DISCUSSION PAPER

February 2009; Revised March 2011 ■ RFF DP 09-02-REV

Comparing Policies to Combat Emissions Leakage

Border Carbon Adjustments versus Rebates

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RESOURCES
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Comparing Policies to Combat Emissions Leakage: Border Carbon Adjustments versus Rebates

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Abstract

We explore conditions determining which anti-leakage policies might be more effective complements to regulation of domestic greenhouse gas emissions. We consider four policies that could be combined with unilateral emissions pricing to counter effects on international competitiveness: a border charge on imports, a border rebate for exports, full border adjustment, and domestic output-based rebating. Each option faces different potential legal hurdles in international trade law; each also has different economic impacts. While all can support competitiveness, none is necessarily effective at reducing global emissions. Nor is it possible to rank the options; effectiveness depends on the relative emissions rates, elasticities of substitution, and consumption volumes. We illustrate these results with simulations for the energy-intensive sectors of three different economies—the United States, Canada, and Europe. Although most controversial, full border adjustment is usually most effective, but output-based rebating for key manufacturing sectors can achieve many of the gains.

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. As a consequence, interest has been growing in policies that have the potential to combat leakage.

A popular option is border adjustment for imports, which typically implies requiring importers to pay a tax according to the emissions associated with their product's production, at the same price as faced by domestic producers. This idea was incorporated into the successful Waxman/Markey bill (H.R. 2454 "The American Clean Energy and Security Act of 2009") as a requirement for purchasing "international reserve allowances" to cover goods imported from countries that have not undertaken adequate steps to mitigate GHG emissions (Section 766).[1] 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 (and would not begin until 2025). The Bingaman/Specter bill (S. 1766 "Low Carbon Economy Act") included a weak form of border adjustment 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 has also gained ground in Europe (e.g., Godard 2007; Grubb and Neuhoff 2006),

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[1] The failed companion Senate legislation, Kerry/Lieberman ("American Power Act") proposed nearly identical treatment.

as the European Union is preparing the next phase of the Emissions Trading System (ETS) and considering options in the absence of a major international agreement to cap GHG emissions. Karp and Zhao (2008) argue that trade measures against carbon leakage could help support a new multilateral climate agreement. Given the practical difficulties involved in measuring embodied emissions in foreign production, some of these proposals would base adjustments on alternate measures of emissions intensity, such as sector averages, domestic averages, or best practices benchmarks, which imply different degrees of adjustment.

Conceptually, however, there are several unilateral policy options for dealing with the relative price changes that cause leakage. In addition to import charges, which level the playing field only for domestic consumption, border rebates for exports keep the playing field level abroad between domestic and foreign products. Full border adjustment policies would combine these two measures, such that only the emissions from domestic consumption are taxed (with an analogy to the way in which value-added taxes are implemented).

A final option is to mitigate the impacts of emissions regulation on domestic production costs in the first place by offering rebates to domestic production, rather than adjusting at the border; we will refer to this type of policy as “output-based rebating.” This mechanism keeps the playing field level both at home and abroad, but at the expense of opportunities to reduce emissions by reducing consumption. Such a policy could equivalently be implemented by using rate-based mechanisms for regulation or emissions permit allocation (e.g., tradable performance standards or output-based allocation with updating; Fischer 2001). For example, the Waxman/Markey bill proposes to distribute emissions allowances among certain trade-sensitive sectors according to output, multiplied by a sector-based emissions factor. Australia’s Carbon Pollution Reduction Scheme proposes to use a similar approach.

Many trade law experts express concerns that border adjustments in particular may not be compatible with World Trade Organization (WTO) obligations, and we review these arguments in the next section. Others voice apprehensions that unilateral trade measures could poison future climate negotiations (Houser et al. 2008). The U.S. Trade Representative has expressed worries that such measures could harm trade relations (ICTSD 2008) and has vowed to resist any EU attempt to impose climate taxes on U.S. products. Concerns for international relations notwithstanding, fewer people have challenged the notion that import charges would, if allowed, be appropriate and effective at combating leakage and enhancing global emissions reductions.

This paper explores the conditions that determine which anti-leakage policies are the most effective complements to domestic GHG emissions regulation. It reveals that while *all* these policies help to protect domestic production, *none* of them necessarily enhances the environmental integrity of climate policies from a global perspective. 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. The subsequent numerical analysis compares the effectiveness of the different policies for different kinds of sectors and economies, using the United States, Canada, and Europe as examples. The simulations show that the policy rankings do differ across countries and sectors, and while some adjustment policies can mitigate leakage on the margin, they are quite limited in terms of reducing global emissions.

Background

In a provocative article, Stiglitz (2006) argues 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 the absence of regulation would be an "actionable" subsidy (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.

The Stiglitz argument is an extension of the "polluter pays principle" by which the efficient allocation of resources in the long run is achieved by ensuring that the polluting party bears the economic burden of the environmental costs. In the case of a transboundary pollutant like GHGs, those parties may lie in other countries. Fischer et al. (2004) note that the legal institutions for international trade do not formally recognize this fundamental principle of environmental economics. Nor do they recognize another core principle: the economic equivalence of emissions tax and permit regimes. Both introduce an emissions price to induce 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 General Agreement on Tariffs and Trade (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. Thus, it is important to understand both the legal and the economic tradeoffs in policy design. In this section, we review some of the literature on the legal arguments as well as previous economic analysis of the policy options.

Legal Analysis of Border Adjustment

There are several good reviews of the compatibility of GATT/WTO law with climate policy in general and border adjustment options in particular. Charnovitz et al. (2009), Pauwelyn (2007), Brewer (2008), Biermann and Brohm (2005), Kommerskollegium (2004), Zhang and

Assunção (2001), Sampson (1998), and Esty (1994) take a primarily legal view. Fischer et al. (2004), and Ismer and Neuhoff (2004), and Bordoff (2008) add an economic perspective. de Cendra (2006) and van Asselt and Biermann (2007) focus on options for incorporating border adjustment 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 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 taxes, which are imposed on factors of production in the country of origin. Taxes on end-of-pipe emissions are likely to be considered direct taxes, but the issue becomes murkier when looking at taxes on products used in the production process, particularly energy. Furthermore, different aspects of GATT law govern the border adjustability of imports versus exports.

Regarding export rebates, the agreement governing Subsidies and Countervailing Measures (SCM) 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 (SCM, Annex II, footnote 61). 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 GHG 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.

For import adjustments, two key principles are important. First, the National Treatment principle embedded in Article III of the GATT requires that imported goods be treated no less favorably than "like" domestic products. Second, Most Favored Nation Treatment prohibits WTO members from discriminating among trading partners. These obligations may constrain what level of border adjustment might be allowed. One challenge is calculating the carbon content of imports in a way that does not discriminate against them. Some scholars interpret the trade rules to imply that the tax burden on imports may 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 United States. 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.

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; Charnovitz et al. 2009; 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; furthermore, this analysis reveals that the validity of the assertion that border adjustments contribute to the conservation of the climate is not assured.

A further complication regards the method of adjustment; while economists would note that an allowance requirement for imports has similar effects to a tariff, the law is likely to make a distinction. Pauwelyn (2007) 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" (27). 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. Brewer (2008) concurs that an emissions permit purchase requirement (as opposed to a tax) for imports is more likely to qualify as an environmental regulation allowable under the Article XX(g) exception.

However, auctioning may be a prerequisite for border adjustment, since the free allocation of permits through grandfathering might then appear to be an unfair subsidy (de Cendra 2006; Hepburn et al. 2006). 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 United States. These legal arguments run counter to the fact that grandfathering permits has little economic incentive effect, being a transfer.

Output-based allocations, on the other hand, function as a rebate (or subsidy) to production, which does have incentive effects. An open question is whether such rebates or allocations would raise SCM issues. If such rebates are found to be actionable, even if they do promote better environmental outcomes, no Article XX exception exists in the SCM agreement (Charnovitz et al. 2009).[2] While product-specific tax rebates might be hard to combine with a cap-and-trade system, permit allocations embedded in a domestic climate regulation seem less likely to raise eyebrows, unless significant overallocations are perceived. Indeed, we have seen no objections by WTO analysts to a policy of tradable performance standards, such as was used to phase out lead in gasoline in the U.S., which is equivalent to combining an emissions price with output-based allocation. However, allocations in a cap-and-trade system may be considered as distinct subsidies (including free allocations that are not conditional on output; Charnovitz et al. 2009). Of course, countries that might want to use the mechanism themselves in the future would be unlikely to dispute free allocation of allowances in principle. In the European Union, furthermore, rebates and allocations would also have to navigate State Aid rules that are more stringent than those in the WTO.

