax". It combines an emissions price in the home country with a tax on the emissions "embodied" in imports of the foreign good into the home country. Since the definition of embodied emissions is also a policy choice, we denote the defined emissions intensity as $\hat{e}_F$. In the base case, $\hat{e}_F = e_F$, the actual emissions intensity. However, many of the proposed BTA policies that are thought to be WTO-compatible involve a smaller border tax. Some propose using home emissions intensity ($\hat{e}_F = e_H$), or best-available technologies. The Bingaman-Specter proposal only imposes the tax on embodied emissions above some baseline (essentially, $\hat{e}_F = e_F - e_F^0$).

Consequently, the price impacts of this policy are

$$
\begin{aligned}
p_H &= p_X = c_H(r_H) + t(e_H - r_H) \\
p_M &= c_F + t\hat{e}_F \\
p_F &= c_F
\end{aligned}
$$

Simplifying the changes in global emissions, we get

$$
\begin{aligned}
dE_{\text{ImpTax}} &= (e_H^0 - r_H)\left(h\left(\eta_{hH}\frac{dp_H}{p_H} + \eta_{hM}\frac{dp_M}{p_M} \right) + x\left(\eta_{xX}\frac{dp_H}{p_H} \right) \right) \\
&\quad + e_F\left(m\left(\eta_{mH}\frac{dp_H}{p_H} + \eta_{mM}\frac{dp_M}{p_M} \right) + f\left(\eta_{fX}\frac{dp_H}{p_H} \right) \right) - r_H H \\
&= \frac{c_H - c_H^0 + te_H}{c_H^0}\Big(e_H\left(\eta_{hH}h + \eta_{xX}x \right) + e_F\left(\eta_{mH}m + \eta_{fX}f \right) \Big) + \frac{t\hat{e}_F}{c_F^0}\Big(e_H\eta_{hM}h + e_F\eta_{mM}m \Big) - r_H H
\end{aligned}
$$

Thus, we have the same direct effects of the emissions price inducing cost increases in the domestically produced good, plus an additional effect on home and import consumption due to the increased price of imports.

The change in domestic production is then

$$dH_{\text{ImpTax}} = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\eta_{hH} h + \eta_{xX} x\right) + \frac{t\hat{e}_F}{c_F^0}\left(\eta_{hM} h\right)$$

Border Rebate for Exports

Contrary to the border tax on imports, offering a border rebate for exports attempts to level the playing field abroad. This export rebate policy (“ExpReb”) rebates the value of the emissions embodied in exports, so that they do not face a competitive disadvantage in foreign markets, but maintains the full emissions pricing at home:

$$\begin{aligned} p_H &= c_H(r_H) + t(e_H - r_H) \\ p_X &= c_H(r_H) \\ p_F &= p_M = c_F \end{aligned}$$

Simplifying the change in emissions, we get

$$\begin{aligned} dE_{\text{ExpReb}} &= (e_H^0 - r_H)\left(h\left(\eta_{hH} \frac{dp_H}{p_H} \right) + x\left(\eta_{xX} \frac{dp_X}{p_X} \right) \right) + e_F \left(m\left(\eta_{mH} \frac{dp_H}{p_H} \right) + f\left(\eta_{fX} \frac{dp_X}{p_X} \right) \right) - r_H H \\ &= \frac{c_H - c_H^0 + te_H}{c_H^0}\left(e_H \eta_{hH} h + e_F \eta_{mH} m \right) + \frac{c_H - c_H^0}{c_H^0}\left(e_H \eta_{xX} x + e_F \eta_{fX} f \right) - r_H H \end{aligned}$$

Thus, the price change for exports, and the corresponding impacts on emissions from exports and foreign good consumption, are smaller than with the emissions tax alone.

The change in domestic production is then

$$dH_{\text{ExpReb}} = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\eta_{hH} h\right) + \frac{c_H - c_H^0}{c_H^0}\left(\eta_{xX} x\right)$$

Full Border Adjustment

Full border adjustment combines the previous two policies, forgiving the value of the emissions embodied in exports and taxing the emissions embodied in imports. This adjustment essentially turns the emissions price into a destination-based tax, much like most revenue-raising consumption taxes. The corresponding price changes are

$$\begin{aligned} p_H &= c_H(r_H) + t(e_H - r_H) \\ p_X &= c_H(r_H) \\ p_M &= c_F + t\hat{e}_F \\ p_F &= c_F \end{aligned}$$

