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THE DESIGN OF BORDER ADJUSTMENTS FOR CARBON PRICES

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We consider the economics and the design of border adjustments (BAs) under a carbon tax. BAs under a carbon tax are taxes on imports and rebates on exports, based on the emissions from the production of a good. They are thought to be a method of reducing inefficiencies from a unilateral carbon price, such as shifts in the location of production, known as leakage. After examining the basic economics of BAs, we examine three design issues: which goods BAs should apply to, which emissions from the production of those goods should be taxed, and from and to which countries BAs should apply. We conclude that BAs will impose high administrative costs and need stronger welfare justifications.

Keywords: carbon taxes, leakage, border adjustments

JEL Codes: F13, F18, H23, Q37, Q54, Q56

I. INTRODUCTION

Suppose that the United States, or a coalition of countries including the United States, puts a price on carbon. The goal of a price on carbon is to cause actors to internalize the harms from emissions of CO_2. It forces actors to face the full set of costs and benefits of their choices.

If the carbon price is imposed only in a subset of countries, however, the price will internalize emissions only from activities in those countries. Activities taking place elsewhere would not face a carbon price. As a result, a unilateral carbon price creates an incentive to shift activities to countries where there is no price on emissions, a phenomenon known as leakage. To the extent of leakage, the carbon price fails to internalize the harms from emissions and distorts the location of activities. Moreover, the potential for leakage may create incentives for countries not to price carbon so as to

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attract high-emitting industries. For these reasons, concerns about leakage have been, and remain, central to U.S. climate policy.[1]

The best method for internalizing the global externality from emissions of carbon dioxide, as well as to control leakage, is a harmonized, global carbon price. Because it may not be possible to achieve a harmonized regime, commentators and policy makers have considered alternative mechanisms to control leakage. A prominent approach is to impose border adjustments (BAs, also called border tax adjustments or border carbon adjustments). BAs are taxes or other prices on imports and rebates on exports based on "embedded carbon," the additional emissions of carbon dioxide caused by production of a good. For imports, they can be thought of as the carbon tax that would have been imposed had the foreign (exporting) country had a carbon tax.[2] They therefore eliminate the carbon-pricing advantage of producing abroad and selling domestically because the carbon price is the same regardless of where production takes place. For exports, BAs are a rebate of the carbon price that was previously paid when the exported good was produced. By rebating previously paid carbon prices on exports, BAs eliminate the disadvantage of carbon pricing when producing domestically and selling into foreign markets.

Leakage and BAs have generated a substantial prior literature.[3] Previous work, mostly using computable general equilibrium (CGE) models, has attempted to estimate the potential size of leakage and the extent to which BAs reduce it. It has also considered

[1] For example, during the negotiations over the Kyoto Protocol, the Senate passed the Byrd Hagel Resolution 99 to 0 (U.S. Senate, 1997). The key focus of the Byrd Hagel resolution was the potential for carbon leakage under the Kyoto structure. The resolution stated that "the United States should not be a signatory to any protocol to, or other agreement regarding, the United Nations Framework Convention on Climate Change of 1992, at negotiations in Kyoto in December 1997, or thereafter, which would mandate new commitments to limit or reduce greenhouse gas emissions for the Annex I Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period."

[2] For cap and trade systems, BAs would be a requirement that an importer purchase permits in the same way that a domestic entity would. A producer would not need to purchase permits for its exports.

[3] Papers focused on design issues include Branger and Quirion (2014a), Congressional Budget (2013), Cosbey (2008), Cosbey et al. (2012), Houser et al. (2008), Ismer and Neuhoff (2007), Izard, Weber, and Matthews (2010), McLure (2014), Metcalf and Weisbach (2009), Monjon and Quirion (2010), Persson (2010), van Asselt and Brewer (2010), and Zhang (2012).

Papers addressing BAs more generally include Alexeeva-Talebi et al. (2012), Babiker (2005), Balistreri and Rutherford (2012), Bednar-Friedl, Schinko, and Steininger (2012), Boeters and Bollen (2012), Böhringer, Balistreri, and Rutherford (2012), Böhringer et al. (2012), Böhringer, Carbone, and Rutherford (2012), Böhringer et al. (2012), Branger and Quirion (2014a), Branger and Quirion (2014b), Caron (2012), Dong and Walley (2012), Dröge (2009), Elliott et al. (2010), Felder and Rutherford (1993), Jakob, Marschinski, and Hübler (2013), Jakob, Steckel, and Edenhofer (2014), Lockwood and Whalley (2010), Richels, Blanford, and Rutherford (2009), van Asselt and Brewer (2010), Weitzel, Hübler, and Peterson (2012), Winchester, Paltsev, and Reilly (2011), Kuik and Gerlagh (2003), Kuik and Hofkes (2010), Kuik and Verbruggen (2002), Monjon and Quirion (2011), Helm, Hepburn, and Ruta (2012), de Cendra (2006), Fischer and Fox (2011), Fischer and Fox (2012a), Fischer and Fox (2012b), and Elliott et al. (2013).

the design of BAs and their legality, as well as alternatives to BAs that are simpler or that address potential legal problems related to World Trade Organization compatibility. BAs have also been included in bills considered by the U.S. Congress, which means that design issues have been given detailed enough thought to be drafted into legislative language.[4]

In this paper, we consider the design of BAs, building on and extending the prior literature.[5] We begin with background on the effects of unilateral carbon taxes and the arguments for BAs. We then turn to three core design issues: what types of goods should get BAs, what emissions from those goods should count, and from or to which countries should BAs be imposed.

II. CONCEPTUAL ISSUES

To understand the design issues, it is helpful to start with an understanding of the effects of BAs and what perfect BAs (i.e., BAs when there is perfect information) would look like. A full exploration of the economics of unilateral carbon prices is outside the scope of this paper. Instead, we seek, to establish the following through a heuristic examination of unilateral carbon taxes: (1) BAs shift carbon taxes downstream from extraction or production in the taxing country (regardless of where goods are consumed) to consumption in the taxing country (regardless of where goods are produced); (2) taxes on the use of fossil fuels in production or on the goods produced with fuels lower the global price of fossil fuels; (3) leakage from a tax on production shifts production from the taxing country to other regions and should not be thought of as arising from the reduction in the price of fuels, which is global; (4) the choice to impose BAs should be based on whether they increase the welfare of the taxing region; welfare is at best tenuously related to reduced leakage and welfare could even fall as leakage declines; and (5) competitiveness is not a good reason for imposing BAs.