Most of the restrictions that multilateral trade agreements pose for market-based climate policies remain speculative at this point. And 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. Of course, whether this is desirable and whether such measures are likely to be justifiable under trade law depends on the economics of border adjustment.

Economic Analysis of Border Adjustment

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, production, or market share. We focus on changes in production in this study. Ho et al. (2008) analyze the competitiveness effects of a \$10/ton CO_2 price in the United States and find that a readily identifiable set of industries is at greatest risk of contraction. However, Aldy and Pizer (2009) find that only a

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[2] Some transitional assistance is permitted to accompany new environmental regulations, however.

portion of lost production is due to changes in international competitiveness; the majority of the production response to energy price increases reflects reduced consumption.

Recent European studies have focused on the cost impacts by sector of the EU ETS (Reinaud 2008; Climate Strategies: Hourcade et al., 2007; European Commission et al., 2006), as well as some indicators of the extent which different kinds of firms are likely to be able to pass on costs. These studies of the first phase of the EU ETS have found little evidence of significant effects on competitiveness; however, emissions prices were quite low in the first phase, and competitiveness impacts and leakage could loom larger as the cap is tightened. Looking toward future phases, Grubb and Neuhoff (2006) and Neuhoff and Droege (2007) 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 carbon adjustments. The third option is to employ free allocation, particularly output-indexed allocation of emissions allowances.[3]

Each of these options has been explored individually by economists, many of whom use similar multicountry, multisector 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 prices, while from a welfare perspective, most countries prefer tariffs. Peterson and Schleich (2007) investigate border carbon adjustment options for the EU ETS, concentrating on the calculation of the carbon content for imports, which affects the stringency of the border adjustment. Fischer and Fox (2007) use a general equilibrium framework to 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.

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[3] Hoerner and Muller (1996) also consider technology subsidies and targeted tax relief. Hoel (1996) considers whether carbon prices should be differentiated across sectors if border adjustment is not allowed.

Other papers have analyzed leakage in specific sectors. In the cement industry, Ponssard and Walker (2008) find that the EU ETS is likely to induce a high level of carbon leakage through increased imports and production relocation. Demailly and Quirion (2006) use a detailed spatial model of the cement industry to compare two combinations of a CO_2 tax with border adjustment. In the first case, the border adjustment is based on actual emissions intensities, both for export rebates and for import taxes. In the second scenario, the border adjustment corresponds to the BAT, with rebates given according to the least CO_2-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, border adjustment also causes the cement price in the regulated countries to increase, further affecting their cement consumers. Demailly and Quirion (2008) perform some similar analysis for the iron and steel industry and include updating allocation options; they find little competitiveness effect from the EU ETS. Monjon and Quirion (2009) compare border adjustments and allocation options for cement, steel, and aluminum in the European Union, finding a general preference for border adjustments. Gielen and Moriguchi (2002) simulate the effects of carbon pricing on the Japanese iron and steel industry, finding leakage rates of 70 percent and calculating the import tariffs needed to balance that. Ho et al. (2008) also find considerable leakage in some sectors.

While economic modelers have addressed particular trade-related and allocation-related options for addressing leakage individually or for specific sectors, 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 analytical 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 United States, Canada, and Europe, with some sensitivity analysis using alternate scenarios, followed by discussion, caveats, and directions for further research.

Model

The basic issues of international emissions leakage within a given sector can be addressed parsimoniously with a two-country, two-good, partial equilibrium model. Since we are ultimately taking a sector-specific focus rather than an economy-wide perspective, we do not require a general equilibrium, although these aspects will be discussed in the numerical section. While general equilibrium effects have significant implications for the climate policy itself, they have smaller effects regarding most adjustment measures.

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. For notational simplicity, let $c_H^0 = c_H(0)$. 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* be *h* and *x* (exports), respectively, and let home and foreign consumption of good *F* be *m* (imports) and *f*, respectively. Consumer demand for each good is a simple function of the prices of both competing goods in the country of consumption: $h(p_H, p_M)$, $m(p_H, p_M)$, $x(p_X, p_F)$, and $f(p_X, p_F)$. Those prices in turn will equal the (constant) marginal costs of production, inclusive of any taxes or rebates. The resulting demand will determine production and, along with the emissions intensities, total emissions.

Formally, in the market equilibrium, $H = h(p_H, p_M) + x(p_X, p_F)$ and $F = m(p_H, p_M) + f(p_X, p_F)$. Let us assume constant elasticity of demand functions, so $h = \alpha_h p_H^{\eta_{hH}} p_M^{\eta_{hM}}$, $m = \alpha_m p_H^{\eta_{mH}} p_M^{\eta_{mM}}$, $x = \alpha_x p_X^{\eta_{xX}} p_F^{\eta_{xF}}$ and $f = \alpha_f p_X^{\eta_{fX}} p_F^{\eta_{fF}}$. Own-price elasticities are negative, while cross-price elasticities are assumed to be positive, meaning the goods are to some extent substitutes. With this formulation, a first-order approximation of the change in demand is $dh = \eta_{hH} h \frac{dp_H}{p_H} + \eta_{hM} h \frac{dp_M}{p_M}$, for example.

As the term "competitiveness" has no firm definition in economics, we consider two candidate metrics. One is simply the change in domestic production, reflecting concern for manufacturing output and jobs. Simplifying,

$$dH = h\left(\eta_{hH}\frac{dp_H}{p_H} + \eta_{hM}\frac{dp_M}{p_M}\right) + x\left(\eta_{xX}\frac{dp_X}{p_X} + \eta_{xF}\frac{dp_F}{p_F}\right) \tag{1}$$

Another is the change in net exports, *N*, where $N = m(p_H, p_F) + x(p_X, p_F)$. Arguably, this metric may be more appropriate for climate concerns, because it does not include the lost production associated with reduced consumption at home. Simplifying,

$$dN = -m\left(\eta_{mH}\frac{dp_H}{p_H} + \eta_{mM}\frac{dp_M}{p_M}\right) + x\left(\eta_{xX}\frac{dp_X}{p_X} + \eta_{xF}\frac{dp_F}{p_F}\right) \tag{2}$$

Leakage is conventionally defined as the change in foreign emissions as a share of the change in domestic emissions induced by the policy. From a policy effectiveness point of view, however, the change in global emissions is what matters, and we focus on this variable:

$$\begin{aligned} dE = -dr_H H + (e_H^0 - r_H)\left(h\left(\eta_{hH}\frac{dp_H}{p_H} + \eta_{hM}\frac{dp_M}{p_M} \right) + x\left(\eta_{xX}\frac{dp_X}{p_X} + \eta_{xF}\frac{dp_F}{p_F} \right) \right) \\ + e_F\left(m\left(\eta_{mH}\frac{dp_H}{p_H} + \eta_{mM}\frac{dp_M}{p_M} \right) + f\left(\eta_{fX}\frac{dp_X}{p_X} + \eta_{fF}\frac{dp_F}{p_F} \right) \right) \end{aligned} \quad (3)$$

Within this framework, we next 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 temper reductions in domestic production, as an indicator both of the competitiveness concerns and of pressures for protection.

Policy Options

In the absence of any climate policy, prices are simply the marginal production costs without reductions: $p_H = p_X = c_H^0$, and $p_F = p_M = c_F$. First, to see the effects of the climate policy alone, we impose an emissions price *t*. Next, to compare different policies for controlling emissions leakage, we start from a reference scenario of this domestic emissions pricing program: all of the adjustment scenarios will retain that price and the corresponding reduction in emissions intensity in home production. Furthermore, since we are evaluating the imposition of the full policies, rather than a marginal increase in the rate, we assume $dr_H = r_H$.

