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Border Adjustments for Carbon Emissions

Basic Concepts and Design

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RESOURCES FOR THE FUTURE

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Abstract

We consider the economics and the design of border adjustments (BAs) under a carbon tax. BAs are taxes on imports and rebates on exports 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 strong welfare justifications.

Key Words: carbon taxes, leakage, border adjustments

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Border Adjustments for Carbon Emissions: Basic Concepts and Design

Sam Kortum and David Weisbach*

1. 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 carbon dioxide (CO_2). Actors facing a price for activities that result in emissions will reduce those activities and the resulting emissions.

If the carbon price is imposed only in a single country or region, however, it internalizes emissions only from activities in that country. Activities taking place elsewhere would not face a carbon price. A unilateral price therefore creates an incentive to shift activities offshore 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 benefit from the relocation of high-emitting industries. For these reasons, concerns about leakage have been central to US climate policy.[1]

The best method for internalizing the global externality from emissions from carbon dioxide, as well as to control leakage, is a harmonized, global carbon price. Because it may not be possible to impose such a policy, commentators and policymakers 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

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[1] For example, during the negotiations over the Kyoto Protocol, in 1997 the Senate passed the Byrd-Hagel Resolution (SR 98) 99 to 0. 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."

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 good been produced domestically (but using the production process and fuel that was actually used abroad).[2] They therefore reduce the 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 tax that was previously paid when the exported good was produced. By rebating previously paid taxes or carbon prices on exports, BAs reduce the disadvantage of producing domestically when selling into foreign markets. BAs therefore reduce the incentive to shift the location of activities and the resulting leakage.

Because of their prominence in debates about leakage, 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 the design of BAs and their legality, as well as alternatives to BAs that are simpler or that reduce potential legal problems related to World Trade Organization (WTO) compatibility. BAs have also been included in bills considered by 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] Before getting into the details of design, we discuss the basic economics of unilateral

[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.

[3] Papers focused on design issues include Branger and Quirion (2014a, b), CBO (2013), Cosbey (2008), Cosbey et al. (2012), Houser et al. (2008), Ismer and Neuhoff (2007), Izard et al. (2010), McLure (2014), Metcalf and Weisbach (2009), Monjon and Quirion (2010), Moore (2011), Persson (2010), van Asselt and Brewer (2010), Zhang (2012).

Papers addressing border adjustments more generally include Alexeeva-Talebi et al. (2012), Babiker (2005), Balistreri and Rutherford (2012), Bednar-Friedl et al. (2012), Boeters and Bollen (2012), Böhringer et al. (2012a, b, c, d), Branger and Quirion (2014a, b), Caron (2012), Dong and Walley (2012), Dröge (2009), Elliott et al. (2010), Felder and Rutherford (1993), Jakob et al. (2013, 2014), Lockwood and Whalley (2010), Richels et al. (2009), van Asselt and Brewer (2010), Weitzel et al. (2012), Winchester et al. (2011), Kuik and Gerlagh (2003), Kuik and Hofkes (2010), Kuik and Verbruggen (2002), Monjon and Quirion (2011), Helm et al. (2012), de Cendra (2006), Fischer and Fox (2011, 2012a, b), and Elliott et al. (2013).

[4] The American Clean Energy and Security Act of 2009. The international effects of this bill, including the provisions related to border adjustments, are examined in EPA (2009).

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

carbon prices and border adjustments. We base our discussion on a simple model of carbon taxes and trade, found in a companion working paper.[6] We show that BAs do not have simple or strong economic justifications.

After discussing the economics of border adjustments, we turn to their design. We consider three basic sets of design choices: which goods should be subject to BAs, which emissions from those goods should be included, and from and to which countries should BAs be imposed. .

We conclude that because of the high administrative costs of implementing BAs, the best that can be done is to impose BAs on a limited set of goods. Even for those goods, there is no simple measure of emissions, which means that a rough proxy must be used. Finally, choosing which importing and exporting countries should be covered will inevitably be complex. Moreover, because there are no clear criteria for the included countries, the choice will be political. In combination, these three sets of administrative problems mean that imposing BAs will be complex, expensive, and imperfect. As a result, we should demand strong justifications before attempting to impose border adjustments. Because the economic justifications for BAs are not apparent, countries considering unilateral carbon prices should consider alternatives to BAs to address concerns about leakage.

An initial question before turning to our analysis is whether an examination of BAs remains relevant after the Paris Agreement of 2015. Under the Paris Agreement, almost all countries will (if they comply) have some sort of emissions reduction policy. This world looks different from the Kyoto Protocol world, where some countries were to meet stringent emissions targets and the rest of the world had no obligations at all. Much of the analysis of BAs assumed a Kyoto-type world where leakage concerns were starkly presented.

Although the leakage problem and the need for BAs were reduced after Paris, the problem did not go away. Countries agreed to a wide variety of emissions reductions policies, and some countries are hardly constrained at all. For example, China will continue to increase its emissions until 2030. India agreed only to reduce the carbon intensity of its economy, not to reduce emissions in an absolute sense. While these policies impose implicit or shadow prices on carbon, the shadow prices are likely well below the shadow prices in developed countries.