To illustrate the issue, consider a simplified world where there are only two regions, Home (H) and Foreign (F). H and F each have deposits of fossil fuels which they extract. Once extracted, fossil fuels are costlessly traded, so that there is a world price for fossil fuels. Each country then uses fossil fuels and labor to manufacture goods, and each country also uses labor to provide services. Consumers in both H and F provide labor and deposits of fossil fuels, and use the income this generates to purchase manufactured goods and services (from both H and F). Because services are traded, there is a global price for labor (set in efficiency units). For simplicity, we will assume that labor supply is fixed, all markets are competitive, and all emissions come from the use of fossil fuels.[6]

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[4] The American Clean Energy and Security Act of 2009. The international effects of this bill, including the provisions related to BAs, were examined in Interagency Report (2009).

[5] Because the prior literature is so large, we do not attempt to cite all of the literature for each issue.

[6] This set up is an extension of the model used in Elliott et al. (2010).

We want to examine the effects when H but not F imposes a carbon price. H can impose a carbon price all the way upstream, on the extraction of fossil fuels (which we will call an extraction tax), midstream, on the use of fossil fuels in production (which we will call a production tax), or downstream, on the consumption of items created with fossil fuels (which we will call a consumption tax). The issues are similar if the price is imposed through a tax or through an alternative mechanism such as a cap and trade system. We will use the terms carbon price and carbon tax interchangeably.

Suppose that H imposes a production tax. A production tax in H will have two effects: it will lower the global price of fossil fuels (known as the fuel price effect) and it will shift the comparative advantage of producers in H and F. The fuel price effect arises because producers in H will shift away from the use of fossil fuel because that input now bears a tax. Moreover, consumers (in both H and F) may reduce their purchases of goods produced in H. Together, these effects reduce the demand for, and, therefore the price of, fossil fuels. The fuel price effect is global since everyone sees the same world price for fossil fuels. It does not differentiate producers in H and F.

What differentiates producers in H and F is the tax on the use of fossil fuel in production in H but not F. The tax on the use of fuel in production in H forces those producers to shift away from the use of fuel in production and, to the extent they cannot shift their production methods, to sell their products at a higher price than producers in F. As a result, consumers of goods produced in H, regardless of where they live, will buy fewer of these goods and will instead shift to goods produced in F. For example, if consumers used to purchase cement or steel produced in H, they may shift to cement or steel produced in F. This effect, the shift in production from H to F, is what generates leakage, which is generally defined as the increase in emissions in F as a fraction of the reduction in emissions in H. When production shifts to F, emissions in F go up, and the greater the shift, the greater the leakage.

Suppose that H imposes BAs. The BA on imports to H is equal to the carbon price that would have been due had F imposed a carbon price; it is a tax on emissions during production of the good in F, imposed when the good enters H. If goods produced in F but consumed in H bear a tax, there is no advantage to shifting production from H to F for items sold in H because they bear a tax regardless. The BA on exports from H is a rebate of taxes or other carbon prices paid during the production of a good in H when it is exported. If there is a BA on exports, there is no incentive to shift production abroad for items sold in F because there is no tax regardless of where the good is produced.

One way to think about the combined effects of BAs on imports and exports is that they shift the tax from production in H (regardless of where the goods are consumed) to consumption in H (regardless of where the goods are produced). Imposing BAs is equivalent to shifting the tax from mid-stream, on production, to downstream, on consumption.

BAs have a similar effect if H imposes an extraction tax instead of a production tax. An extraction tax plus BAs is the same as a tax on either production in H (if BAs apply only to the import and export of fossil fuels) or as a tax on consumption (if BAs apply to goods produced with fossil fuels).[7]

If H imposes a tax on consumption (either directly or by imposing a production or extraction tax and adding BAs), there is no incentive to shift the location of production. We should expect leakage, as measured by the shift in the use of fossil fuels in production, to go down. CGE modeling confirms this: in every paper we are aware of, BAs either significantly reduce or eliminate leakage. For example, in 2012, the Energy Modeling Forum compared the output of 12 CGE models, all set so that the taxes in Framework Convention Annex I countries (excluding the Russian Federation) led to a 20 percent decline in emissions (Böhringer et al., 2012). Without BAs, leakage rates, defined as the rise in emissions in the non-taxing region as a percentage of the decline in the taxing region, ranged from 5 percent to 19 percent with a mean of 12 percent. Leakage rates with BAs were between 2 and 12 percent, with a mean value of 8 percent.[8]

Note, however, that taxes on consumption have a fuel price effect similar to taxes on production. They will reduce the price of fossil fuels because of the incentives they create to reduce consumption of energy or goods produced with energy. In fact, for the same global reduction in emissions, the fuel price effect under production and consumption taxes has to be the same. The reason is that the extent of reduction in emissions depends on the extent of extraction of fossil fuels. The extent of extraction, in turn, depends on the price that extractors receive. To have the same reduction in extraction, production and consumption taxes need to have the same effect on the price of fuel. BAs, therefore, do not change the fuel price effect if tax rates are set to keep the reduction in emissions constant.[9]

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[7] In the first case, adding BAs to an extraction tax in H effectively shifts it to a production tax in H. The BAs tax the importation of energy to H and grant a rebate on the export of energy from H. To see the effects, consider fossil fuels that are extracted in H but sold to a producer in F and used there for production. There is no tax on this production because any tax on the extraction in H is removed when the fuel is exported to F. If fossil fuels that are extracted in F are used for production in H, there is a tax when the fuels are imported into H. Therefore, all energy used for production in H bears a tax. The BAs shift the tax base downstream from extraction to production.

Moving downstream, adding BAs to a tax on production in H effectively shifts it to a consumption tax in H. To see the effect, consider a good produced in H that is subject to a tax on the energy used in production. If it is exported to F, there is a rebate of the tax, so there is no tax on goods consumed in F. If it is consumed in H, the tax remains. If the good were instead produced in F and consumed in F, there would be no tax. And if it were imported to H and consumed there, there would be a tax on the import. The BAs shift the tax base from production to consumption.

[8] Note that the BAs in the study were assumed to be imperfect. They were not based on the actual emissions from the production of the imported good. With perfect BAs, the reduction in production leakage would likely have been greater. For example, in the simulations in Elliott et al. (2013), perfect BAs effectively eliminate production leakage.

[9] Note that tax rates in many modeling exercises are set so that emissions reductions in H are held constant (e.g., Böhringer et al., 2012). The fuel price effect will not be the same under this approach.