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. The implicit assumption is that changes in a given sector do not affect the emissions price; this situation would also occur in an emissions cap framework if the sector is fairly small, if international or intertemporal linking occur, or if a safety valve (price ceiling) or a price floor is binding. The implication of this assumption is that domestic emissions are sensitive to the subsequent adjustment policies; we will discuss the effects under a hard cap in the penultimate section.

With an emissions price *t* in the home country and no adjustment mechanisms, $p_H = p_X = c_H(r_H) + t(e_H^0 - r_H)$ and $p_F = p_M = c_F$. 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.

Substituting these prices and changes into (1) and (2), we see the changes in domestic production and net exports that result from the price changes:

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

$$dN_{\text{CTax}} = \frac{c_H - c_H^0 + te_H}{c_H^0}\left(\eta_{xX} x - \eta_{mH} m\right).$$

Simplifying (3), we see the corresponding change in global emissions is

$$dE_{\text{CTax}} = -r_H H + \frac{c_H - c_H^0 + te_H}{c_H^0}\Big(e_H\left(\eta_{hH} h + \eta_{xX} x\right) + e_F\left(\eta_{mH} m + \eta_{fX} f\right)\Big).$$

where $e_H = (e_H^0 - r_H)$ is shorthand for the home emissions rate in the presence of the emissions price. The first effect of the emissions price is to reduce the emissions rate for all home production; the second effect is to raise the price of the home good, which causes substitution effects across all goods, with corresponding emissions changes.

Next we compare these changes when different adjustment policies are added to the carbon price.

Import Tax

Border adjustment for imports 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 $\hat{e}_F$. Consequently, the price impacts of this policy are $p_H = p_X = c_H(r_H) + t(e_H - r_H)$, $p_M = c_F + t\hat{e}_F$, and $p_F = c_F$. In the base case, we will let $\hat{e}_F = e_F$, the actual foreign emissions intensity (e.g., a weighted average of foreign emissions per unit of output in the sector). However, many of the proposed border adjustment policies that are thought to be WTO compatible involve a smaller border charge. Some propose using home emissions intensity ($\hat{e}_F = e_H$), or BATs. For example, the Bingaman/Specter proposal only imposes the tax on embodied emissions above some baseline (essentially, $\hat{e}_F = e_F - e_F^0$).

Substituting these prices, we compare the changes in domestic production and net exports to that with the carbon tax alone:

$$\begin{aligned} dH_{\text{ImpTax}} - dH_{\text{CTax}} &= \left(t\hat{e}_F / c_F^0\right)\eta_{hM} h \\ dN_{\text{ImpTax}} - dN_{\text{CTax}} &= -\left(t\hat{e}_F / c_F^0\right)\eta_{mM} m \end{aligned}.$$

Simplifying the changes in global emissions, we get

$$dE_{\text{ImpTax}} - dE_{\text{CTax}} = \frac{t\hat{e}_F}{c_F^0}\left(\underbrace{-\eta_{hM}}_{-} e_H h \underbrace{-\eta_{mM}}_{+} e_F m\right)$$

Thus, we have an additional effect on emissions from home and import consumption due to the increased price of imports.

Export Rebate

Contrary to the border adjustment for imports, adjusting at the border for exports with an export rebate 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: $p_H = c_H(r_H) + t(e_H - r_H)$, $p_X = c_H(r_H)$, and $p_F = p_M = c_F$.

The change in our competitiveness metrics over the emissions tax alone is then

$$dH_{\text{ExpReb}} - dH_{\text{CTax}} = dN_{\text{ExpReb}} - dN_{\text{CTax}} = \left(te_H / c_H^0\right)\left(-\eta_{xX}\right)x$$

Simplifying the change in emissions, we get

$$dE_{\text{ExpReb}} - dE_{\text{CTax}} = \frac{te_H}{c_H^0}\left(\underbrace{\eta_{xX}}_{-} e_H x + \underbrace{\eta_{fX}}_{+} e_F f\right)$$

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

Full Border Adjustment

Full border adjustment (FBA) 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 $p_H = c_H(r_H) + t(e_H - r_H)$, $p_X = c_H(r_H)$, $p_M = c_F + t\hat{e}_F$, and $p_F = c_F$.

Simplifying, we compare the change in production to that under the carbon tax alone:

$$\begin{aligned} dH_{\text{FBA}} - dH_{\text{CTax}} &= \left(te_H / c_H^0\right)\left(-\eta_{xX}\right)x + \left(t\hat{e}_F / c_F\right)\eta_{hM} h \\ dN_{\text{FBA}} - dN_{\text{CTax}} &= \left(te_H / c_H^0\right)\left(-\eta_{xX}\right)x - \left(t\hat{e}_F / c_F\right)\eta_{mM} m \end{aligned}$$

The changes in emissions due to this combined policy reduce to

$$dE_{\text{FBA}} - dE_{\text{CTax}} = \frac{te_H}{c_H^0}\left(\underbrace{\eta_{xX}}_{-} e_H x + \underbrace{\eta_{fX}}_{+} e_F f\right) + \frac{t\hat{e}_F}{c_F}\left(\underbrace{-\eta_{hM}}_{-} e_H h \underbrace{-\eta_{mM}}_{+} e_F m\right)$$

In both cases, the effects are a combination of those from the import tax and export rebate.

Output-Based Rebating

Output-based rebating ("OBR") 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: $p_H = p_X = c_H(r_H)$ and $p_F = p_M = c_F$.

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 NO$_x$ tax-rebate program), or by rate-based allocation of emissions permits in a cap-and-trade policy (see Fischer 2001; Fischer and Fox, 2007). 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.

The effect on domestic production, relative to the carbon tax alone, is

$$\begin{aligned} dH_{\text{OBR}} - dH_{\text{CTax}} &= \left(te_H / c_H^0\right)\left(-\eta_{hH} h - \eta_{xX} x\right) \\ dN_{\text{OBR}} - dN_{\text{CTax}} &= \left(te_H / c_H^0\right)\left(\eta_{mH} m - \eta_{xX} x\right) \end{aligned}.$$

Simplifying the change in global emissions, we get

$$dE_{\text{OBR}} - dE_{\text{CTax}} = \frac{te_H}{c_H^0}\left(e_H \left(\underbrace{\eta_{hH}}_{-} h + \underbrace{\eta_{xX}}_{-} x \right) + e_F \left(\underbrace{\eta_{mH}}_{+} m + \underbrace{\eta_{fX}}_{+} f \right) \right)$$

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 (and production cost increases) induced by the emissions price.

Costs Not Adjusted

Note that none of the policies modeled here 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, the adjustment policies defined here 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. The other costs ignored in this partial equilibrium framework are upstream cost increases, such as electricity price rises (a particular concern for aluminum, for example). Some proposals (including Waxman/Markey) include adjustment for these cost changes as well as emissions payment requirements; none to date address the costs of changing production techniques.

Comparing Anti-Leakage Policies

How do these policies compare in terms of reducing competitiveness impacts and ensuring more genuine emissions reductions globally? Table 1 summarizes the direction of the effects of each adjustment policy on home good consumption, imports, exports, and foreign consumption. All the policies either raise the cost of foreign-sourced goods or lower the cost of home-produced goods. As a result (assuming the substitution elasticities are well behaved), all adjustment policies raise domestic output relative to the tax alone by increasing home consumption or exports or both (as viewed by those columns in Table 1). However, all adjustment policies then also raise domestic emissions. Furthermore, they all reduce foreign output relative to the tax alone, by decreasing imports or foreign consumption or both, and thereby reduce foreign emissions. Consequently, none of the policies *necessarily* reduce global emissions, since displaced foreign emissions are to some extent replaced by domestic emissions (as viewed by noting that each row in Table 1 has effects of both signs). Nor do they necessarily reduce leakage, as conventionally defined, since they drive down both the numerator of foreign increases and denominator of domestic reductions. Nor is it possible to rank order the options. In each case, the effectiveness depends on the relative elasticities of substitution, size, and emissions rates.