The changes in emissions due to this combined policy reduce to

$$\begin{aligned} dE_{\text{FullBTA}} &= e_H\left(h\left(\eta_{hH}\,\frac{c_H - c_H^0 + te_H}{c_H^0} + \eta_{hM}\,\frac{te_F}{c_F}\right) + x\left(\eta_{xX}\,\frac{c_H - c_H^0}{c_H^0}\right)\right) \\ &\quad + e_F\left(m\left(\eta_{mH}\,\frac{c_H - c_H^0 + te_H}{c_H^0} + \eta_{mM}\,\frac{te_F}{c_F}\right) + f\left(\eta_{fX}\,\frac{c_H - c_H^0}{c_H^0}\right)\right) - r_H H \\ &= \frac{c_H - c_H^0 + te_H}{c_H^0}\left(e_H\eta_{hH}h + e_F\eta_{mH}m\right) + \frac{c_H - c_H^0}{c_H^0}\left(e_H\eta_{xX}x + e_F\eta_{fX}f\right) + \frac{t\hat{e}_F}{c_F}\left(e_H\eta_{hM}h + e_F\eta_{mM}m\right) - r_H H \end{aligned}$$

These effects are also a combination of those from the border tax and rebate policies, which is also evident when we simplify the effects on domestic production.

$$dH_{\text{FullBTA}} = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\eta_{hH} h\right) + \frac{c_H - c_H^0}{c_H^0}\left(\eta_{xX} x\right) + \frac{t\hat{e}_F}{c_F}\left(\eta_{hM} h\right)$$

Home Rebate

The full home rebate ("HomeReb") directs the full value of the emission rents to be rebated to producers of the home good, whether for domestic consumption or exports. In other words, while the emissions price induces reductions in the emissions rate, the tax is not imposed on the emissions embodied in an additional unit of output:

$$\begin{aligned} p_H &= p_X = c_H(r_H) \\ p_F &= p_M = c_F \end{aligned}$$

This policy mimics an intensity-based regulation, and can be implemented that way, or by output-based rebating of emissions payments (as in the Swedish NOx tax-rebate program), or by rate-based allocation of emissions permits in a cap-and-trade policy (see Fischer 1999; Fischer and Fox, forthcoming). Because it does not tax embodied emissions, this policy is only effective to the extent opportunities exist to reduce emissions in production processes, as opposed to reducing consumption of the good.

Simplifying the change in global emissions, we get

$$\begin{aligned} dE_{\text{HomeReb}} &= (e_H - r_H)\left(h\left(\eta_{hH}\frac{dp_H}{p_H}\right) + x\left(\eta_{xX}\frac{dp_H}{p_H}\right)\right) + e_F\left(m\left(\eta_{mH}\frac{dp_H}{p_H}\right) + f\left(\eta_{fX}\frac{dp_H}{p_H}\right)\right) - r_H H \\ &= \frac{c_H - c_H^0}{c_H^0}\Big(e_H\left(\eta_{hH} h + \eta_{xX} x\right) + e_F\left(\eta_{mH} m + \eta_{fX} f\right)\Big) - r_H H \end{aligned}$$

Thus, the full rebate mitigates the substitution impacts induced by the increase in the price of the domestically produced good. Like all the policies, it retains the direct effect of emissions rate reductions induced by the emissions price.

The effect on domestic production is

$$dH_{\text{HomeReb}} = \frac{c_H - c_H^0}{c_H^0}\left(\eta_{hH} h + \eta_{xX} x\right)$$

Comparing Anti-Leakage Policies

How do these policies compare in terms of ensuring more genuine emissions reductions globally? A policy *i* will provide additional global emissions reductions if its changes in emissions are smaller (more negative) than those induced by the emissions price alone; that is, if $dE_{\text{Ctax}} - dE_i > 0$. Table 1 presents these additional emissions reductions for each of our policy options.

Table 1: Additional Emissions Reductions of Adjustment Policies

	Additional Emissions Reductions Relative to Carbon Tax Alone
Import Tax	$-\frac{t\hat{e}_F}{c_F^0}\left(\eta_{hM} e_H h + \eta_{mM} e_F m\right)$
Export Rebate	$\frac{te_H}{c_H^0}\left(\eta_{xX} e_H x + \eta_{fX} e_F f\right)$
Full Border Adjustment	$\frac{te_H}{c_H^0}\left(\eta_{xX} e_H x + \eta_{fX} e_F f\right) - \frac{t\hat{e}_F}{c_F}\left(\eta_{hM} e_H h + \eta_{mM} e_F m\right)$
Home Rebate	$\frac{te_H}{c_H^0}\left(e_H\left(\eta_{hH} h + \eta_{xX} x\right) + e_F\left(\eta_{mH} m + \eta_{fX} f\right)\right)$

One thing to notice is that none of the policies address the cost increases due to changes in production methods to reduce emissions ($c_H - c_H^0$); rather, they only impose or remove the carbon tax costs of the remaining emissions associated with production. Thus, an adjustment policy will only offset a large portion of the competitiveness change if these tax costs are large relative to the costs of fuel-switching and improving energy efficiency.