[6] On file with the authors.

In addition, countries may be able to meet their obligations under the Paris Agreement by reducing emissions primarily within nonexporting sectors of the economy, protecting their export sectors. If they take this approach, leakage will remain a concern even if the shadow price of carbon were the same across countries. Finally, countries may not comply with their obligations because there are no sanctions in the Paris Agreement for noncompliance. As a result, leakage will still be a concern after Paris. Paris nevertheless weakens the need for BAs and therefore should reduce our tolerance for the high administrative costs and complexities that BAs would impose.

2. Basic Theory

In this section, we describe some basic results from economic modeling of carbon taxes and border adjustments. Our goal is to understand what the effects of BAs are likely to be and the reasons why we might want BAs. We divide the discussion into five points.

2.1. Extraction, Production, and Consumption Taxes

As a general matter, Pigouvian taxes need to be imposed directly on the externality-causing activity. A Pigouvian tax should be on the release of a pollutant into the atmosphere, the earth, or water, not on a related output or input.[7] For example, attempting to tax emissions by taxing driving would lead to less driving but not necessarily more fuel-efficient vehicles. If carbon taxes follow this principle, they would have to be imposed on the release of carbon dioxide into the atmosphere, such as on the tailpipe of an automobile and on the smokestack of a power plant.

Monitoring emissions of carbon dioxide in this way would be infeasible. Fortunately, we can greatly simplify the administration of a carbon tax because there is a (nearly) one-to-one correspondence between the carbon molecules in fossil fuels and the release of those carbon molecules into the atmosphere when the fuels are combusted.[8] This means we can impose a carbon tax on fossil fuels rather than on emissions without raising additional distortions. For example, we know the number of carbon molecules purchased by a driver when he buys gasoline. When he drives, those carbon molecules will be released, which means that we can tax

[7] Cropper and Oates (1992); Schmutzler and Goulder (1997).

[8] There are some exceptions. For example, carbon emissions might be captured and stored, or some parts of crude oil might be turned into tarmac. A tax on the fuel would have to allow credits for these exceptions.

the purchase of gasoline at the pump rather than tracking emissions from the tailpipe. Similarly, we can tax coal or natural gas purchases by power plants rather than emissions from the smokestack when the fuel is burned.

Because of this flexibility, we can impose carbon taxes anywhere in the chain of production, from upstream on the extraction of fossil fuels to downstream on the consumption of products created with fossil fuels. We will consider three generic types of carbon taxes: (1) a tax all the way upstream, on the extraction of fossil fuels, which we call an extraction tax; (2) a tax on the use of fossil fuels in production (including home production for heating and transportation), which we call a production tax; and (3) a tax on the consumption of goods created with fossil fuels based on the emissions when the goods were created (the embedded emissions), which we call a consumption tax.

In a closed economy, each of these taxes, if implemented accurately, would be identical. They would each capture all of emissions from the use of fossil fuels. The choice among these different forms of taxes would be one of administrative convenience.

Most commentators have proposed upstream taxes because there are far fewer entities that would have to calculate and remit the tax. For example, Metcalf and Weisbach (2009) suggest a tax on fossil fuels at the point where they enter the economy: the extraction of coal, the refining of oil, and the processing of natural gas. They estimate that there would be around 2,500 taxpaying entities in the United States under this system. This tax can be seen as a mix of an extraction tax on coal and natural gas (because to the extent there is trade in these fuels, it is after the tax is imposed) and a production tax on oil (because trade in oil is before the tax is imposed on refining).

A downstream tax would be much more difficult to impose. There are more than 250 million vehicles in the United States. A tax on tailpipes would increase the number of taxpayers by orders of magnitude. Moreover, determining the emissions from each of these millions of vehicles would be challenging because doing so would require monitoring tailpipes. For other goods, such as steel, cement, paper, and chemicals, a tax would require estimating the embedded emissions. Estimating embedded emissions would be difficult because the carbon dioxide emitted when a good was created is not apparent from inspection of the good. Therefore, in a closed economy, an upstream tax is superior to a downstream tax.

With an open economy, the economic effects of these three tax bases—extraction, production, and consumption—can vary substantially. The choice is no longer one of just administrative convenience. Understanding the differences is central to understanding the role of border adjustments.

2.2 Effects of These Taxes: Extraction Tax Raises the Price of Energy; Production and Consumption Lower It

2.2.1 Global Taxes

To see the difference, start with a global tax in which countries impose a common tax rate. Because of the (near) one-to-one correspondence between extraction and emissions, the tax bases are the same. The difference is where the revenue ends up. With trade in fossil fuels and in goods embodying them, extraction, production, and consumption can take place in different countries. A tax on each of these bases will provide tax revenue to the countries where those activities take place. Countries that have relatively more extraction would want an extraction tax, and the same for production and consumption. Because the only difference is which country gets more of the tax revenue, however, countries could agree to impose the tax in the most administratively convenient spot and split the tax revenue as they wish.