Table 1. Comparison of Effects of Adjustment Policies

	Home good consumption	*Imports*	*Exports*	*Foreign own-good consumption*
Import Tax	+	−	0	0
Export Rebate	0	0	+	−
Full Border Adjustment	+	−	+	−
Output-Based Rebating	+	−	+	−

First, compare the effects on our measures of competitiveness ($dH_i - dH_{\text{Ctax}}$ and $dN_i - dN_{\text{Ctax}}$, for each policy *i*). Since the import tax and the export rebate each raise domestic production, the full border adjustment dominates either of its single components. However, it does not necessarily dominate OBR: $dH_{\text{FBA}} - dH_{\text{OBR}} = \left(\frac{t\hat{e}_F}{c_F}(\eta_{hM}) - \frac{te_H}{c_H^0}(-\eta_{hH}) \right) h$, while $dN_{\text{FBA}} - dN_{\text{OBR}} = \left(-\frac{t\hat{e}_F}{c_F}(\eta_{mM}) - \frac{te_H}{c_H^0}(\eta_{mH}) \right) m$. Both policies mitigate the cost increase for exports, so which policy induces more home production (or net exports) depends on the relative cost changes for imported and domestic goods and whether home good consumption (or imports) are more sensitive to home or import price changes. If the import adjustment is relatively stringent, given that own-price effects are likely to be larger than cross-price effects, full border adjustment is likely to be the most effective policy for preserving net exports.

The impacts of adjustment policies on global emissions are less obvious. The border adjustment on imports reduces emissions relative to the tax if the displaced emissions from fewer imports exceeds the increased emissions from more domestic consumption (i.e., if $-\eta_{mM} e_F m > \eta_{hM} e_H h$). 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 allows home exports to crowd out some of the foreign good in foreign consumption. It reduces emissions relative to the tax if the displaced emissions from less foreign production for foreign consumption exceeds the increased emissions from the additional exports (if $\eta_{fX} e_F f > -\eta_{xX} e_H x$). 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 may or may not be more effective than the import tax, depending 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.

The full border adjustment policy combines the preceding two policies. If each of these policies is effective on its own, then the combination will result in fewer global emissions 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.

OBR is effective in its own right if the displaced foreign emissions exceed the additional home emissions. OBR also provides more reductions than the export rebate alone if the displaced emissions from fewer imports exceeds the increased emissions from more domestic consumption (if $\eta_{mH} e_F m > -\eta_{hH} e_H h$). Note that 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. Since both policies affect the export market similarly, full border adjustment is more effective than OBR if the change in emissions from different import levels outweighs the change in emissions from different home good consumption.

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 from a global perspective, such as if demand for foreign-produced goods is highly inelastic (i.e., $\eta_{mH}, \eta_{mM}, \eta_{fX}$ all close to zero).

In the next section, we illustrate the results by parameterizing this model with estimates from different sectors that are likely to be regulated for GHG emissions. We also select countries (the United States, Canada, and Europe) with very different profiles in terms of trade sensitivities and emissions intensities for these sectors.

Simulations

Fischer and Fox (2009) use a multi-sector, multi-region 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 (or \$14/ton CO2) implemented unilaterally in the United States and applied to certain emissions-intensive sectors. We utilize similar and additional simulations from this complex model to parameterize the analytical model that makes the trade-offs among border adjustment policies more transparent. We perform this analysis for the following covered sectors separately: electricity (ELE); refined petroleum products (OIL); chemicals (CRP); nonmetallic minerals (NMM), which includes some ceramic production; pulp, paper, and print (PPP); iron and steel (I_S); and nonferrous metals (NFM) which includes aluminum and copper smelting.

The current version of this model represents the world economy as of 2004 and has been updated to include process emissions for the above energy-intensive sectors. We make certain adjustments to the extractive energy sectors to calibrate supply elasticities carefully;[4] as we discuss later, this parameterization is important for calculating leakage. The model assumes firms are perfectly competitive (no profits), but consumers consider domestic and foreign varieties to be imperfect substitutes (represented with Armington elasticities). The production functions incorporate most intermediate inputs in fixed proportion, although it builds energy inputs into a separate energy nest; thus, reductions in emissions intensity can be made by changing the energy mix, and trading off energy for labor and capital, but not by substituting other inputs. This assumption raises important qualifications for the analysis, which we discuss later. More details of the model can be found in Fischer and Fox (2010).

From the \$50/ton C experiment using the CGE model, we first derive the emissions, prices, intensities, and quantities in response to the carbon price, including the predicted leakage and production changes, in the absence of any adjustment policies.[5] To calculate marginal changes from this new baseline, we then turn to a parameterized version of the simpler analytical model. Specifically, for the parameterized model, 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_j and η_{ij} are the relevant cross price and elasticity. The cost of these

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[4] Capital in the extractive sectors is divided between a fixed portion (the natural resource) and mobile capital so as to target particular elasticities of supply, drawn from the literature and expert opinion: 0.8 for crude oil, 2.0 for natural gas, and 2.5 for coal.

[5] Since our CGE model includes a labor-leisure tradeoff, the use of the emissions revenues can be important. This scenario includes revenue recycling to lower labor taxes; while this assumption is important for welfare calculations, in terms of leakage and the production changes induced by border adjustments and rebate policies, the results are quite similar to those with emissions permit grandfathering. See also Fischer and Fox (2010).

simplifications is that we ignore cross-price and income effects that influence energy demands in other sectors, as well as terms-of-trade effects. An advantage of these simplifications is that, unlike in the complex CGE model, we can easily perform sensitivity analysis—indeed, the reader is welcome to substitute preferred parameters.

We calibrate this model using the CGE model again; from the new baseline of the $50/ton C carbon price, we then add a small taxes or tariffs in the covered sectors that raise the prices of *h, x*, and then *m* by 0.01 percent, which allows us to estimate the elasticities $\eta_{hH}, \eta_{mH}, \eta_{xX}, \eta_{fX}, \eta_{mM}, \eta_{hM}$. 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. Since the foreign good price does not change in our partial equilibrium model simulations, the elasticities η_{fF}, η_{xF} do not come into play.[6] (All relevant elasticities are reported in the Appendix).

Effects of the Carbon Price

First, we report the effects of the $50 carbon price, without any adjustment policies, as simulated in the CGE model. Table 2 presents these results for our different indicators of emissions, competitiveness, and leakage. In particular, we notice some important distinctions between the energy sectors (ELE and OIL) and energy-intensive manufacturing.

The scale of emissions reductions (in mtC) reveal that the vast majority of reductions arise in the electricity sector, where emissions fall 20 percent. Reductions in the other energy-intensive sectors range from 4 to 11 percent. Electricity also experiences the biggest contraction in output: 4 percent, while the others lose 1 to 2 percent of production. However, when we look at the portion of that production lost to changes in net exports, we see that it is relatively unimportant for both electricity and refined products, while for all but pulp and paper,[7] lost competitiveness comprises the majority of lost production. Similarly, the leakage rates are smaller for the energy sectors than most energy-intensive manufacturing sectors, although they do not necessarily map closely with the competitiveness effects.

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[6] Even for a large economy like the United States, foreign price changes are not significant for the covered energy-intensive sectors, with the exception of petroleum products and electricity; still, the equilibrium quantity reactions are implicit in our parameterization.

[7] Results for PPP in particular should be taken with caution, as the print component may distort our ability to interpret the findings for pulp and paper.

Table 2: Effects of $50/ton Carbon Price without Adjustment Policies

	ELE	OIL	CRP	NMM	PPP	I_S	NFM
Reductions (mtC)	138603	4746	5995	3161	1945	1223	330
Emissions change, % (dE^H/E^H)	-20.1%	-10.6%	-7.1%	-8.8%	-11.3%	-4.3%	-5.4%
Production change, % (dH/H)	-4.2%	-1.4%	-1.5%	-1.4%	-0.2%	-1.4%	-2.2%
Competitiveness change, % (dN/H)	-0.3%	-0.1%	-1.0%	-1.1%	-0.1%	-1.2%	-1.6%
Competitiveness change as share of production change (dN/dH)	6%	11%	67%	76%	33%	87%	73%
Leakage rate ($-dE^F/dE^H$)	5%	10%	16%	26%	2%	58%	57%

Leakage is conventionally defined as the change in the foreign sector's emissions as a share of the reduction in the domestic sector's emissions. Importantly, competitiveness effects—that is, the relocation of economic activity in a given sector—are only one source of leakage. Another mechanism for leakage is represented in the CGE model through linkages in global energy markets. For example, the emissions price causes the United States to withdraw demand for oil and coal, which drives down fossil fuel prices globally; as a result, foreign manufacturing tends to become more emissions intensive. Previous studies have shown that leakage estimates are highly sensitive to the parameterization of fossil fuel supply curves (Burniaux and Martins 2000), as well as to the specification of international trade (including Armington elasticities and market structure) in the model (Böhringer et al. 1998; Babiker 2005).[8] Of course, energy price-driven leakage is less important for comparing anti-leakage policies. 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 a large extent unavoidable.