Next, this comparison table makes it apparent that none of these policies *necessarily* reduces leakage. Nor is it possible to rank order the options. In each case, the effectiveness depend on the relative emissions rates and elasticities of substitution.

The border tax on imports reduces emissions relative to the tax if the displaced emissions from fewer imports exceeds the increased emissions from more domestic consumption: $-\eta_{mM} e_F m > \eta_{hM} e_H h$. This result is more likely the larger the elasticity of demand for imports, foreign emission rate, and import volume relative to the domestic emissions rate, home consumption, and the elasticity of home demand with respect to the import price.

The export rebate reduces emissions relative to the tax if the displaced emissions from less foreign consumption exceeds the increased emissions from the additional exports: $\eta_{fX}(e_F f) > -\eta_{xX}(e_H x)$. This result is more likely the greater is the substitutability between exports and the foreign good, the larger are the foreign good emissions, and the more inelastically demanded are exports. The export rebate is more effective than the import tax if the net emissions displaced by the additional exports in the rebate case exceed the net emissions reductions from fewer imports with the import tax:

$$\frac{e_H}{c_H^0}\left(\eta_{xX}e_H x+\eta_{fX}e_F f\right)+\frac{e_F}{c_F}\left(\eta_{hM}e_H h+\eta_{mM}e_F m\right)>0\,.$$

The full border adjustment policy combines the preceding two policies. If each of these policies is effective on its own, then the combination will have less leakage than either an import tax or export rebate alone. If only one of these policies is effective, then that policy dominates full border adjustment, which in turn dominates the ineffective policy.

The full home rebate is effective in its own right if the displaced foreign emissions exceed the additional home emissions: $e_F\left(\eta_{mH}m+\eta_{fX}f\right)>-e_H\left(\eta_{hH}h+\eta_{xX}x\right)$. Furthermore, it provides more reductions than the export rebate if the displaced emissions from fewer imports exceeds the increased emissions from more domestic consumption: $\eta_{mH}e_F m>-\eta_{hH}e_H h$. (This condition differs from that for the import tax being effective, since the different relevant elasticities are those with respect to the home good price, rather than the import price.) This result is more likely, the more sensitive are imports to the home good price, the larger are emissions from imports, and the less price-sensitive is the home good.

Full border adjustment is more effective than the full home rebate if $e_F m\left(-\frac{e_H}{c_H^0}\eta_{mH}-\frac{\hat{e}_F}{c_F}\eta_{mM}\right)>e_H h\left(\frac{e_H}{c_H^0}\eta_{hH}+\frac{\hat{e}_F}{c_F}\eta_{hM}\right)$; that is, if the change in emissions from different import levels exceeds the change in emissions from different home good consumption. Otherwise written, full border adjustment is preferred if $-\frac{t\hat{e}_F}{c_F}\left(\eta_{hM}e_H h+\eta_{mM}e_F m\right)-\frac{te_H}{c_H^0}\left(\eta_{hH}e_H h+\eta_{mH}e_F m\right)>0$. The first term is positive if the border tax on imports is effective, and the second term is positive if the export rebate is preferred to the full home rebate. Thus, we have the obvious result that if both the import tax and export rebate are effective, and the full home rebate is less effective than the export rebate alone, the full border adjustment policy dominates all the others.

Overall, however, little can be said definitively without understanding the relative magnitude of the elasticities, emissions rates, and consumption volumes. *Any* of these policies could potentially dominate. Furthermore, it may be that *none* of the adjustment policies is warranted, such as if demand for foreign produced goods is highly inelastic ($\eta_{mH}, \eta_{mM}, \eta_{fX}$ all close to zero).

From the point of view of domestic production, the story is somewhat clearer. All adjustment policies raise domestic output relative to the tax alone (assuming the substitution elasticities are well behaved). These results ($dH_i - dH_{\text{Ctax}}$, for each policy *i*) are summarized in Table 2.

Table 2: Additional Increases in Domestic Production of Adjustment Policies

	Additional Domestic Production Relative to Tax Alone
Import Tax	$\frac{t\hat{e}_F}{c_F^0}\left(\eta_{hM} h\right)$
Export Rebate	$\frac{te_H}{c_H^0}\left(-\eta_{xX} x\right)$
Full Border Adjustment	$\frac{te_H}{c_H^0}\left(-\eta_{xX} x\right)+\frac{t\hat{e}_F}{c_F}\left(\eta_{hM} h\right)$

Home Rebate	$\frac{te_H}{c_H^0}\left(-\eta_{hH}h-\eta_{xX}x\right)$

Since the border tax and the border rebate each raise domestic production, the full border adjustment dominates either of its single components. However, it does not necessarily dominate the home rebate: $dH_{\text{FullBTA}}-dH_{\text{HomeReb}}=\left(\frac{te_F}{c_F}\left(\eta_{hM}\right)-\frac{te_H}{c_H^0}\left(-\eta_{hH}\right)\right)h$. Both policies mitigate the cost increase for exports, so which policy induces more home production depends on the relative cost changes for imported and domestic goods and whether home good consumption is more sensitive to home or import price changes.