In addition, consumption taxes create an incentive to shift the location of consumption. Because of the fuel price effect and the tax on consumption in H, consumption of energy and goods produced with energy is less expensive in F than in H, resulting in a distortion in consumption. A unilateral carbon tax, whether on production or consumption (i.e., a production tax plus BAs) will distort either production or consumption. Measures of leakage are based on shifts in production, and BAs do indeed reduce such shifts, but the shift in consumption in a world with BAs will also produce inefficiencies.

Here is another way to think about it. Traditional measures of emissions attribute emissions to the place where the fossil fuel is burned — where the smokestack or tailpipe is located. Some have proposed an alternative measure, which is to attribute emissions to the place where goods are consumed (e.g., Peters, 2008; Larsen and Hertwich, 2009). Neither one is, a priori, the right way to attribute emissions. Using a production measure of emissions, production taxes shift the location of emissions and consumption taxes, for the most part, do not. Using a consumption measure of emissions, production taxes do not shift the location of emissions but consumption taxes do. (In both cases home bias in the consumption of goods, as captured in CGE models through trade costs or home bias in preferences, complicates the picture. With home bias we could see consumption distortions under a production tax and production distortions under a consumption tax.)

Rather than using a measure of leakage to determine whether we should impose BAs, what we should care about is their effect on welfare. Reduced leakage and welfare are not the same. In fact, we can show that, in some cases, welfare may increase along with leakage, which means that reduced leakage is not a good proxy for welfare.

To see why this can be the case, compare production and consumption taxes, setting the tax rates so that the resulting (global) emissions are the same. This allows us to compare the effects of the taxes while holding emissions, and, therefore, harms from climate change, constant.

If emissions and the harms from climate change are the same under production and consumption taxes, the difference in the two taxes will depend only on the consumption in each country. To understand consumption levels under the two taxes, we need to start by determining each country's income. There are two sources of income in our simple model: labor and returns from exploiting energy deposits plus, for H, tax revenues.

We have assumed that labor supply is fixed, and wage rates are pinned down by the productivity of labor in producing services. Therefore, income from labor is the same under both taxes. Moreover, if tax rates are set so that emissions are the same under the two taxes, the returns to energy extraction will be the same. The reason is that if emissions are the same, total extraction must also be the same in both cases. But if extraction is the same, then the price of energy is the same, which means that the rents from extraction, and where extraction takes place, do not change. Therefore, income from labor and from fuel deposits is the same under either tax, in both H and F.

Consider welfare in F. Since F does not impose a carbon tax, it does not have tax revenue under either type of tax. Therefore, F's income is the same under a consumption tax and a production tax. With the same income under the two taxes, the only question is what consumers in F can purchase with that income. With the production tax, the price for F's consumption of goods produced in H includes the tax, whereas under a consumption tax, it does not. Therefore, consumers in F can consume more under the consumption tax. Consumers in F are better off with BAs.

The effects in H are more complex and will depend on the tax rates under the two scenarios, the production technology, and the extent to which H is a net importer or exporter of carbon. In many cases, however, consumers in H will be worse off with BAs. For example, if production is Leontief and H's tax revenue is the same under production and consumption taxes, consumers in H are worse off with a consumption tax (that is, with BAs). If H imposes a consumption tax, consumers in H but not F bear the tax, which means that consumers in H alone will substitute away from manufactured goods, reducing their welfare. (Leontief production means that producers cannot substitute away from energy use.) With a production tax, consumers in both countries substitute away from manufactured goods produced in H. Consumers in both countries, therefore, bear the burden of the tax, so that H is better off. That is, we can think of a production tax relative to a consumption tax as effectively shifting some of the burden to foreign consumers.

With more general production technologies and differences in tax revenues, consumers in H may be either better off or worse off with BAs, depending on the relevant parameters. In addition, labor supply may not be fixed, at least in the short to medium term: imposing a carbon tax may create dislocations and welfare losses in H. Moreover, there may be profits in some manufacturing sectors in H that are lost with a production tax. While these and other factors may offset the effects illustrated here, the core underlying logic still holds: there are reasons why production taxes may be better for H than consumption taxes and vice versa for F.

Another reason often cited for imposing BAs is "competitiveness." In particular, energy-intensive industries worry that a carbon price would increase their costs relative to foreign producers. BAs by shifting the tax to a consumption base would mean that the tax is based on the location of consumers, not producers, thereby "leveling the playing field" for producers.

It is not, however, easy to translate this argument into economic terms. Because in the long run trade must balance, any effect on energy-intensive industries in H will be offset by effects on other industries in H. That is, to the extent that a production tax reduces the competitiveness of energy-intensive industries in H, it will increase the competitiveness of non-energy-intensive industries in H, and vice versa in F. The net effect is a change in the industry structures in H and F, but no change in the overall competitiveness of producers in H.

Ultimately, the choice to have BAs and their design has to be based on a belief that they enhance H's welfare. It is not clear whether BAs do this and, therefore, even leaving aside administrative problems, it is not clear that BAs are advisable.

Let us suppose that H decides to have BAs. The question for the remainder of this paper is how they should be designed. Answering this question might depend on why H wants to impose BAs. For example, if a powerful industry can block H from imposing a carbon price if there are not BAs, perhaps H should impose the minimum necessary to buy off the blocking industry. The choice to have BAs and their design, in this case, is a political problem of how to pass a law.

Although this political approach has much to recommend it, for the remainder of this paper we will assume that the goal of BAs is to shift the carbon tax in H from production or extraction in H to consumption in H. As a result, BAs on producers in F should act like a carbon tax imposed by F to internalize the harms from emissions for goods produced in F and sold in H. This means that perfect BAs would impose a tax on F producers based on marginal harm from their emissions. For similar reasons, BAs should remove the tax on exports from H to F.

Perfect BAs are not feasible because of the costs of gathering the necessary information. Administering and complying with the system would far exceed the benefits. A wide variety of different goods are imported from many different countries. Supply chains can be complex. A single import may have parts produced in many different countries, using different production methods, and fuel sources. The design of BAs therefore is about deciding on the compromises necessary to balance the costs of administering the system with the benefits. There are three broad sets of trade-offs: which goods, which emissions, and from which countries. We discuss each in turn in the following three sections.