With our parameterization, we find an overall leakage rate of 7 percent, of which approximately 2 percentage points of explained by foreign emissions intensity changes.[9]

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[8] Sinn (2008) argues that since fossil fuels are exhaustible resources, leakage can occur not only across countries but over time and can in theory approach 100%.

[9] Our estimate is on the lower end of many CGE models, which we attribute to two factors: First, we have carefully and more conservatively parameterized the fossil fuel supply responses. Second, our scenario does not cover emissions from downstream transportation,which would have a much bigger impact on oil demand.

However, we see that leakage rates are substantially higher among the manufacturing sectors. Thus, although overall leakage is modest—and the majority occurs in the electricity sector, in which trade is negligible—the leakage in the energy-intensive manufacturing sectors can be quite substantial relative to their more modest reductions, and furthermore, a larger share of that leakage is attributed to production rather than intensity changes.

Table 3 reports many of the factors that indicate the scope for production-related leakage from energy intensive sectors in the United States. In the baseline (2004), the export intensities of production and import intensities of consumption range from nearly zero percent for electricity to over 20 percent in some sectors. The relative emissions intensity is the average emissions intensity of foreign production as a percentage of the average emissions intensity of domestic production. Foreign intensities are higher for all but the chemicals sector, and much higher for iron and steel, nonferrous metals, and nonmetallic minerals.

Table 3. Indicators of Leakage Potential for the United States

	ELE	OIL	CRP	NMM	PPP	I_S	NFM
Baseline export share of home production	0%	6%	21%	6%	6%	8%	16%
Baseline import share of home consumption	1%	11%	20%	15%	7%	17%	25%
Foreign emissions intensity relative to U.S.	117%	146%	85%	174%	107%	160%	152%
Emissions payments as % of cost increase	92%	88%	59%	79%	54%	59%	59%

From these indicators we can see in part why a sector like chemicals suffers significant competitiveness effects, given its trade exposure, but the leakage impacts may be smaller, since foreign competitors seem to be less emissions intensive. The larger leakage in the metals and minerals sectors reflect a combination of trade exposure and more polluting competitors. The last indicator, the share of the cost increase represented by emissions payments, reflects in part the extent to which the adjustment policies can recover the cost changes.

Effects of Adjustment Policies

Switching to the calibrated partial-equilibrium model, we next calculate the changes that would be induced by the different adjustment policies. As indicated in the preceding discussion, the energy sectors exhibit different characteristics from the energy-intensive manufacturing sectors, and we discuss them in turn.

Table 4 presents the results for the energy sectors: electricity and refined petroleum and coal products. All of the policies recapture lost competitiveness, with full border adjustment (at the foreign carbon intensity) being the most effective, while OBR is a close second, on par with the constrained full border adjustment (which can be seen if we add the import tax at the home intensity to the export rebate effects). Only OBR avoids a large share of the lost production, but this is to the detriment of net emissions reductions, due to the lost conservation incentives. Full border adjustment is the most effective at generating additional reductions, but these are quite small in proportion to the reductions achieved under the carbon tax alone.

Table 4: Effects of Adjustment Policies on Energy Sectors

	Production Loss Avoided		*Net Export Loss Avoided*		*Additional Net Reductions*	
	ELE	OIL	ELE	OIL	ELE	OIL
Import Tax (foreign carbon intensity)	4%	14%	61%	148%	0%	1%
Import Tax (home carbon intensity)	3%	10%	53%	102%	0%	1%
Export Rebate	5%	12%	71%	107%	0%	1%
OBR	81%	42%	126%	191%	-13%	-1%
FBA (foreign carbon intensity)	8%	25%	132%	255%	0%	2%

These results are somewhat different for the manufacturing sectors, Figure 1 displays the effectiveness of the different anti-leakage policies on stemming the loss in production. For most sectors, OBR is more effective than import or export adjustment alone; however, for the metals and nonmetallic minerals sectors, full border adjustment (with foreign embodied emissions fully taxed) offers the most protection. The reason is twofold and follows the theoretical analysis: home goods in these sectors are more sensitive to import price changes, and imports in these sectors are more carbon intensive than their domestic counterparts.

Figure 1. Production Loss Avoided in the United States Manufacturing Sectors by Adjustment Policies

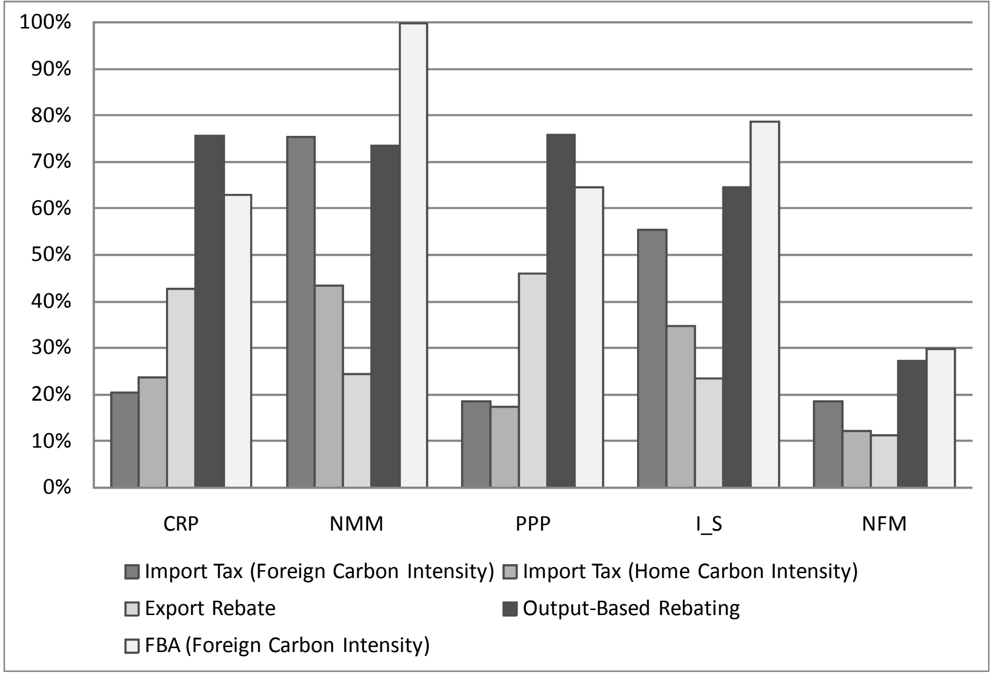
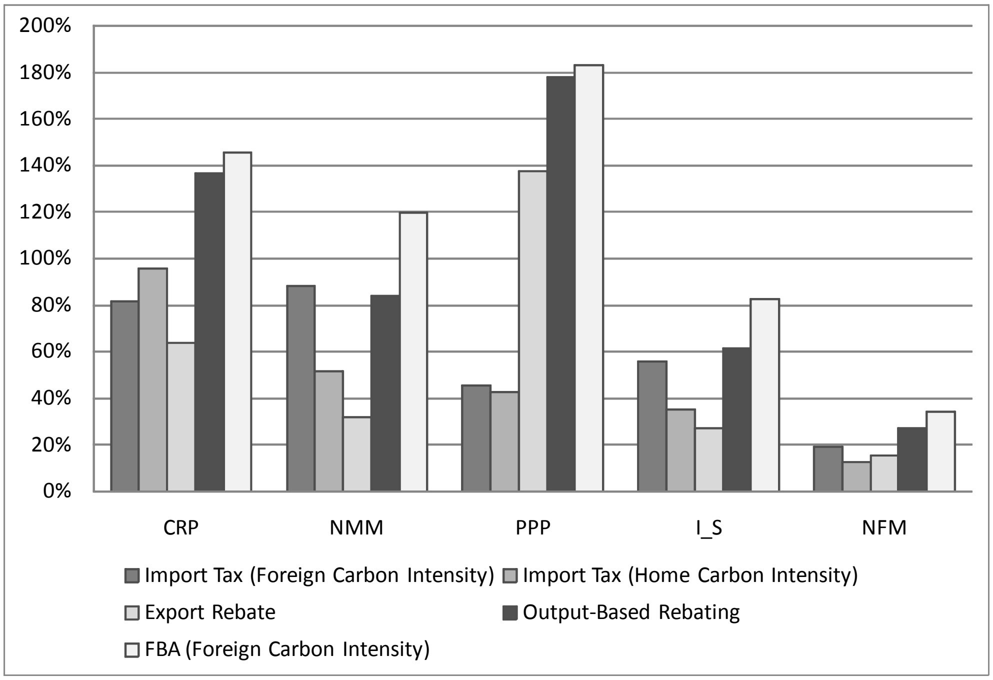