In the next section, we parameterize this model to estimates from different sectors that are likely to be regulated for greenhouse gas emissions.

Simulations

Fischer and Fox (2007) use a computable general equilibrium (CGE) model of global trade (based on GTAP-EG in GAMS) to simulate the effects of a $50/ton C emissions price implemented unilaterally in the U.S. and applied to certain emissions intensive sectors. We utilize these and additional simulations from this complex model to parameterize a simpler model that makes the tradeoffs among border-adjustment policies more transparent.

Specifically, we assume simple functional forms with constant elasticity of substitution, so that the change in production for good *i* (i.e., *h*, *m*, *f*, or *x*) is $\Delta q_i = Q_{i0}\left(\left(\frac{p_i}{p_{i0}}\right)^{\eta_{ii}}\left(\frac{p_j}{p_{j0}}\right)^{\eta_{ij}}-1\right)$, where Q_{i0} is baseline production, p_i and η_{ii} are its own price and elasticity, while p_i and η_{ii} are the relevant cross price and elasticity. We focus here on the covered sectors separately: Electricity (ELE); refined petroleum products (OIL); chemicals (CRP); nonmetallic minerals (NMM), which includes some ceramic production; pulp, paper and print (PPP); and iron and steel (I_S). The cost of these simplifications is that we ignore cross-price and income effects that affect energy demands in other sectors, as well as terms-of-trade effects. However, we calibrate these parameters using the full general-equilibrium results from Fischer and Fox (2007) for the emissions price scenario.[2] An advantage of these simplifications is that, unlike in the complex CGE model, we can easily perform sensitivity analysis.

From the $50/tonC experiment, we derive the emissions intensities, prices, and quantities in response to the carbon price, as well as the predicted leakage in the absence of any adjustment policies. To calculate marginal changes from this new baseline, we then add a small production tax in the covered sectors that raises the prices of h and x by 0.01 percent, which allows us to estimate the elasticities $\eta_{hH}, \eta_{mH}, \eta_{xX}, \eta_{fX}$, reported in Table 9 in the Appendix, as well as the emissions intensities of the changes in foreign production. In this manner, we control for the larger effects of the emissions pricing on the average responses and focus on the marginal responses attributable to production cost changes, which is the mechanism of the adjustment policies. The parameters η_{mM}, η_{hM} were estimated from the same model by imposing increases

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[2] This scenario includes revenue recycling, but in terms of leakage and the changes induced by border adjustments and rebate policies, the results are quite similar to those with emissions permit grandfathering.

in the tariff, on a sector-by-sector basis, by 0.01 percent. Since the foreign good price does not change in our simulations, the elasticities η_{fF}, η_{xF} do not come into play.[3]

In this manner, we focus on the leakage—that is, the change in the foreign sector's emissions as a share of the reduction in the domestic sector's emissions—induced by production price changes in that sector. These effects are distinct from the leakage induced by the overall carbon price, which turns out to be a substantial share of emissions reductions in some sectors (up to 60% in iron and steel). Much of the increase in foreign emissions arises due to the general equilibrium effects of the emissions price, which not only changes the relative prices of manufactured goods, but also drive down fossil fuel prices globally, due to the large-scale withdrawal of demand from the U.S. For example, foreign OIL sector prices fall about 0.5% (while domestic prices rise 4.3%), and similar declines in other fossil fuel prices lead to a small drop in foreign electricity prices, and in turn increase fuel use and emissions abroad. Unlike the carbon price, border adjustments and rebates based on production do little to change relative fuel prices. Thus, these energy price changes remain in the background and are to large extent unavoidable.

Table 3 reports many of the factors that indicate the scope for leakage from the U.S. In the baseline (2001, for the GTAP model), the export intensities of production and import intensities of consumption range from nearly zero for electricity to 15% in some sectors. The

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[3] Even for a large economy like the U.S., foreign price changes are negligible for the covered energy-intensive sectors, with the exception perhaps of petroleum products and electricity.

relative emissions intensity is the emissions intensity of (marginal) foreign production as a percentage of the average emissions intensity of domestic production. For chemicals and pulp and paper, foreign intensities are quite similar to domestic ones, but they are lower for electricity and higher for the other sectors.