2.2.2 Taxes only in H

The analysis is more complex if just one country or region imposes a carbon tax and the rest of the world does not. For simplicity, assume there are two countries or regions, one with a carbon tax and one without. Call the country that imposes a carbon tax the home country, or H, and the country that does not the foreign country, or F. We want to understand the effects of extraction, production, and consumption taxes when H but not F imposes the tax.

A simple way to think about the differences in these three tax bases is to focus on their effects on the price of energy.[9] Once we understand their effect on the price of energy, we can see how the price change propagates through the economy to understand all of the effects of the tax.

[9] To keep the discussion simple, we use the terms *energy* and *fossil fuels* interchangeably, as if all energy were produced using fossil fuels. A central, maybe *the* central, effect of carbon taxes is a switch to non–fossil fuel sources of energy. The ability to switch to clean energy dampens the effects discussed here but does not change the basic economics, so we can simplify the discussion by assuming that energy and fossil fuels are interchangeable.

Start with an extraction tax. A tax on extraction increases the costs of extraction in H. If an extractor previously had to pay $1 to recover a unit of fuel, it now must pay $1(1+*t*) where *t* is the tax rate.

To the extent energy is traded (so that we are considering an open economy rather than a closed economy), an increase in the after-tax price of energy in H increases the global price of energy. If the price of energy goes up, however, foreign extractors will have an incentive to extract more. As a result, extraction will increase in F. This increase in extraction in F is a form of leakage that we call extraction leakage. The relevant activity, here extraction, goes up in F, which partially offsets the reduction in H.

Conditional on this new, higher global price of energy, production and consumption take place based on market conditions, without being affected (directly) by the tax. For example, energy-intensive goods will be more expensive, so consumers will substitute away from these goods. This happens globally because all consumers face a higher price for energy. Similarly, production of energy-intensive goods becomes more expensive, so production methods and the overall level of production will change. This effect is global, and the location of the effect does not depend on the tax.[10] Overall, an extraction tax, by increasing the price of energy, reduces global consumption of energy and energy-intensive goods, reduces domestic extraction, and increases foreign extraction.

Compare those results to a tax on consumption. A consumption tax is a tax on the embedded carbon in goods purchased in H. Goods with a high embedded-carbon content (i.e., they were energy-intensive to produce) will be more costly because of the tax. Consumers in H therefore will purchaser fewer of these goods, and producers everywhere will economize on energy inputs for goods sold in H. This will lower the demand for fossil fuels. With less demand, the price of fossil fuels will drop. Therefore, a consumption tax reduces the price of energy, which is the opposite of the effect of an extraction tax. To the extent fossil fuels are traded, this effect is global: a consumption tax lowers the global price of fossil fuels.

With a lower global price of fuel, less fuel will be extracted, globally. The location of the changes in extraction are not determined by the tax. With a lower price of fossil fuels, however, consumers abroad, who do not pay a tax, will substitute toward these goods, creating what we call consumption leakage. On net, there is a change in the demand for carbon-intensive goods

[10] This conclusion assumes no costs of trade. Taking into account trade costs would make these results less stark.

(consumers in H reduce their demand and consumers in F increase their demand, partially offsetting the reduction). This creates a change in production, but the location of the change is not directly determined by the tax. Overall, a consumption tax reduces domestic consumption of energy-intensive goods, reduces global energy prices and global extraction, but increases foreign consumption of energy-intensive goods.

Finally, consider a tax on the use of fossil fuel in production, which will lower the price of fuel in much the same way as a consumption tax does. It is a tax on the use of fuel in H. Facing this tax, producers will reduce their use of fossil fuels in production, and consumers will reduce their purchases of goods produced with fossil fuels. As a result, the tax lowers the demand for fossil fuels. Because of the lower demand, a production tax will reduce the price of energy.

The results of a lower price of energy flow through the economy. As with a consumption tax, lowering the price of fossil fuels lowers global extraction, but the location of the changes in extraction is not determined by the tax. The tax on production in H means that it becomes relatively more expensive than production in F, so some production will shift to F, an effect we call production leakage. Finally, the costs of the energy-intensive goods previously produced in H will go up (either because they are still produced in H and bear a tax or because they are produced in F, which was revealed to have a comparative disadvantage). The price of energy-intensive goods originally produced in F will go down because of the lower price of energy. Consumers will shift their patterns of purchases accordingly.[11]

We can see, then, that extraction taxes increase the price of energy while production and consumption taxes reduce it. The effects then flow through the economy. Each results in a different type of leakage; in each case, some of the taxed activity—extraction, production, or consumption—shifts abroad. Untaxed activities may also shift because of the way the burden of the tax flows through the economy. The extent and location of these shifts depend on the economic fundamentals rather than the tax. For example, a tax on consumption, by lowering the global price, will reduce energy extraction; where the reduction takes place will depend on the relative costs of extraction in different locations and the price reduction, and not on where the tax

[11] It is common to describe a production tax as generating two forms of leakage: the shift of production from H to F and, because of the lower price of fossil fuels, an increase in consumption in F and in the use of energy by producers in F. The lower price of fossil fuels, however, affects production and consumption everywhere. Since it applies equally to consumers and producers in H and F, we do not think of the lower price as a separate form of leakage.

is imposed. Similarly, a tax on production does not directly affect where extraction and consumption take place, and a tax on consumption does not directly affect the location of extraction and production. Table 1 summarizes these conclusions.