Figure 2 displays the effects on net exports, expressed as a share of the net exports lost under the carbon tax alone. In this case, as surmised in the analytical section, full border adjustment is always the most effective policy by this competitiveness measure; in some cases, the effects exceed 100%, meaning net exports increase relative to no policy. OBR is as or more effective than adjusting imports or exports alone. Except for the pulp and paper sector, import adjustments tend to be more important than export rebates for preserving competitiveness.

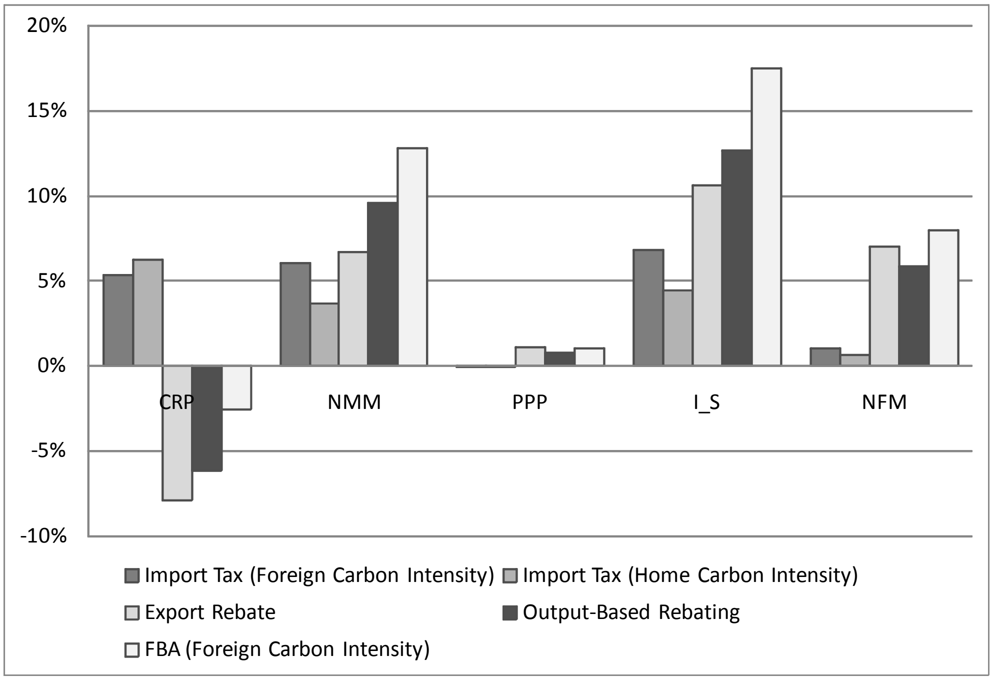
Figure 3 depicts the additional net reductions achieved relative to the emissions tax policy alone as a percentage of the domestic reductions under that scenario. We find that full border adjustment (at the foreign emissions intensity) tends to offer the most gains, with the export rebate playing the more important part here, in contrast to the competitiveness metrics. The exception is the chemicals sector, which emits more than the foreign production it displaces; as a result, policies with rebates tend to increase emissions. Since foreign emissions rates are higher in all but chemicals, weakening the import tax by using domestic or BAT emissions intensities to calculate the adjustment produces smaller results. Again, OBR is about as or more effective than the individual adjustment policies for the other energy-intensive manufacturing sectors, but it actually increases global emissions when applied to chemicals. Most of the improvements are modest, but they can exceed 10 percent of the emissions reductions in nonmetallic minerals and iron and steel.

Figure 2. Net Export Loss Avoided in the United States Manufacturing Sectors by Adjustment Policies



Of course, all of these results are sensitive to the underlying parameters and policy assumptions. For example, if we would also adjust for upstream cost changes from the carbon price, the policies unsurprisingly have stronger effects (e.g., net reductions roughly double for the steel sector). If we double the import own-price elasticities, the policy effects on production are unchanged, but net exports and net reductions are more sensitive to import adjustment. If we double the import sensitivity to home good prices, production impacts are again unchanged, but OBR becomes more effective at improving competitiveness and net reductions. If we double the own-price elasticity for exports, the adjustment policies with export or output-based rebates become more effective at protecting production and net exports, but net reductions in many sectors turn negative (i.e., global emissions increase with the adjustment policies). Given that our highly aggregated data may not adequately represent the smaller set of energy-intensive, trade-exposed sectors, one should bear in mind these effects as better data become available.

Figure 3. Additional Net Reductions in the United States Manufacturing Sectors by Adjustment Policies



Effects in Other Regions

Another way to gauge the sensitivity of the policy rankings to the parameter assumptions is to apply the model to other regions. We conduct the same analysis for Canada and for Europe, which exhibit quite different economic structures from the U.S. and from each other. Table 5 displays some indicators of leakage potential for these countries. Larger shares of Canadian goods are traded, but as a smaller country, the foreign response is smaller (see elasticity tables in the Appendix). Furthermore, the emissions intensities of displaced foreign goods are higher in chemicals but lower in other sectors. European trade intensities are more similar to those of the United States, but the relative emissions intensities of its trading partners are higher.

Table 5. Trade Shares and Relative Emissions Intensities for Canada and Europe

	ELE	OIL	CRP	NMM	PPP	I_S	NFM
Canada							
Export share of home production	5%	14%	46%	18%	41%	26%	71%
Import share of home consumption	4%	10%	51%	27%	22%	34%	51%
Foreign Emissions / Domestic	196%	118%	168%	190%	78%	108%	128%
Europe							
Export share of home production	1%	7%	13%	5%	4%	9%	14%
Import share of home consumption	1%	8%	8%	3%	2%	8%	19%
Foreign Emissions / Domestic	259%	113%	366%	264%	363%	185%	241%

The results of the border adjustment policies on avoiding production losses on the manufacturing sectors are displayed in Figure 4. For Canada, OBR is across the board the most effective at avoiding lost production, while in Europe, full border adjustment is preferred. As the theoretical analysis would indicate, these results arise in part because home good own-price elasticities are higher across the board in Canada, while import price elasticities are higher in Europe. Thus, import adjustments are more effective in Europe, particularly if they can be assessed on the much larger foreign emissions intensities; export rebates are more important in the Canadian sectors with high export price elasticities. In both regions, for some sectors, the combination of these effects means that production may increase relative to no climate policy with some of the adjustment mechanisms.

Figure 5 shows the effects on net export losses. For both regions, as for the U.S., full border adjustment is the most effective policy. Again, rebates play a much larger role in Canada, while in Europe the import adjustments have the greater effect. Furthermore, for the chemicals and pulp and paper sectors, we see large increases in net exports, relative to no carbon tax, with the more effective adjustment policies, due to their high price sensitivity in Canada and import sensitivity in Europe.