<Table 3>

The first line in Table 4 shows the contraction in production in the covered sectors that accompanies the carbon price; in the baseline, for energy intensive manufacturing, production falls by roughly 1% or less. Next, the table reports the effectiveness of the different anti-leakage policies on stemming the loss in production. For most sectors, the home rebate is the most effective. Iron and steel production and nonmetallic minerals benefit more from full border adjustment, but only when imports are taxed according to the foreign emissions intensity.

Table 5 first reports the leakage avoided as a share of total domestic reductions by sector. These numbers are noticeably smaller than those for the avoided production loss. The tax on embodied emissions for imports reduces the leakage rate by 5-6 percentage points for steel and nonmetallic minerals, and by a 16 percentage points for refined petroleum products. Export rebates are particularly effective for reducing leakage in petroleum. Full border adjustment then tends to be the most effective across the board, but when the import tax is restricted to comparable domestic tax rates, the home rebate generates similar effects. Still, for most sectors, it is apparently difficult to reduce leakage significantly. An exception is refined petroleum products, where export rebates do avoid displacement of exports and the corresponding increase in foreign emissions.

Globally, though, one is less concerned about total leakage (which can be reduced by shifting emissions home from abroad) than net emissions reductions. The table next reports the additional net reductions achieved relative to the emissions tax policy alone, as a percentage of the domestic reductions under that scenario. We find that, with the exception of petroleum products, the policies achieve less than an 8% improvement in net emissions reductions. Full border adjustment (at the foreign emissions intensity) is most effective, but only weakly so for several sectors. Since foreign emissions rates are higher in all sectors but electricity, any weakening of the import adjustment by using domestic or BAT emissions intensities to calculate the adjustment produces smaller results. When the import adjustment is restricted to the comparable domestic tax, the home rebate is more effective for steel and of comparable effectiveness for the other energy-intensive manufacturing sectors. However, the home rebate actually increases global emissions when applied to electricity and petroleum products, as the domestic expansion (from lower home energy prices) exceeds any foreign reduction.

Some of these results are sensitive to our assumptions about the import price elasticities. When the cross-price elasticity of the home good with respect to import prices is more elastic, the border tax on imports can eventually cause an increase in global emissions across all sectors, due to a strong substitution effect that raises domestic emissions. Similarly, a stronger foreign production response to higher prices of the home export good exacerbates foreign leakage and makes rebate policies relatively more attractive.

We see some of these effects in the results for Canada, where larger shares of goods are traded (Table 6), but as a smaller country, the foreign response is smaller (elasticities of substitution are in the Appendix). Furthermore, the emissions intensities of displaced foreign goods are closer to parity and occasionally lower than domestic intensities (Table 6). As a result, there is little difference between the border tax adjustment for imports based on domestic or foreign emissions intensities. None of the policies really improve net reductions in nonmetallic minerals and pulp and paper. For the other sectors, full border adjustment is most effective, improving net reductions by 4-10% (Table 7). Of the single policies, the export rebate most often delivers the greatest net reductions, in contrast to the U.S. case, where the import tax was more effective. While the home rebate is across the board the most effective at avoiding lost production, and reasonably effective at avoiding leakage in the manufacturing sectors, it is utterly ineffective at improving net reductions and quite counterproductive for electricity and especially refined petroleum products.

Some stakeholders argue for rebates that account for not only emissions allowance costs but also upstream cost changes. In Table 8, we assume the U.S. uses the full cost change under the carbon price as the basis for adjustments and rebates. The policies unsurprisingly have stronger effects, and net reductions double for the steel sector, but otherwise the improvements remain modest as a share of baseline domestic reductions.

Conclusion

Our analysis indicates that border adjustments for climate policy are not only likely to be contentious and disputed under trade law, but may not even be very effective at improving overall emissions reductions net of foreign leakage. A border tax on imports only affects the relative price of domestic and foreign goods in the home country. Policies that provide export relief, on the other hand, affect the relative price of the home good in the rest of the world and discourage substitution abroad, but not at home. Rebates at home discourage substitution toward foreign goods at home and abroad, but they also discourage conservation at home. All policies do, however, avoid some of the losses in production associated with a carbon tax.

While it seems that full border adjustment is likely to be the most effective policy for the U.S. at avoiding leakage, if this option is not judged to be consistent with trade law, the home rebate is able to achieve most of those gains. The exceptions are in the electricity and refined oil products sectors, where the subsidy undoes the incentives to curb domestic consumption and thus expands emissions at home considerably.