Table 1. Effects of Extraction, Production, and Consumption Taxes

Tax	Effect on the price of energy	Why	Leakage	Knock-on effects
Extraction	Increase	Increases cost of extraction in H	Extraction shifts	Increase in energy price reduces energy use in the production and consumption of energy-intensive goods
Production	Reduce	Reduces use of energy in production in H	Production shifts	Reduction in energy price reduces global extraction; increase in price reduces consumption of energy-intensive goods produced in H
Consumption	Reduce	Reduces demand for energy-intensive goods in H	Consumption shifts	Reduction in energy price reduces global extraction; consumers in in H reduce consumption of energy-intensive goods

Once we understand the effects of these taxes on the price of energy, we can also see how the supply and demand elasticities for energy affect the amount of leakage. Consider the price elasticity of energy supply. If it is low, the amount extracted does not respond very much to a change in the price of energy. As a result, an extraction tax, which will only slightly increase the world price of energy, does not generate a large effect on extraction abroad, so leakage is low. Consumption and production taxes suppress the price of energy, but with a low elasticity of supply, supply remains roughly constant. As a result, foreign producers or consumers will use more energy, nearly offsetting the decline in H, hence generating substantial leakage. Therefore, the elasticity of supply works in the opposite direction for consumption and production taxes than it does for extraction taxes.

2.3 BAs Shift the Tax Downstream

Border taxes fit neatly into this framework. We can think of BAs as shifting the tax downstream. To illustrate, suppose that H imposes an extraction tax and adds BAs. 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 fuel that is extracted in F is used for production in H, there is a tax when the fuel is imported into H. Therefore, all energy used for production in H bears a tax. The net effect of an extraction tax in H with BAs is a tax on production in H. That is, we can think of BAs as shifting the tax base downstream from extraction to production.[12]

Adding BAs to a tax on production in H effectively shifts it to a consumption tax in H. To see this, 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. Therefore, we can think of BAs as shifting the tax base from production to consumption.[13]

The choice to impose BAs therefore can be seen simply as the choice to have a downstream tax base. Because we can impose a tax on a downstream base directly, the argument for BAs must be that it is better to impose the tax on a downstream base indirectly by initially imposing the tax upstream and then shifting it downstream via BAs. This argument holds if and only if BAs are cheaper to administer than imposing the downstream tax directly. For example, as noted above, imposing a tax on consumption will be administratively challenging. If a tax on consumption is otherwise desirable, we might be able to tax consumption by taxing extraction and imposing BAs. That is, the argument for BAs must be (1) that it is better to have a downstream tax than an upstream tax and (2) that BAs are a relatively inexpensive means of administering a downstream tax.

We consider point (1), the comparison among the three tax bases, in the remainder of this section, and then turn to point (2), design issues, in the next section.

2.4 To Determine Which Tax Base Is Best, We Need to Examine Welfare Effects

The choice of a consumption, production, or extraction tax should depend on the welfare effects of each system. H will want to choose a tax that maximizes its welfare, although in a

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[12] BAs in theory could shift the tax upstream from a production tax to an extraction tax. To do so, the home country would have to subsidize imports and tax exports.

[13] We can also impose BAs on the import of energy and on goods produced with energy. This would shift an extraction tax all the way downstream to consumption.

treaty context, it might instead pick a tax that maximizes global welfare. Which of the three tax bases maximizes welfare, either just for H or globally, will depend on parameters, such as the countries' relative endowments of fossil fuel, the size of comparative advantage, and the supply and demand elasticities for energy.

Although estimating the welfare effects is not straightforward, we offer some preliminary observations.

2.4.1 Competitiveness Is Not a Good Reason for Choosing the Base

One of the arguments often seen for imposing BAs is that they correct the loss of competitiveness created by a unilateral carbon tax on production. 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.

It is not easy, however, to translate this argument into welfare 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—which we take to mean their global market share—it will increase the competitiveness of non-energy-intensive industries in H, and vice versa in F. The net effect is a changed industry structure.

Moreover, there is no clear connection between competitiveness and welfare. Recall that all three taxes cause leakage, each of a different kind. Using BAs to shift a production tax to a consumption tax changes the type of leakage from production leakage to consumption leakage. Understanding the welfare effects requires more than looking to the relative effects on one segment of the economy.

2.4.2 Leakage Is Not Welfare

An alternative to competitiveness is to try to assess which of the three tax bases has the least leakage. Recall that the source of leakage for each of the three taxes is different. In each case, leakage comes from a shift in the taxed activity offshore. We can compare the three types of leakage by estimating the increase in emissions from the shift in the taxed activity abroad as a percentage of the emissions reductions at home. For an extraction tax, we would estimate the emissions due to the increased extraction abroad (regardless of where the fuel is actually used) as a percentage of the reduction in emissions from the reduced extraction at home. For a production tax, we would estimate the increase in emissions due to changes in production abroad as a percentage of the reduction at home. For a consumption tax, we would estimate the increase in carbon consumption abroad as a percentage of the reduction in carbon consumption at home.