Figure 4. Production Loss Avoided from Adjustment Policies

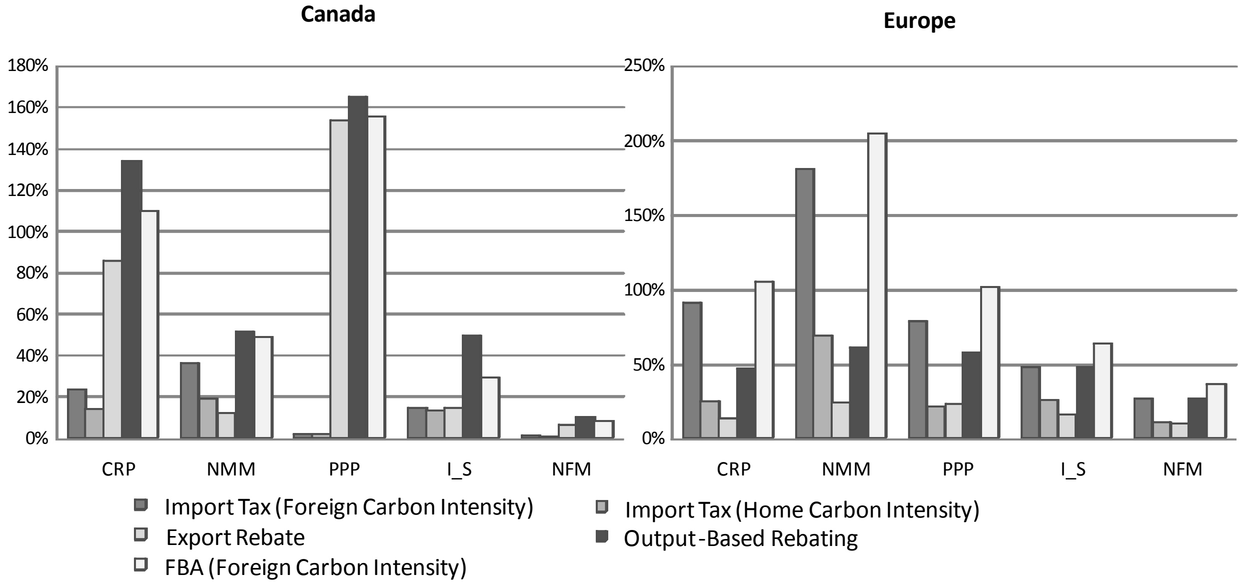


Figure 5. Net Export Loss Avoided from Adjustment Policies

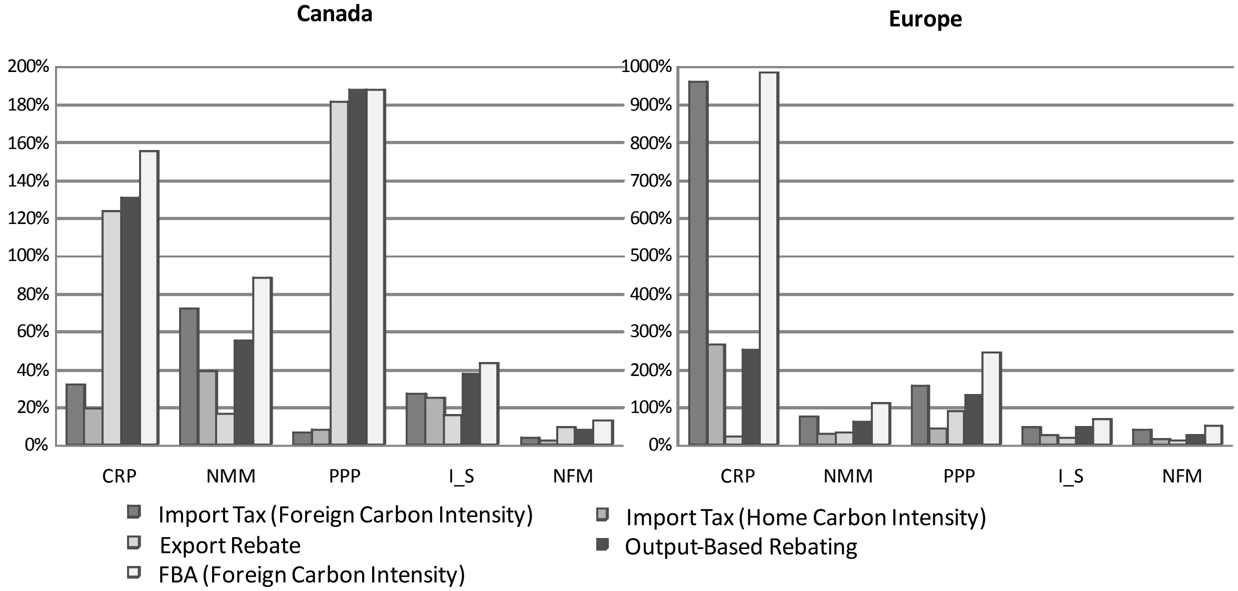
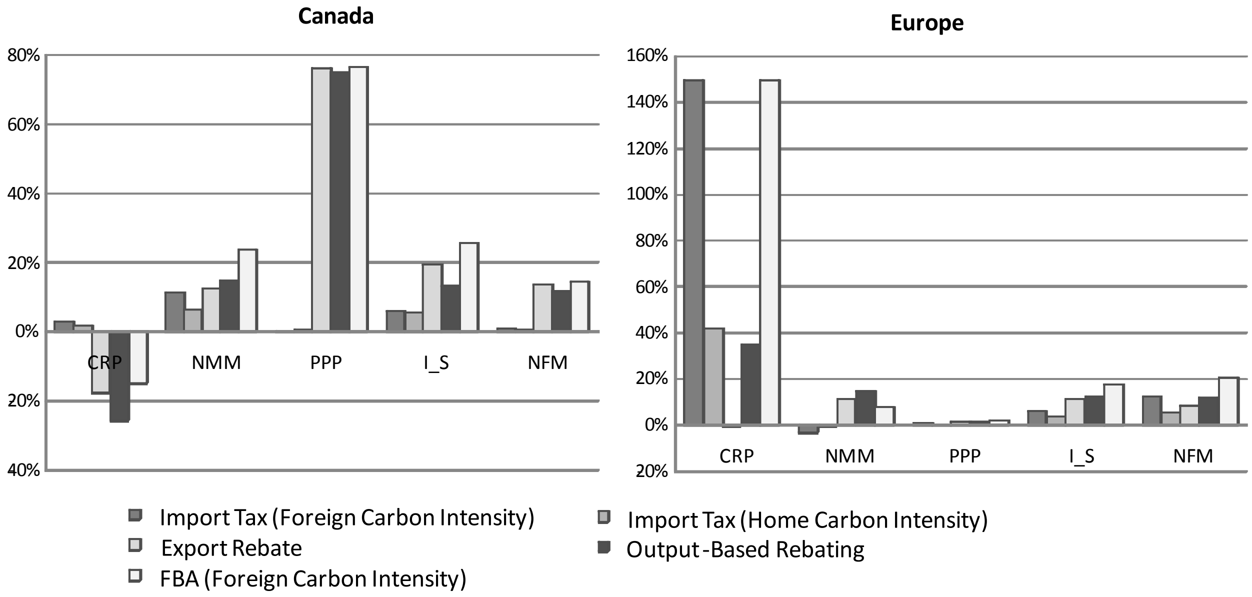


Figure 6 displays the results of the border adjustment policies on net reductions. In most cases, full border adjustment is the most effective policy, typically followed by OBR. For both regions, rebating (including for exports) is relatively more important in achieving additional reductions. For Europe, there is a larger difference between the border adjustment for imports based on domestic or foreign emissions intensities. We see large regional differences in certain sectors. In chemicals, Europe is exceptionally clean (and import sensitive), meaning border adjustments can achieve large gains, while in Canada, which is dirtier, the adjustment policies incorporating rebates increase global emissions in that sector. In pulp and paper, adjustment policies have little effect in Europe, but large effects in Canada. These results have less to do with the relative emissions intensities than large differences in trade sensitivities (see Appendix). The results in the metals and minerals sectors more closely resemble those in the U.S., although the potential for additional reductions is larger, more often reaching 20 percent.

Figure 6. Additional Net Reductions from Adjustment Policies



Though not displayed in the figures, a consistent result across all countries is that OBR is counterproductive for generating additional emissions reductions in the refining sectors. Import (and full border) adjustments are the most effective measures for improving net reductions in these sectors in all cases. The electricity sector in Canada is sufficiently less emissions intensive than its U.S. trading partner that OBR has a positive effect on net reductions.