Note that in each of these cases, many of the same problems apply to both imports and exports. The only real difference between BAs on imports and exports is that exports are produced domestically, which means that information about fuel sources and production processes will be less expensive to obtain for exports (and provision of the information for exports can more easily be required by law for exports than for imports because exporting entities are subject to U.S. jurisdiction). Because imports present a more difficult problem than exports, our discussion focuses on imports, keeping in mind that many of the problems may also apply to exports.[10]

III. PRACTICAL ISSUES

A. Which Goods?

The BA for a good is the tax rate multiplied by the embedded carbon (the emissions from the production of the good). The embedded carbon depends on how the good was produced and the energy source used (at each stage of production). Calculating these values for all goods and for each year (because the values will change regularly, in part in response to desired incentive effects of the tax) would be an overwhelming admin-

[10] Note that merely because the tax is imposed domestically does not mean that we have the information needed to compute export rebates. If the tax is imposed upstream, such as when fossil fuels enter the economy, the tax would be embedded in the price of fossil fuels and not computed directly when a good is produced. To determine the rebate, we would need information on the amount and sources of energy used in the production of the good, which means that most of the issues discussed for foreign production apply for domestic production.

istrative task. There are a vast number of imported and exported goods, produced in different ways, with differing energy sources, and in many different places. Moreover, for most goods, energy is a small portion of the overall cost, which means that the BA would be small relative to the total price.[11] The administrative cost of attempting to impose BAs on all goods would vastly exceed any imaginable benefits. Researchers have proposed two methods of reducing this complexity to make BAs manageable.

The first is that instead of applying BAs to all goods, researchers recommend limiting BAs to goods where BAs would have the largest effects on leakage. The two central factors are whether the good requires a lot of energy to produce (so that its price is substantially affected by BAs) and whether the good is exposed to trade (so that the risk of leakage is high). Only these goods, the so-called "energy-intensive, trade-exposed" or EITE goods, would be subject to BAs, thereby making the system less difficult to administer.

There are many different ways of defining EITE goods. In general, the definition requires a combination of a minimum level of energy or greenhouse gas intensity and a minimum level of trade exposure. Researchers differ on the precise combination.

The second method of simplifying BAs is to aggregate EITE goods into a small number of categories and apply the same BA to all goods in the category. The reason for aggregation is that if we try to impose separate BAs for each individual good, the number of BAs quickly goes up to unadministrable levels, even if BAs are limited to EITE goods.

For example, Houser et al. (2008) aggregate EITE goods into just five broad categories: other than refining (which involves the direct import or export of a fossil fuel so it raises different and easier issues), they highlight chemicals, ferrous metals, nonferrous metals, paper, and minerals as both energy intensive and trade exposed. Most industries that are highly exposed to trade, such as apparel and electronics, are not very energy intensive, so a carbon price would have little effect. Nonferrous metals, such as aluminum, are most at risk from leakage because of their particular combination of energy intensity and trade exposure.

The Waxman–Markey Bill took a more disaggregated approach. It defined an industry as "presumptively eligible" for provisions designed to address leakage if (1) its energy intensity or greenhouse gas intensity[12] is at least 5 percent and its trade intensity is at least 15 percent,[13] or (2) its energy intensity is 20 percent regardless of its trade intensity. Using 6-digit NAICS categories, an interagency study of the Waxman–Markey Bill (Interagency Report, 2009) determined that 44 industry categories would meet this definition, mostly within the five broad industries highlighted by Houser et al. (2008).

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[11] Interagency Report (2009) says that for 75 percent of manufactured output, energy expenditures are less than 2 percent of the total. Only 1/10 of the value of manufacturing has energy expenditures above 5 percent. Note that this data is for a situation where there is no tax or other price on carbon. The values could change with a tax.

[12] Energy intensity is energy expenditures as a share of the value of shipments. Greenhouse gas intensity is greenhouse gas emissions priced at $20/ton as a share of the value of shipments.

[13] Trade intensity is the combined value of exports and imports as a share of domestic production plus imports.

Moving from 6-digit NAICS codes to the individual product level would create a very large number of different tax rates, and the number of calculations needed to determine the rates would go up dramatically. To see this, we can take the 44 NAICS categories that meet the Waxman–Markey test and look at the number of different individual products that these categories include. For example, within the industry category "basic organic chemicals" (NAICS code 325199) there are 153 different chemicals. These include calcium organic compounds, carbon organic compounds, enzyme proteins (i.e., basic synthetic chemicals except for pharmaceutical use), fatty acids (e.g., margaric, oleic, and stearic) manufacturing, organo-inorganic compounds, plasticizers (i.e., basic synthetic chemicals), silicone (except resins), and synthetic sweeteners (i.e., sweetening agents).

Other categories are similarly diverse. Within the category of plastics (NAICS code 325211) there are 83 different types of plastic. There are 198 different types of inorganic chemicals (NAICS code 325180). In total, within the 44 NAICS codes from the interagency report on the Waxman–Markey Bill, there are just under 1,500 different products (using the NAICS breakdown for products under each 6-digit category) that would have been presumptively eligible for trade relief under the Waxman–Markey Bill.[14]

For each product we would have to determine the BA on imports, computing the embedded emissions for each unit of the product. Most of these products will be produced and exported by many different countries. Each country, or each factory within each country, may use a different production process, the same production process at a different efficiency level, or have different energy sources, so the emissions will be different.

Suppose each product is imported from ten countries. Using these crude numbers, there will be 15,000 different tax calculations. That is, for each of 15,000 different product/country combinations, the government will have to calculate the emissions from the production of the good using data on the production process used in the foreign country and the type of fuel that was used.

Moreover, these taxes will change over time as the production processes, the fuel sources, the types of goods, and the exporting countries change. Therefore, the 15,000 different tax rates will have to be recomputed every few years if we were to use product-level rates.

Because of the administrative costs, no country would likely attempt to impose a tax this way. A central design question is whether, or the extent to which, we can reduce the number of taxes by aggregating individual products into broader categories and applying average taxes across the categories. The relevant question is how much the emissions from the production of different products in a given sector vary from one another, creating inaccuracies from aggregation. We suspect that the ability to aggregate will vary across industrial sectors. Note however that the determination of when aggregation makes sense itself requires knowing the underlying information, so

[14] These values were computed using the NAICS product identification tool on www.naics.com. The value is inexact because some of the NAICS categories have changed since the interagency report.

aggregating products into larger categories may not reduce the informational demands significantly.