Comparing production and consumption taxes, the general view is that consumption taxes have less leakage. Recall that a production tax causes shifts in the location of production, while a consumption tax causes shifts in the location of consumption. If production is more mobile than consumption, leakage may be higher with a production tax. CGE modeling generally confirms this: in every CGE model that we know of, adding BAs to a production tax reduces leakage.[14]

One way to think about the reason for this is that developed (Annex B) countries are net importers of carbon. They trade services for energy-intensive goods, which means that if we trace the embedded carbon in trade, the net flow is from developing countries to developed countries.[15] That is, we can think of the consumption tax base in a developed country as bigger than a production tax base. Shifting a production tax in Annex B to a consumption tax should capture more sources of emissions.

The comparison between a production tax and an extraction tax is less clear. Extraction taxes and production taxes work in opposite directions on energy prices, and the effects of the relevant elasticities are reversed. If the supply of energy is inelastic, an extraction tax may have less leakage than either a production or consumption tax, but if the supply of energy is elastic, an extraction tax may have more leakage.

The problem with using leakage estimates to choose a tax base is that leakage is not the same thing as welfare. To illustrate, consider the extreme case where the supply elasticity is zero. With a zero supply elasticity, an extraction tax does not affect extraction abroad, which means that there is no extraction leakage.[16] The tax also does not affect extraction at home, however. Global supply—and emissions—are fixed. With vertical supply, all the extraction tax does is

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[14] One problem with these studies is that they count the consumption shifts under a production tax as leakage. In our terminology, these shifts are not leakage because the production tax causes *global* consumption of energy-intensive goods to go down. By counting consumption shifts under a production tax as leakage, these studies overestimate the leakage from a production tax, which in turn makes BAs and consumption taxes look better when using leakage as a criterion.

[15] This is confirmed by studies using multiregional input-output analysis, such as Davis and Caldeira (2010).

[16] There will also be no change in domestic emissions, which means that leakage is undefined because it is equal to zero divided by zero. Nevertheless, there is no increase in foreign emissions, which is what the leakage definition is intended to capture.

extract rents from local fossil fuel reserve owners. The global energy price is unchanged, but the after-tax price received by reserve owners in H falls by the full amount of the tax.

With a consumption tax, H consumers will substitute away from energy-intensive goods, but with a zero elasticity of supply, this will simply lead to a fall in the price of energy, which in turn encourages F consumers to buy more energy-intensive goods. Leakage is 100 percent, but the global impact on emissions is once again zero.

The difference between the extraction and consumption taxes is simply who bears the burden of the tax. In the former case, it is H country reserve owners; in the latter, it is H and F country reserve owners. While we might think that higher leakage rates disproportionately impact H (imposing the tax unilaterally), just the opposite is true: the burden of the tax is shifted more to foreign reserve owners with the consumption tax (and high leakage). Therefore, leakage and H's welfare may move in opposite directions in this case.[17] We cannot use leakage as a surrogate for welfare.

2.4.3 BAs May Make F Better Off and H Worse Off

To compare the welfare effects of each of the three possible tax bases, we should set the tax rates so that emissions are the same under the two policies. This allows a direct comparison of the taxes for a given level of effectiveness. Using this strategy, we can draw some preliminary conclusions. In particular, we can show that within the assumptions of our simple model, F's welfare will be higher when H imposes a consumption tax (or equivalently, a production tax with BAs) than with a production tax. That is, F should prefer BAs. Moreover, in at least some cases, H is better off without BAs.

To see why this is the case, set the tax rates so that emissions are the same under a production tax and a consumption tax. If emissions are the same, differences in welfare will depend only on consumption.

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. Moreover, H (but not F) has tax revenue that adds to its overall income.

[17] The welfare of H's consumers is ambiguous in this case. Their income goes up, but their consumption patterns are distorted because of the tax.

Labor supply and the global wage rate are fixed in our model. This means that labor income 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 profits from extraction do not change. F does not have any tax revenue. 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, 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. They are better off with BAs.

The analysis of H is more complex, as H's income may differ under the two taxes because the tax receipts may differ. In general, H will be better off if more of its tax receipts are paid by producers or consumers in F. This means that if H dominates global production, H will be better off with a production tax. To see this, consider an extreme case where all production takes place in H, and compare a production tax to a consumption tax. With a production tax, H gets tax revenue from production no matter where the goods are consumed. If H were to add BAs, shifting the base to consumption, it would be forgiving the tax on exports but gaining no additional revenues from BAs on imports. Therefore, H is strictly worse off with BAs. This extreme case with all production taking place in H, of course, ignores one of the central reasons for BAs, which is to prevent shifts of production from H to F. Nevertheless, it illustrates an effect that will likely also be true in less extreme cases, but where H still dominates global production.