This analysis has several important caveats. First, it does not include emissions caps in countries other than the U.S.; nor does it reflect emissions changes in uncovered sectors. Second, it assumes the domestic emissions price remains fixed. With a cap-and-trade system (at home or abroad), any policy that would otherwise raise emissions instead drives up the allowance price; while overall emissions may not rise in the covered sectors, costs will rise, and their distribution across sectors can change. Since all of these policies tend to raise domestic emissions, the extent they do is an indicator of the size of distortions they would create in the domestic emissions market. Third, and perhaps most importantly, our level of aggregation for the sectors (chosen because of the availability of the trade elasticities) is arguably too high. The relative emissions intensities of foreign goods and elasticities may be quite different for more narrowly defined subsectors. Since elasticities of substitution typically rise with greater disaggregation, it is possible that the small numbers for aggregate leakage avoided mask larger effects for particular energy-intensive and trade-sensitive subsectors. Thus, improving estimates of these parameters for the specific industries being targeted by climate policies is of great importance for understanding the potential benefits of engaging in border adjustment or rebate policies.

Finally, we acknowledge some important practical considerations. Policymakers do need to be careful not to undo the incentive effects of the emissions price. Any export relief or rebate should be based on sector-wide measures of emissions intensity, rather than actual firm-level emissions, to ensure that the subsidy supports output and not emissions. However, average intensity metrics face the challenge of defining the denominator—the unit of production. The same sector (and even firm) can produce different kinds of products. Defining and implementing these kinds of rebates is akin to setting and enforcing emissions performance standards by product. Such efforts are certainly being considered, particularly in the context of potential sectoral agreements, but the devil will be in the details.

References

Asselt, H. van & Biermann, F. (2007). European emissions trading and the international competitiveness of energy-intensive industries: A legal and political evaluation of possible supporting measures. *Energy Policy* 35(1), 497-507.

Babiker, Mustafa H. and Thomas F. Rutherford 2005 “The Economic Effects of Border Measures in Subglobal Climate Agreements” *The Energy Journal* 26 (4): 99-126.

Bagwati and Mavroidis (2007) *World Trade Review*

Biermann F. and R. Brohm, (2005) Implementing the Kyoto Protocol Without the United States: The Strategic Role of Energy Tax Adjustments at the Border, Global Governance *Climate Policy* 4: 289–302.

Brewer, Thomas L. (2008) U.S. Climate Change Policy and International Trade Policy Intersections: Issues Needing Innovation for a Rapidly Expanding Agenda. Paper Prepared for a Seminar of the Center for Business and Public Policy Georgetown University - February 12, 2008.

de Cendra, Javier. 2006. Can Emissions Trading Schemes be Coupled with Border Tax Adjustments? An Analysis vis-à-vis WTO Law. *RECIEL* 15 (2): 131-145. ISSN 0962 8797

Demailly, D., and P. Quirion. 2006. European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry. *Energy Economics* 30: 2009–2027.

Demailly, D., and P. Quirion. 2006. CO2 abatement, competitiveness and leakage in the European Cement Industry under the EU ETS: grandfathering versus output-based allocation. *Climate Policy* 6 (1), 93–113.

Demailly, D., and P. Quirion. 2008.

Esty, Daniel C. 1994. *Greening the GATT: Trade, Environment, and the Future*. (Washington, D.C.: Institute of International Economics).

Fischer, Carolyn. 2001. "Rebating Environmental Policy Revenues: Output-Based Allocations and Tradable Performance Standards," RFF Discussion Paper 01-22.

Fischer, Carolyn and Alan K. Fox. 2007. Output-Based Allocation of Emissions Permits for Mitigating Tax and Trade Interactions. *Land Economics*, 83: 575 - 599.

Fischer, Carolyn, Sandra Hoffmann, and Yutaka Yoshino. 2004. Multilateral Trade Agreements and Market-Based Environmental Policies, in Janet Milne, Kurt Deketelaere, Larry Kreiser, Hope Ashiabor, Ed., *Critical Issues in Environmental Taxation: International and Comparative Perspectives*, vol 1. Richmond, UK: Richmond Law and Tax Ltd.) pp. 363-384.

Gielen, Dolf and Yuichi Moriguchi (2002) "CO2 in the iron and steel industry: an analysis of Japanese emission reduction potentials," *Energy Policy* 30: 849–863

Godard, Olivier (2007). "Unilateral European Post-Kyoto climate policy and economic adjustment at EU borders." EDF – Ecole Polytechnique: Cahier n° DDX 07-15.

Green, Andrew. (2006) *World Trade Review*

Grubb, M. and K. Neuhoff (2006). "Allocation and competitiveness in the EU emissions trading scheme: policy overview." *Climate Policy* 6(1): 7–30.

Ismer R., Neuhoff K. (2004) Border Tax Adjustments : A Feasible Way to Address Nonparticipation in Emission Trading, CMI Working Papers, n° 36, Cambridge.