While aggregation of individual products into broad categories is likely necessary to implement BAs, it may also reduce their effectiveness. The reason is that aggregation means that the BA would not be based on the actual emissions from the production of any particular good. For example, if we set a single tax rate for all organic chemicals, it would not matter that the production of fatty acids has a different level of emissions than the production of synthetic sweeteners or that the production of fatty acids by a particular individual producer had lower emissions than average for fatty acids. The tax would be the same regardless because it is set for the whole NAICS category. Individual producers could no longer affect their tax by reducing their emissions per unit of production or shifting their product mix, which was one of the points of imposing a tax in the first place (the other being that the resulting higher price would reduce demand).

A number of commentators have suggested that one way to solve the information and incentive problems is to set a relatively-high presumptive BA on most goods and allow producers to come forward with information about their actual emissions to obtain a lower (and more accurate) BA based on that information. This approach would create an incentive for producers to provide the necessary information, reducing the need for tax administrators in the United States to discover the information themselves. The ability to prove out of a broad category is also central to some arguments about the legality of BAs.

These mechanisms undercut the use of category averages. If we allow producers of lower emissions products within the category to prove that a lower tax should apply, we would effectively revert to product-level taxes. For example, if we apply the same BA to all organic chemicals, we cannot let producers of fatty acids get a lower rate by providing information that their emissions are lower than average. If they can do this, we would end up with a far greater number of tax rates and tax rate determinations, reducing or possibly eliminating the advantage of using aggregates.

Before moving on, note that some of the literature suggests that we should limit BAs to raw materials excluding final goods (e.g., Cosbey et al., 2012). The argument for this exclusion is that calculating BAs for final goods is more difficult than for raw materials because final goods are assembled using a complex mix of raw materials and because the chain of production may span many countries.

On the other hand, a substantial portion of imported emissions (i.e., emissions associated with the production of imported goods) comes from final goods. Excluding final goods may exclude a large portion of emissions. In addition, excluding final goods requires a definition of final goods. While for some goods it will be clear whether they are intermediates or final goods, for many others it will be ambiguous as they can be both directly consumed or used in production. Moreover, whether something is a raw material or a final good is not directly related to whether a carbon tax will affect the location of the production of the good. The Waxman–Markey Bill avoided this complication by defining the category of covered goods by reference to what it was concerned about: whether the good was energy intensive and trade exposed.

B. Which Emissions?

For each product or product category, we have to determine the emissions associated with its production. That is, if the tax is to be on the emissions from the production of goods consumed in the United States, we have to calculate the emissions associated with the production of imports.

There are two factors needed to determine emissions in production: the type of fuel used and the production process (for the particular factory where the good was produced).

1. Fuel

The problem of determining the type of fuel that was used to produce a good has not attracted a lot of attention in the literature. The basic thought is that we would use the actual fuel used in the production of a good. If this is too complex to compute, we could impose a proxy such as a country average but, if an individual producer uses a cleaner fuel than the proxy, we would allow that producer to document this fact and lower its BA accordingly. This system, however, may not work if only exports in F are subject to a carbon price (such as through BAs) rather than all production in F.

To see why this is the case, suppose that F imposes a production tax on all production within F. In addition, assume that there are two types of fuels, hydro and coal, and that they are interchangeable for production. The tax raises the cost of using coal but not hydro. It does not matter where in the economy the coal is used — whatever goods are produced using coal will bear the price increase. The coal will be used where, and to the extent to which, it remains cost-efficient even when it bears a higher tax.

Now suppose that only exports from F are subject to a tax (because the importing country imposes BAs). Compared to when all production is taxed, it now matters which goods are produced using coal. If and only if an export is produced using coal does it bear a tax. Exports produced using hydro do not. This means that there is an incentive to rearrange fuel use to minimize the tax.

To illustrate, compare two extreme cases. The first case is if coal is used entirely for exports and hydro is used entirely for domestic consumption. The tax would be imposed on the amount of coal used. The second case is the reverse: hydro is used entirely for exports and coal entirely for domestic consumption. In this case there would be no tax whatsoever even though emissions, production, and the types of goods that are exported is exactly the same as in the first case.

What this example shows is that if BAs do not apply to the entire economy, they need to be based on the additional emissions from the production of a good rather than actual emissions. As the example illustrates, the two may not be the same. For example, in the case where hydro was used for export, if the production of the export good leads to additional coal use, it should not matter that the producers can hypothetically trace their power to a hydroelectric plant. The use of hydro might merely reflect artificial fuel switching.

The problem with following this policy is that there is no easy way to compute the additional emissions because of the production of a good. It requires determining the hypothetical additional fuel because of the production of an export, not something that is directly measurable.

One possible solution is to use the fuel type for new energy sources under construction in a region as a reasonable proxy for the marginal source of energy. For example, in the United States, most new power is from gas. Therefore, emissions for goods would be computed based on an assumption that gas (rather than the current mix of gas, coal, hydro, and nuclear) is the marginal source of power. Although it would be a rough proxy, it may be sufficient. This approach also generates the correct incentives in F for which new energy sources to construct.

A simpler but less accurate alternative is to use some sort of rough average of fuel that is actually used. This eliminates the fuel switching problem but it does not attempt to measure the marginal source of fuel. To the extent that the marginal and average fuel sources differ, therefore, it produces the wrong result. This approach would still be better, however, than using the actual fuel source because at least it eliminates the fuel switching problem.

2. Production Process

Once we know the type of fuel used, we can combine that information with the amount of that fuel used in production to determine emissions. Similar goods, however, may be produced using widely varying production processes. This means that the BA for each good would have to be tailored to the particular production process used to create it.

Houser et al. (2008, pp. 46–51) contains an extensive discussion of the production processes used around the world for the five categories of EITE goods. For example, cement can be produced using either wet kilns or dry kilns with very substantial differences in energy use between the two. Similarly, steel can be produced from scrap using an electric arc or with a blast furnace using coal and coke to melt iron ore. There are substantial differences in energy use in the two methods.

Countries around the world use these varying production processes. Moreover, within a single generic type of process, countries may have plants of varying ages and efficiency levels. Accurate BAs will require an assessment of the different processes and efficiency levels in exporting countries.

Like with fuel sources, the correct measure would look to the additional emissions from the production of the good. If a country has, say, older and newer plants producing the same good, it could use the newer, more efficient plants for export and the older, less efficient ones for domestic consumption. This would lead to a reduction in taxes with no change in production or exports. Like with fuel sources, we would likely have to use some sort of proxy, such as a country average, or an estimate of the marginal production process.