In prior work considering a model with a somewhat different structure (Elliott et al. 2013), we produced the same result regarding F's welfare (and we suspect in that model the result regarding H's welfare when it dominates production was also true). In that work, we noted the following, which is applicable to the current model as well:

> These results about welfare are contrary to standard intuitions which hold that the taxing regions will want to impose border taxes and the non-taxing regions will oppose them. U.S. climate change legislation regularly includes measures to protect domestic industries while developing countries strenuously object to these measures. The simple model is not capturing something going on in the world that motivates political preferences over these policies.
>
> We have three hypotheses about what these motivations are. The first is that views about border taxes are informed by flawed mercantilist thinking, and that if

> analysts focused on consumer welfare they would agree with the results of our model. Second, our model abstracts from considerations of good or bad jobs or unemployment. The wage is always 1 regardless of where individuals work. There are also no producer profits. If for some reason wages vary across industries (in ways not related to worker productivity), there could be reasons for preferring one system or the other. Finally, our model does not have adjustment costs. It might be the case that in the long run the results of our model would obtain but it is not easy to take a steel worker and turn him into a nurse. To the extent there are efficiency wages (or similar effects) or transition costs, these effects should temper our result, but we would still expect the effects we see in the model to occur in the real world. (p. 223)

2.5 Leverage

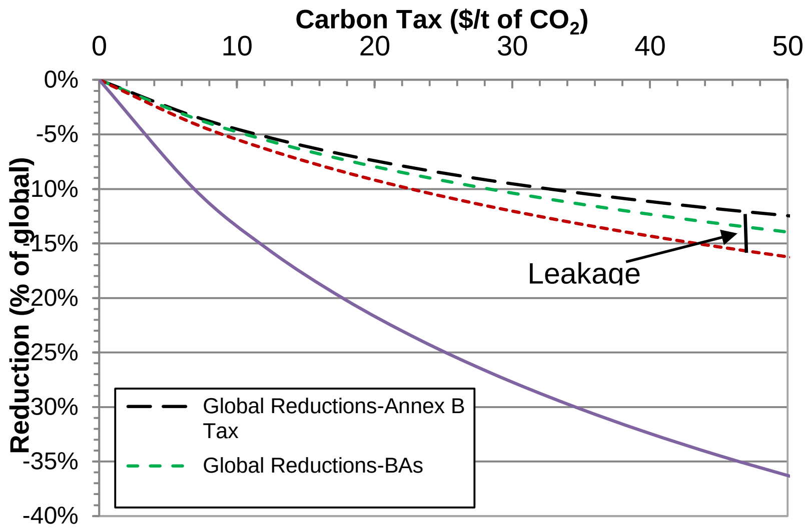
An argument often used for BAs is that they will create an incentive for other countries to adopt a carbon tax. The reason is that with BAs, other countries will not benefit from leakage. That is, BAs take away the ability of a country to be a pollution haven.

The motivation for the leverage argument is the observation that a unilateral carbon tax, even if imposed in all developed countries, would be far less effective than a global tax would be. Emissions reductions in fast-growing developing nations are needed to achieve a reasonable level of global reductions, at least relative to baseline emissions.

To see the size of the effects, consider Figure 1, which is an estimate from a CGE model of the emissions reductions from a given tax rate for a tax imposed on production. It compares the global emissions reductions from a production tax on Kyoto Annex B countries (top line) to the global reductions with the same tax rate but with a tax imposed on all countries (bottom line). As can be seen, the Annex B tax reduces emissions only by one-third as much as a global tax.

Figure 1 also shows the effects of leakage and BAs. The line labeled "Annex B Reductions–Annex B Tax" shows the reductions that would occur in Annex B with a unilateral Annex B tax. Comparing this line with the global reductions that would occur with that same tax (top line) shows the extent of leakage. Global reductions are smaller than Annex B reductions because of the increase in emissions in non–Annex B countries, which partially offsets the Annex B reductions. The vertical distance between these lines, marked on Figure 1, is the extent of leakage. The line labeled Global Reductions–BAs shows the effects of BAs, which reduce leakage. As can be seen, leakage and the effects of BAs are swamped by the benefits of a global tax. What this model tells us is that the focus of policy needs to be on achieving global emissions reductions rather than reducing leakage.

Figure 1. Emissions Reductions under a Carbon Tax



Source: Elliott et al. (2013), figure 8.

The extent to which BAs can be used as leverage to create a global carbon price is disputed. Some analysts, such as Helm et al. (2012), argue that BAs will create the necessary incentives. Others, such as Nordhaus (2015), argue that if countries otherwise face high domestic costs of pricing carbon, BAs will not be sufficient. Nordhaus notes that for most countries, most of their energy-intensive production is for domestic purposes. Only a small portion of energy-intensive production is exported, which means that BAs would be small relative to a tax on all emissions. If BAs are sufficiently small, they would not create the necessary incentives to impose a carbon tax for a country that otherwise would not.

Moreover, the results from our simple model suggest that foreign countries may be better off with BAs, and in some cases, the taxing country may be worse off. Therefore, BAs may not create the necessary incentives. .