Hoerner J., and Muller F. 1997. Carbon Taxes for Climate Protection in a Competitive World. In E. Staehelin-Witt and H. Blöchliger, *Ökologisch orientierte Steuerreformen: Die fiskal- und aussenwirtschaftspolitischen Aspekte*, Verlag Paul Haupt, Bern, Switzerland, 1997. (published for Swiss Federal Office for International Economic Affairs).

Kommerskollegium. 2004. Climate and Trade Rules - harmony or conflict? Stockholm, Sweden: National Board of Trade.

Morris, Michael G. and Edwin D. Hill. 2007. Trade Is The Key To Climate Change. *The Energy Daily* 35 (33): Tuesday, February 20.

Neuhoff K., Droege S. (2007) International Strategies to Address Competitiveness Concerns, EPRG Working Paper, n° 6, juillet, University of Cambridge.

Pauwelyn, Joost. 2007. U.S. Federal Climate Policy and Competitiveness Concerns: The Limits and Options of International Trade Law. Nicholas Institute for Environmental Policy Solutions, Duke University: WP 07-02.

Peters, Glen P. and Edgar G. Hertwich. Forthcoming. *Environmental Science and Technology*.

Peterson, Everett B. and Joachim Schleich (2007) "Economic and Environmental Effects of Border Tax Adjustments" Working Paper Sustainability and Innovation No. S1/2007. Fraunhofer Institute Systems and Innovation Research.

Sampson, Gary. 1998. WTO Rules and Climate Change: The Need for Policy Coherence, Chapter 4 in *Global Climate Governance: Inter-linkages between the Kyoto Protocol and other Multilateral Regimes*. Tokyo, Japan: Global Environment Information Centre.

Stiglitz, Joseph E. 2006. A New Agenda for Global Warming. *The Economist's Voice*, July. Berkeley Electronic Press.

Zhang, ZhongXiang and Lucas Assunção. 2001. Domestic Climate Policies and the WTO. FEEM Working Paper 91.2001. Milan, Italy: Fondazione Eni Enrico Mattei.

Table 3: Trade Shares and Relative Emissions Intensities for the United States

	ELE	OIL	CRP	NMM	PPP	I_S
Baseline Export Share of Home Production	0%	5%	13%	11%	5%	5%
Baseline Import Share of Home Consumption	1%	11%	14%	15%	6%	11%
Foreign Emissions Intensity Relative to U.S.	98%	143%	118%	215%	168%	295%
Emissions payments as % of cost increase	103%	101%	46%	78%	59%	46%

Table 4: Results of Border Adjustment Policies for the U.S.: Production

	ELE	OIL	CRP	NMM	PPP	I_S
Baseline production change	-6.1%	-4.4%	-1.1%	-0.9%	-0.3%	-0.6%
Production Loss Avoided (as % of Production Decrease with Emissions Tax Alone)						
Import Tax (foreign rate)	3%	18%	12%	54%	18%	47%
Import Tax (home rate)	2%	14%	10%	25%	11%	18%
Export Rebate	2%	18%	14%	29%	12%	12%
Home Rebate	87%	97%	33%	57%	38%	33%
Full BTA (foreign rate)	4%	37%	26%	82%	31%	59%
Full BTA (home rate)	4%	32%	24%	54%	23%	29%

Table 5: Results of Border Adjustment Policies for the U.S.: Reductions

	ELE	OIL	CRP	NMM	PPP	I_S
Leakage Avoided (as % of Domestic Reductions)						
Import Tax (foreign rate)	1%	16%	1%	5%	1%	6%
Import Tax (home rate)	1%	12%	1%	2%	0%	2%
Export Rebate	1%	23%	2%	3%	1%	4%
Home Rebate	1%	6%	3%	5%	1%	6%
Full BTA (foreign rate)	3%	44%	3%	8%	1%	10%
Full BTA (home rate)	2%	39%	3%	5%	1%	6%
Additional Net Reductions (as % of Reductions with Emissions Tax Alone)						
Import Tax (foreign rate)	1%	10%	0%	3%	0%	5%
Import Tax (home rate)	0%	8%	0%	1%	0%	2%
Export Rebate	1%	17%	1%	2%	0%	3%
Home Rebate	-20%	-17%	0%	3%	0%	5%
Full BTA (foreign rate)	2%	27%	1%	5%	1%	8%
Full BTA (home rate)	1%	25%	1%	3%	1%	5%