Because of the difficulties with determining how a good was produced, a number of authors have proposed proxy measures or benchmarks. Cosbey et al. (2012) list four possible benchmarks: (1) the average emissions intensity of production for each product category in each exporting country, (2) the average emissions intensity of production for each product category in the importing country (which we assume to be the United States), (3) the emissions intensity of the best available technology for each product category, and (4) the emissions intensity of the worst available technology for each product category (in either the importing or each exporting country). None of these benchmarks is perfect. For example, using a benchmark based on technology in the exporting country would require information about production in each foreign country. Using a benchmark based on technology used in the United States (the importing country) would mute incentives for foreign producers to reduce emissions because their behavior would have no effect on the BA that they would pay.

We do not have a view on which approach, or some hybrid of these approaches, is best. The key is to note the tradeoff: emissions measures better tailored to the marginal decisions made by foreign producers create better incentives and, at the same time, are more informationally intensive. Determining the correct tradeoff requires knowing how difficult it would be to obtain the needed information and how much accuracy helps with incentives.

3. Direct versus Indirect Emissions

The final issue in estimating the emissions from the production of a good is determining which emissions count. In theory, BAs should cover all emissions including direct emissions from the production process, so-called indirect emissions from the generation of electricity used in production (even if a third party produced the electricity), and other emissions (such as emissions from the production and transport of intermediate goods, from waste disposal, and from purchases of capital goods).

Most commentators suggest imposing BAs on direct and indirect emissions but not on other emissions. While indirect emissions may be somewhat difficult to measure, they may be substantial and if they are not included in BAs, there would be an incentive to outsource electricity production. The remaining emissions, commentators argue, are too hard to measure, and, therefore, should be excluded (e.g., Cosbey et al., 2012, p. 14).

Leaving out the remaining emissions, however, creates a number of problems. Like with indirect emissions, it creates an incentive to outsource. We can think of not imposing BAs on outsourced production as the equivalent of imposing a tax on in-house production. Although BAs may often be small enough that this tax on in-house production will not matter, firms that are on the margin between in-house production and outsourcing will have an incentive to move toward outsourcing.

Moreover, defining what it means to be a direct emission, produced by the exporting firm, and an emission produced by a different firm is not straightforward because firms can have complex and intertwined ownership structures. The system of BAs would have to have rules to determine when groups of firms are treated as a single firm. If there is a tax on being a single firm, there will be incentives to structure co-ownership to avoid being considered a single firm. For example, in U.S. domestic tax law, there are rules for treating firms as consolidated. Sometimes there are benefits to consolidation and sometimes there are costs. It is relatively easy for taxpayers to ensure that where there are benefits, firms will be treated as consolidated and where there are costs, they will not.

To illustrate, consider a "firm" that produces an intermediate good, which it then turns into a final good. Suppose the intermediate is produced through a wholly-owned subsidiary, which sells the good to its parent who turns it into a final good. That is, the "firm" is two separate corporations. Presumably, the two corporations would be aggregated, and emissions from the production of the intermediate would be treated as in-house emissions. But what if the parent corporation sold a 20 percent stake in the subsidiary to a third party? Would the production still be in-house? What if the third party received only preferred stock or non-voting common stock, or a 30 percent stake with put options to sell back some of that stake? Or what if the subsidiary was held indirectly through a partnership where the outside partners had limited partnership interests with fixed returns? The combinations are almost endless. It is not impossible to draw up a set of rules, which gives results in all of these cases. Tax laws and accounting rules have systems to deal with these cases, but the systems are complex, to a great extent arbitrary, and are easy to manipulate. As a result, including only direct and indirect emissions in BAs will not be as much of a simplification as it first appears.[15]

C. Which Countries?

The final issue in designing a BA regime is determining which countries it should apply to. The two major choices are all countries or countries without comparable carbon pricing regimes. Neither choice is good.

Start with all countries. To understand the problems in the simplest context, consider a hypothetical world with just two countries H and F, and suppose both have an identical carbon price on domestic production. If both countries impose BAs, exports from H to F have the carbon tax removed at the border by H on export and an identical tax imposed by F on import. Similarly, exports from F to H have the tax removed by F and imposed by H. The net effect is just a transfer of tax revenue to the net importer of carbon from the net exporter. This could be done administratively through an annual cash transfer between the countries rather than by removing and imposing taxes on individual products at the border. With truly harmonized carbon prices, BAs are not necessary even if each country wants their tax base to be domestic consumption of energy-intensive goods (rather than production).

Suppose that H and F both have carbon prices but they are not harmonized. They may have different bases or rates, or apply their tax at different stages of production. In places where the taxes differ, having BAs would make a difference, and we cannot

[15] Cosbey et al. (2012) would look to rules developed by the World Resources Institute to determine lifecycle emissions of greenhouse gases. See http://www.ghgprotocol.org/. It is not clear whether these rules can work in the context of BAs rather than for computing lifecycle emissions, however, because they were not developed in a context where there is an incentive to manipulate the rules.

simply treat the taxing countries as one block with transfers of tax revenue between them. In this case, the countries may want to impose BAs.

It would be important in this case that both countries agree to either imposing BAs or not. That is, they will want to harmonize their decision to have BAs even if their taxes are not harmonized. To see why, suppose that F has a carbon tax on production but no BAs while H has a carbon tax with BAs. Exports from F to H would not have the F tax removed but would have a BA when the good enters H, creating a double tax. And exports from H to F would have the tax removed when the good leaves H but no tax imposed when the good enters F, creating a zero tax. If both countries impose a carbon price, both countries should impose BAs, or, alternatively, neither country should.

A choice to impose BAs on imports from and exports to all countries suggests that all countries with a carbon price should make the same choice. Note also that the design of the BAs would have to be basically similar. Where the BAs differ, problems of the sort just described can arise. Given the complex choices in the design of BAs discussed earlier, it would take substantial coordination to make such a system work.

Suppose instead we only impose BAs on imports from and exports to countries without a comparable carbon price. Doing so might greatly simplify the system because a large percentage of U.S. imports of carbon-intensive trade-exposed goods are from developed countries, which are likely to impose a carbon price. For example, Houser et al. (2008) provide a list of the source of imports to the United States of their five categories of carbon-intensive trade-exposed goods. Table 1 provides an updated version of their list. As can be seen, for most products, Annex I countries dominate the list of exporters.

While possibly an improvement, there are two serious problems. The first is determining whether the carbon price in a given country is sufficiently similar to the U.S. price so that we need not require BAs. The intuition is that we want to target inefficient shifts in the location of production due to differences in the price of carbon.