The resolution of this debate depends on the costs for a given country of imposing a carbon price, the extent to which it exports carbon (and therefore would be affected by BAs), and whether BAs would make it worse off. This likely varies by country.[18]

[18] Some authors, such as Cosbey et al. (2012), argue that using BAs as leverage may lead to tariffs or other sanctions to generate even more leverage. It is not clear, however, that this is a problem. Nordhaus (2015), for example, argues for precisely this result: the use of tariffs as leverage to obtain global carbon policies.

3. Design Issues

To understand the design issues, it helps to start with a model of what perfect BAs would look like (i.e., if there were no information problems or administrative and compliance costs). The tax on the importation of a good would be equal to the tax rate multiplied by the additional emissions because of the production of the imported good. The tax would be on all imports from all countries.[19] There would also be a rebate on exports equal to the additional taxes paid because the good was produced. The rebate would be for all exports to all countries.

Perfect BAs are not feasible because of the costs of gathering the necessary information. The costs of 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. Imagine, for example, a customs agent in Los Angeles faced with a cargo boat filled with automobiles of different makes and models. For a given vehicle, the chassis may have been produced in one country, the glass in another, the engine in a fourth, the tires in a fifth, and so forth, and then all of the parts assembled in a final country before export to the United States. Each make and model may have a different supply chain, and the supply chain for a given make and model may vary by year. Determining the embedded emissions would be a massive task.

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.

Note that in each of these cases, many of the problems apply to both imports and exports. The only real difference between 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 than information about exports (and production of the information for exports can more easily be required by law than for imports because exporting entities are subject to US

[19] Applying the tax to imports from all countries is less important than applying the tax so that the net tax rate on imports from all countries is the same. The reason is that to the extent that the exporting country has a price on emissions, the consumption of goods related to those emissions would be taxed, albeit in the exporting country.

jurisdiction). Because imports present a more difficult problem than exports, our discussion focuses on imports, keeping in mind that many of the issues also apply to exports.[20]

Before turning to the details, it is worth noting our general orientation: if BAs will be imperfect because of administrative costs, it is better to set the default values to be too high rather than too low. There are two related reasons. The first is that if firms are allowed to "prove out" of the default values by providing the needed information to compute more accurate BAs, setting the default values higher than otherwise creates the right incentives. That is, if default BAs are set higher than the correct BAs (i.e., the BAs that would be computed with full information), firms will want to provide the needed information to compute the correct BAs. If default BAs are set below the correct BAs, firms would have no incentive to provide information and may even want to hide information to get the benefit of the default values.

Cicala et al. (in progress), use this mechanism to construct an equilibrium where all but the dirtiest firms provide information. They would allow firms to certify that their emissions from the production of a good are at a specified level, subject to verification, standards, and so forth. They would then impose a border tax on imports by a firm equal to the lower of the firm's certified emissions or the average of emissions from all noncertified firms. Under this system, firms with emissions below the average have an incentive to certify their emissions to lower their tax. If they do so, however, the average of noncertifying firms goes up. This in turn creates an incentive for additional firms to certify, creating a cascade where all but the dirtiest firm have an incentive to provide information about their emissions and production.[21]

The second reason for erring on the high side is that if countries with adequate carbon policies are exempt from BAs, the higher BAs are, the greater the incentive for countries to adopt adequate carbon policies (subject to comments made above about the welfare effects of BAs). As we discuss in our conclusion, Nordhaus (2015) uses this idea for his climate clubs model, except that he goes much farther: he would abandon BAs and use punitive tariffs to create incentives.

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[20] 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.

[21] We would expect legal problems with this approach. To the extent that these legal problems bind, they may limit this information-forcing strategy.

3.1 Which Goods

As noted, there is widespread agreement that BAs for all goods would be too complex to administer. The border adjustment 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 administrative 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.[22] The administrative cost of attempting to impose BAs on all goods would vastly exceed any imaginable benefits.

Instead of applying BAs to all goods, commentators recommend limiting BAs to goods where they would have the largest effects. 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 so-called energy-intensive, trade-exposed (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. Commentators vary on the precise combination.

Beyond the question of the thresholds needed for a product to have BAs, we also have to decide how to aggregate products. If we look at broad industry categories, only a small number would likely qualify for BAs, but if we look at narrower categories, the number of BAs quickly multiplies to unadministrable levels.