Discussion and Caveats

This analysis has several important caveats and areas for future research. First, by modeling a carbon tax, this analysis 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 so under a carbon tax is an indicator of the size of distortions they would create in the domestic emissions market.

The analysis also ignores climate policies in other countries, including the EU ETS. The impact of this unilateralist assumption depends on the sector and country. For example, in our model, 12 percent of the leakage related to production shifting for the U.S. steel sector goes to Europe, and roughly one-third to Annex I nations (and 15 percent to China).[10] Since border adjustments can in theory be designed to distinguish between countries with and without adequate climate policies, while OBR cannot, the policies will have different trade-offs as more countries undertake significant and costly GHG reduction policies.

Policy makers and industry stakeholders have a tendency to worry about competitiveness and leakage on a sector-by-sector basis. We have parameterized a model in that same vein, revealing some important trade-offs among the first-order effects of border adjustment and rebate policies. However, sectors do not operate in a vacuum, and any policy targeting one sector will have secondary effects on other sectors that it buys from and sells to, and so on.[11] Ultimately, from an effectiveness standpoint, one cares about total global emissions from all sectors—both covered and uncovered, and at home and abroad. From an efficiency standpoint, revenues foregone with free allocation are not available to lower other tax rates, which affect real wages, labor costs, and welfare. A better understanding of these general equilibrium effects is an area for ongoing research, but we also conduct an initial evaluation here. We simulated the policy of the full border adjustment by using the home emission rates in the full CGE model and compared the results to those of our parameterized partial equilibrium model for the United States. Unsurprisingly, we found some general equilibrium effects when ELE and OIL were included in the border adjustment policy. Excluding these sectors, the partial equilibrium model did a good job of representing the effects on the sectors receiving the adjustment, particularly at home.

Finally, our model (and the CGE model it is based on) is limited in some important ways for understanding the full potential of competitiveness effects and leakage, particularly in the

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[10] These leakage shares do differ from simple import shares, since they include export-related effects and differences in emissions rates; for example, Houser et al. (2008, Table 3.1) report that over half of steel imports are from Annex I nations, so this import share metric may understate leakage.

[11] Lockwood and Whalley (2008) also raise concerns that the effects of widespread border adjustments for carbon can be partly undone by exchange rate changes.

long run. For one, and perhaps most importantly, our level of aggregation for the sectors—chosen because of the availability of econometrically estimated trade elasticities—is arguably too high. In the pulp and paper aggregate, in particular, the subsectors that would be presumptively eligible under Waxman-Markey legislation represent less than 20 percent of the GTAP PPP sector, and the remaining subsectors (largely print) have very different characteristics. Nor can NMM distinguish the individual characteristics of glass, cement, and clinker production. Thus, for more narrowly defined subsectors, the relative emissions intensities of foreign goods and their elasticities may be quite different. Since elasticities of substitution typically rise with greater disaggregation, it is possible that the small numbers for the aggregate leakage that can be 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.

Even if these sectors were disaggregated, the model framework does not yet allow for substitution among non-energy intermediate inputs (for example, between steel, aluminum, and plastic in automobiles, or between steel and cement in construction). In reality, those substitution possibilities reflect other opportunities for emissions reductions; as a result, the model is likely to overstate the efficiency costs of carbon pricing and understate the efficiency losses of rebating.

In particular, some of those substitution opportunities change over time with innovation that improves energy efficiency, reduces material needs, or creates alternative products. Our static model does not allow for technological change, and therefore cannot represent longer-run effects. Innovation may also have important (and uncertain) implications for leakage. Industries that continue producing under carbon regulation will have the incentive to innovate less carbon-intensive products and processes, and those may in turn spill over to industries in emerging economies that are slower to regulate, thereby reducing carbon leakage. On the other hand, if more energy-intensive manufacturing moves offshore as a result of carbon pricing, there may be less incentive to innovate in those sectors, with more attention paid to the remaining emitters, particularly the energy sectors, and the less-emitting sectors like services. In this scenario, leakage could be exacerbated by greater specialization among regulating countries in less emissions intensive industries.

Conclusion

Our analysis indicates that border adjustments for climate policy are not only likely to be contentious and disputed under trade law, but may also be limited in their ability to enhance global emissions reductions. Still, while the leakage related to production “outsourcing” may be only part of the problem, little can be gained by allowing domestic industries to contract if the accompanying emissions reductions are offset abroad. Border adjustment for 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 and net exports associated with a carbon tax.

While it seems that full border adjustment would likely be the most effective policy for the United States for avoiding leakage, if this option is not judged to be consistent with trade law or practically feasible, then OBR could achieve most of those gains. The exceptions regard products like electricity and refined petroleum, where the subsidy undoes the incentives to curb domestic energy consumption and thus expands emissions at home considerably, and (in our parameterization) chemicals, which seem to be more emissions intensive than foreign counterparts. Here, import adjustment is more effective. That OBR does not discriminate among competing countries is a legal advantage but a disadvantage in encouraging other countries to improve their performance; a mechanism may be required for phasing out these domestic benefits as more of the important trading partners take on comparable climate policies.

Finally, we acknowledge some important practical considerations. For import adjustments, any version that attempts to discriminate by country raises thorny issues of how to calculate embodied emissions for foreign products and how to define and enforce reliable rules of origin. For rebates, 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 or plant) can produce different kinds of products (chemicals, for example). Firms in the same sector may have different levels of vertical integration that correspond to different emissions intensities; for example, some cement producers also make emissions-intensive clinker, while others buy the input, so it matters whether the rebates are for clinker or cement. Defining and implementing output-based rebating 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.

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Appendix

Table 6. Simulated Elasticities for the United States

Sector	η_{hH}	η_{mH}	η_{xX}	η_{fX}	η_{mM}	η_{hM}
Electricity	(0.33)	2.49	(5.39)	0.00	(2.69)	0.01
Petroleum and coal products (refined)	(0.65)	1.46	(3.57)	0.08	(1.80)	0.20
Chemical industry	(0.95)	1.77	(5.93)	0.61	(2.33)	0.68
Nonmetallic minerals	(0.52)	2.32	(3.86)	0.07	(2.33)	0.47
Paper, pulp, and print	(0.38)	2.44	(8.87)	0.40	(2.58)	0.22
Iron and steel industry	(0.61)	2.18	(4.24)	0.07	(2.25)	0.52
Nonferrous metals	(1.48)	2.33	(5.86)	0.30	(2.49)	1.15

Table 7. Simulated Elasticities for Canada

Sector	η_{hH}	η_{mH}	η_{xX}	η_{fX}	η_{mM}	η_{hM}
Electricity	(0.50)	2.27	(4.78)	0.01	(2.61)	0.09
Refined products	(0.79)	1.30	(0.61)	0.00	(1.79)	0.17
Chemical industry	(2.28)	0.47	(7.07)	0.14	(1.17)	1.42
Nonmetallic minerals	(0.93)	1.85	(1.37)	0.01	(1.88)	0.79
Paper, pulp, and print	(0.97)	1.66	(18.89)	0.70	(2.07)	0.66
Iron and steel industry	(1.31)	1.40	(1.70)	0.01	(1.67)	0.91
Nonferrous metals	(3.34)	(0.62)	(2.55)	0.14	(1.77)	1.32

Table 8. Simulated Elasticities for Europe

Sector	η_{hH}	η_{mH}	η_{xX}	η_{fX}	η_{mM}	η_{hM}
Electricity	(0.36)	4.91	(4.29)	0.02	(4.95)	0.04
Refined products	(0.82)	2.73	(1.83)	0.04	(2.97)	0.35
Chemical industry	(0.90)	4.48	(4.71)	0.72	(5.19)	0.64
Nonmetallic minerals	(0.25)	4.84	(3.02)	0.17	(4.86)	0.21
Paper, pulp, and print	(0.35)	5.17	(5.30)	0.33	(5.18)	0.16
Iron and steel industry	(0.63)	4.39	(3.61)	0.18	(4.62)	0.54
Nonferrous metals	(1.73)	4.87	(6.58)	0.66	(5.07)	1.58