The problem with this standard is that it is very hard to measure. One approach would be to examine the carbon price in another country to see whether it looks similar. Given the vast number of policy choices that can be made in designing a carbon emissions system, it is not clear how to assess the similarity.

For example, countries can impose carbon taxes at varying rates, cap and trade at varying emissions levels and trading prices, hybrid systems, flexible command and control that allows some trading, and traditional command and control systems that impose technology requirements. Many countries or regions have a mix of all of these policies. For example, countries in the European Union (EU) are subject to the EU Emissions Trading System, they impose taxes on transportation fuels, and they have numerous mandates including feed in tariffs and technology standards. In addition, they regulate fuels in different ways, such as encouraging or prohibiting the use of nuclear energy.

Each of these systems — taxes, caps, mandates, and so forth — can be imposed on different bases, exempting favored sectors. They can also include offsets in sectors that are not covered or in other countries. Cap and trade systems can auction or give away permits. Determining what is "comparable" is not straightforward. And all of these

Table 1

U.S. Imports of EITE Goods by Origin, 2015

Steel		Aluminum		Chemicals		Paper		Cement	
Source	Percent	Source	Percent	Source	Percent	Source	Percent	Source	Percent
EU	22.3	Canada	46.7	Trinidad	31.4	Canada	39.7	Canada	39.0
Canada	15.3	China	12.4	Canada	21.0	China	19.6	EU	26.7
Korea	11.5	OPEC	9.2	Korea	10.1	EU	18.0	China	11.6
China	10.5	EU	9.2	EU	8.3	Mexico	6.8	Korea	7.9
Brazil	7.1	Russia	5.8	OPEC	5.3	Korea	2.9	Mexico	5.0
Annex I	50.4		59.4		35.5		61.7		70.3

Source: Authors calculations

systems can change over time, requiring new determinations of whether a country has a comparable carbon price with each change.

One possibility is to try to estimate the implied carbon price or shadow price for any given system. If there is a tax, the price is the net tax rate on emissions. Cap and trade systems allow prices to be observed in the market. For command and control systems, we would calculate a shadow price. Most countries include a mix of policies, which would mean computing some sort of aggregate or average price for the relevant industries. Computing aggregate shadow prices, however, would not be easy given the complexity of emissions regulation, and would likely depend on modeling assumptions, particularly for command and control policies.

Some commentators suggest BAs are unnecessary for countries who are party to a multilateral emissions treaty on the theory that joining the treaty represents an agreement on what each country will do. We now have such a multilateral emissions treaty, the Paris Agreement. All or almost all countries are party to the agreement, so, under this approach, applied naively, there would be no BAs. The Paris Agreement does not eliminate concerns about leakage, however, because many countries agreed to only limited emissions reductions. If we think of countries' obligations as shadow prices on carbon, the shadow price varies dramatically after the agreement. While the Paris Agreement should reduce the need for BAs because all countries agreed to some sort of emissions policy, it is not clear that, on its own, it eliminates concerns about leakage.

Yet another approach would be to try to estimate where leakage will occur and target those countries. That is, we would model the effects of an increase in the carbon price in the United States. Countries that induce substantial leakage would be subject to BAs.

The problem with this approach is that it does not target the right thing. Suppose that the United States and all other countries choose carbon prices, and the location of production is in equilibrium. The proposed test would ask where production shifts if there is a marginal increase in the price of carbon in the United States. Where production shifts, however, is not related to the places that have failed to internalize the cost of emissions. Production may shift to a country with a very high price on carbon because the increase in the U.S. price reduces that country's comparative disadvantage due to its high price.

For example, suppose that the EU had a very high carbon price and the United States had no carbon price. We then estimate the leakage effects of a small carbon price in the United States and impose border taxes on countries where there is leakage. Production might shift to the EU in such a case, but this would likely be because the carbon price eliminates the disadvantage the EU had from its carbon price. The "leakage" is an undoing of the leakage caused by the EU carbon price rather than something caused by a unilateral carbon price in the United States.

The Waxman–Markey Bill tried yet a different approach to determine which countries are subject to BAs. First it limited BAs to industrial sectors where less than 85 percent of U.S. imports are from what we might call "good" countries (p. 1120 of bill). Good countries are countries that are part of a climate treaty or that have a greenhouse gas intensity for the sector below that of the United States. For sectors that are subject to BAs under this test, BAs apply only to countries that are not part of a treaty, and countries with greenhouse gas emissions intensity for the sector higher than the United States for that sector. There were also exceptions for least developed countries and countries with very low emissions (p. 1129 of bill).

While this approach has the advantage of seeming to be objective, it does not track the reason why the bill included BAs in the first place: to prevent leakage. A country may have a greenhouse gas intensity for a sector below that of the United States but still be an attractive place to relocate production. Moreover, the net change in emissions from relocating production depends on the marginal source of emissions, not the average emissions in a country or sector within that country. For example, if a plant that gets its power from gas in the United States relocates abroad and the additional energy needed to power that plant abroad comes from coal, there would be a net increase in emissions.

Moreover, the criteria are not really objective because there is no straightforward way to determine which countries have met the treaty requirement. The bill would define this requirement as a treaty imposing "nationally enforceable and economy wide GHG emissions reduction commitments at least as stringent as US." The bill does not define "stringent" and the term has no clear meaning in this context. Does it mean the same price even if the resulting emissions reductions will be lower in a given country because of conditions there? Or does it mean the same percent (or total) emissions reductions off of a chosen base year (and what if that base year is inappropriate for that country because emissions were unusually high or low that year)? Does it matter whether the country generally has high or low emissions? Similarly, we would not easily be able to determine when an emissions reduction commitment is nationally enforceable and economy wide.

In short, there do not seem to be straightforward criteria for determining which countries should be subject to BAs and which ones should not be. Without straightforward criteria, however, the choice will be, or will at least seem to be, political. And the problem with the choice being political is that BAs can become, or seem to become, a tariff of the sort that trade policy has spent decades trying to eliminate.

The second problem with exempting a broad group of countries, beyond defining the exempt countries, is the problem of transshipping. The basic version of transshipping is simply routing a good produced in a country without a carbon price through a country with a comparable carbon price so that it appears to come from the second country, thereby avoiding BAs. Many commentators have noted that some form of product tracing would be necessary to prevent this sort of evasion.