Table 6: Trade Shares and Relative Emissions Intensities for Canada

	ELE	OIL	CRP	NMM	PPP	I_S
Export share of home production	5%	15%	46%	33%	44%	21%
Import share of home consumption	3%	9%	51%	42%	22%	26%
Emissions rate ratio (foreign to domestic)	216%	89%	115%	107%	80%	115%
Emissions payments as % of cost increase	92%	89%	48%	78%	49%	58%

Table 7: Results of Border Adjustment Policies for Canada

	ELE	OIL	CRP	NMM	PPP	I_S
Baseline production change	-5.6%	-8.2%	-2.5%	-2.7%	-1.5%	-1.6%
Production Loss Avoided (as % of Production Decrease with Emissions Tax Alone)						
Import Tax (foreign rate)	9%	7%	9%	24%	5%	25%
Import Tax (home rate)	4%	8%	8%	23%	6%	22%
Export Rebate	16%	35%	25%	46%	30%	36%
Home Rebate	74%	89%	40%	74%	43%	70%
Full BTA (foreign rate)	25%	42%	34%	71%	35%	61%
Full BTA (home rate)	20%	43%	33%	69%	36%	58%
Leakage Avoided (as % of Domestic Reductions)						
Import Tax (foreign rate)	5%	4%	2%	2%	0%	2%
Import Tax (home rate)	3%	5%	2%	2%	1%	2%
Export Rebate	9%	21%	8%	4%	4%	7%
Home Rebate	7%	-4%	5%	5%	4%	8%
Full BTA (foreign rate)	15%	28%	10%	6%	4%	9%
Full BTA (home rate)	12%	29%	10%	6%	4%	9%
Additional Net Reductions (as % of Reductions with Emissions Tax Alone)						
Import Tax (foreign rate)	4%	2%	1%	0%	0%	0%
Import Tax (home rate)	2%	2%	1%	0%	0%	0%
Export Rebate	6%	4%	4%	1%	0%	3%
Home Rebate	-4%	-31%	0%	0%	-1%	1%
Full BTA (foreign rate)	10%	6%	5%	1%	0%	4%
Full BTA (home rate)	8%	6%	5%	1%	0%	4%

Table 8: Results of Border Adjustment Policies for the U.S.: Adjustment of Full Cost Change

	ELE	OIL	CRP	NMM	PPP	I_S
Production Loss Avoided (as % of Production Decrease with Emissions Tax Alone)						
Import Tax (home rate)	2%	14%	22%	32%	18%	39%
Export Rebate	2%	18%	30%	37%	20%	26%
Home Rebate	85%	96%	71%	74%	64%	73%
Full BTA (home rate)	4%	32%	52%	69%	39%	65%
Leakage Avoided (as % of Domestic Reductions)						
Import Tax (home rate)	1%	12%	2%	3%	1%	5%
Export Rebate	1%	22%	5%	4%	1%	9%
Home Rebate	1%	6%	6%	7%	2%	13%
Full BTA (home rate)	2%	38%	7%	7%	2%	14%
Additional Net Reductions (as % of Reductions with Emissions Tax Alone)						
Import Tax (home rate)	0%	8%	0%	2%	0%	4%
Export Rebate	1%	16%	2%	3%	1%	8%
Home Rebate	-19%	-17%	0%	4%	0%	10%
Full BTA (home rate)	1%	24%	3%	4%	1%	11%

Appendix

Table 9: Simulated Elasticities for the U.S.

Sector	η_{hH}	η_{mH}	η_{xX}	η_{fX}	η_{mM}	η_{hM}
Electricity	(0.66)	1.33	(2.99)	0.05	(2.78)	0.01
Petroleum and coal products (refined)	(0.95)	0.83	(2.97)	0.13	(1.90)	0.17
Chemical industry	(0.89)	1.72	(4.17)	0.30	(2.68)	0.48
Non-metallic minerals	(0.47)	1.77	(3.75)	0.09	(2.38)	0.47
Paper-pulp-print	(0.46)	1.87	(3.55)	0.13	(2.71)	0.20
Iron and steel industry	(0.14)	2.25	(4.05)	0.01	(2.53)	0.35

Table 10: Simulated Elasticities for Canada

Sector	η_{hH}	η_{mH}	η_{xX}	η_{fX}	η_{mM}	η_{hM}
Electricity	(0.65)	1.97	(3.41)	0.01	(2.73)	0.05
Petroleum and coal products (refined)	(0.91)	1.09	(3.64)	0.02	(1.90)	0.14
Chemical industry	(2.59)	0.30	(5.24)	0.05	(1.36)	1.32
Non-metallic minerals	(1.43)	1.29	(4.94)	0.02	(1.54)	1.19
Paper-pulp-print	(1.25)	1.43	(3.95)	0.08	(2.17)	0.63
Iron and steel industry	(1.18)	1.58	(4.90)	0.03	(1.98)	0.78