The transshipping problem, however, is more complex than this simple evasion. Suppose that there are three countries. H and F both price carbon, and, as a result, H does not impose BAs on imports from F. The third country, G, does not have a carbon price, and assume that H imposes BAs on imports from G, but F does not. To be concrete, suppose that F and G each produce 100 units of a carbon-intensive good and currently consume 80 units domestically and export the remaining 20 units to H. Under this arrangement, the 20 units of the good H imports from F do not bear a BA and the 20 units of the good H imports from G do.

Now suppose that G shifts its 20 units of exports to F, and F genuinely consumes the goods there. To meet demand in H, F now exports 40 units to H. All 40 units are genuinely produced in F, which means that they should not bear a tax. There has been no change in the patterns of production or consumption but the tax has been eliminated.

There is, of course, an observable difference in the two cases, which is that in the rearranged world, all of the imports to H come from F. Conceivably, this fact can be used to detect transshipping. But recall that there has been no actual transshipping. All of the goods imported to H were actually produced in F. Therefore, a regime that tried to prevent this sort of rearranging would have to try to measure what would have been produced in F and G absent the incentive to rearrange. But there is no easy way to make such a measurement, because the imposition of BAs is supposed to change behavior. Moreover, after a few years of BAs, there would be no readily comparable pre-BA period to use as a baseline.

IV. CONCLUSION

Each of the design issues — which goods, which emissions, and which countries — raise significant problems. In combination, implementing BAs will be a daunting prospect. The best that can be done is crude BAs that roughly estimate emissions for broad categories of goods from a select group of countries. Even imposing such a system would be difficult. Because of these problems, we should demand strong justifications before imposing BAs. Our review of the economics of unilateral carbon taxes, however, does not find strong justifications for BAs.

There are alternatives to BAs that address many of the problems that BAs are intended to address. These alternatives should be carefully considered before adopting BAs. One alternative is to threaten to impose BAs in the future on countries that do not meet a specified standard for emissions reductions or a specified carbon price. The basic intuition for this approach is that it might induce countries to impose a price on carbon while avoiding the complexities of actually imposing BAs. Moreover, if producers know that imports from a given country will in the future face BAs, they may not relocate there in the first place, reducing leakage. That is, threatening to impose BAs may give all the benefits of actually imposing BAs without the cost.

The Waxman–Markey Bill took this approach. Under the procedures in the Waxman–Markey Bill, the President would notify each country of the potential for BAs in the future. If there were no treaty meeting specified conditions by 2018, the President would then impose a version of BAs on the import of certain goods, which Waxman–Markey calls the International Reserve Allowance.[16] Under this system, importers of covered

[16] Because Waxman–Markey was a cap and trade bill, it would have required importers to purchase permits much like domestic producers would have had to purchase permits. It appears that importers would have purchased permits from a separate pool than domestic producers. It is not clear why this approach was taken because it can mean that the prices in the two markets differ. The bill states that the Administrator (of the EPA, who runs the program) is supposed to ensure that the prices in the two markets are the same, but it is not clear how that is supposed to be done.

Note also that Waxman–Markey did not include rebates on export so it did not impose full BAs. It did contain a rebate program for EITE industries but this was not based on exports. Instead, it was a general subsidy.

goods would have to buy permits in much the same way that the Waxman–Markey permit system would have worked for domestic emissions.[17]

This approach has much to recommend it (the future, contingent use of BAs not the particular details of the program). By threatening BAs, it may get the benefits without the costs. It may be even more relevant in a post-Paris world than it was in 2009 when the Waxman–Markey Bill passed the House. In a post-Paris world, most countries have agreed to some sort of emissions policy. This reduces the need for BAs and the threat of BAs could be tailored to issues that are likely to come up in future negotiations, such as stronger targets or verification of emission reductions.

A second alternative is to focus on obtaining a more robust international agreement than the Paris Agreement. Nordhaus (2015) has proposed an alternative to BAs with precisely this focus.[18] He starts with the premise that the core problem in designing climate policy is free riding. Leakage is just a minor aspect of free riding because most energy use is for domestic consumption. This means that the central reason to free ride is to get the benefit of global emissions reductions while keeping low prices of carbon-intensive goods for domestic consumption. This free-rider problem is present with or without leakage. Nordhaus wants to impose tariffs as a way of preventing free riding, at the cost of distorting trade.

BAs, he argues, are not suitable for this purpose because they are too small. Because most energy in most countries is used for domestic purposes, BAs on exports would be too small to create an incentive to price carbon. Nordhaus instead would impose a uniform percentage tariff on all imports from non-pricing countries. This would be far simpler than BAs and yet better designed to address the free-riding problem.

Finally, Fischer and Fox (2012b) consider output-based rebates, comparing them to BAs. Output-based rebates are payments to producers that are not based on the behavior of the particular producer so that they are, in a sense, lump sum. For example, an output-based rebate may be based on an industry average level of emissions per unit. Producers would get a tax rebate or, for a cap and trade system, free allowances, equal to their production multiplied by the industry-average emissions per unit. Producers given an output-based rebate would still have an incentive to reduce emissions (per unit) because the rebate would not be sensitive to their particular emissions. Therefore, they could lower their tax payments without reducing their rebate by lowering their emissions per unit.

Output-based rebates create the right incentives on the margin for producers to substitute toward lower-emitting production methods. Moreover, on average, domestic and foreign producers of the same good would face the same carbon price, zero. The problem with output-based rebates is that they do not increase the average cost of energy-intensive goods (or said another way, they eliminate the price increase that a tax would otherwise create). This means that consumers do not have an incentive to substitute away from energy-intensive goods. But, for that same reason, output-based rebates greatly reduce the underlying cause of leakage.

[17] Page 1087 through 1115 of the bill.

[18] See also Cottier, Nartova, and Shingal (2014) who proposed a similar system.

Fischer and Fox (2012b) compare output-based rebates, BAs, BAs applied only to imports, and BAs only applied to exports. They estimate the effectiveness of each policy in reducing emissions (they do not measure welfare). They find that they cannot rank these policies consistently across all parameter choices, but that most of the time, BAs are the most effective policy. Output-based rebates, however, often capture most of the gains of BAs. Moreover, output-based rebates would be far simpler to implement because they are based on domestic emissions and only apply to domestic producers. While they seem clearly second best, in that they eliminate one of the benefits of a carbon tax — consumers would not see appreciably higher prices for energy-intensive goods because of the output-based rebate — they may be worth considering if some sort of policy like BAs is necessary.

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