For example, Houser et al. (2008) look at broad industry categories to find those that are both trade-exposed and energy-intensive (see Figure 2). Other than refining (which involves the direct import or export of a fossil fuel, so it raises different and easier issues), they highlight just

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

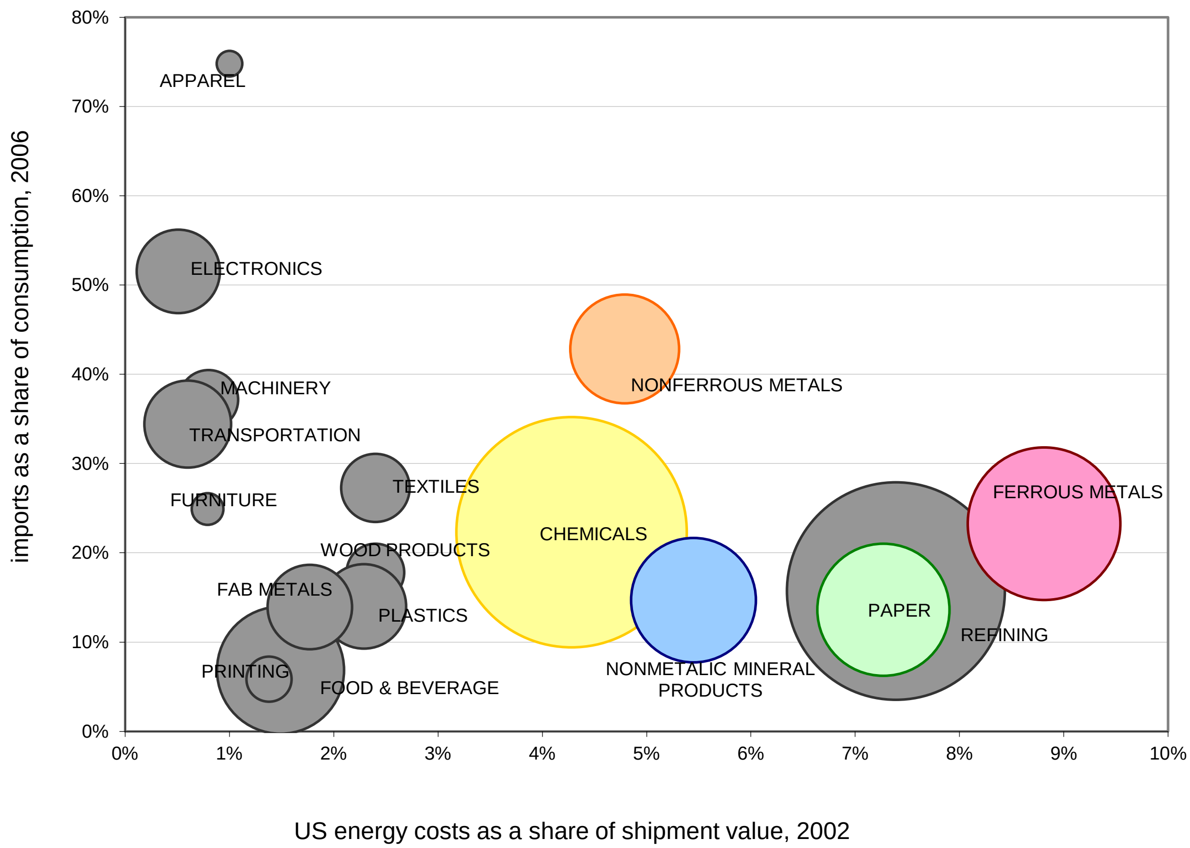
five industries: chemicals, ferrous metals, nonferrous metals, paper, and minerals. Most industries that are highly exposed to trade, such as apparel and electronics, are not very energy-intensive, so a carbon price would have little effect. Nonferrous metals, such as aluminum, are most at risk because of their combination of energy intensity and trade exposure.

The Waxman-Markey bill takes a more disaggregated approach. It defines an industry as "presumptively eligible" for provisions designed to address leakage if (1) its energy intensity or greenhouse gas intensity is at least 5 percent and its trade intensity is at least 15 percent,[23] or (2) its energy intensity is 20 percent regardless of its trade intensity. Using six-digit North American Industry Classification System (NAICS) categories, an interagency study of the Waxman-Markey bill determined that 44 industry categories would meet this definition, mostly within the five broad industries highlighted by Houser et al. (2008) and EPA (2009).

Moving from six-digit NAICS codes to the individual product level would create a very large number of different tax rates, and 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 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, stearic) manufacturing, organo-inorganic compound, plasticizers (i.e., basic synthetic chemicals), silicone (except resins), and synthetic sweeteners (i.e., sweetening agents).

[23] Energy intensity is energy expenditures as a share of value. Greenhouse gas intensity is greenhouse gas emissions priced at $20/ton as a share of value. Trade intensity is combined value of exports and imports as a share of domestic production plus imports.

Figure 2. US Industry Exposure to Climate Costs, Carbon Intensity, and Imports as a Share of Consumption



Source: Houser et al. (2008), figure 1.3

Other categories are similarly diverse. The category of plastics (NAICS code 325211) includes 83 different types of plastic. There are 198 different types of inorganic chemicals (NAICS code 325180). Adding up 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 six-digit category) that would have been presumptively eligible for trade relief under the Waxman-Markey bill.[24]

[24] The calculation was done using the NAICS product identification tool on www.naics.com. The calculation is inexact because some of the NAICS categories have changed since the interagency report.

For each product, we would have to determine the BA on import, 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, may use the same production process at a different efficiency level, or may have different energy sources, so the emissions will be different.

Suppose each product is imported from 10 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 utilizing data on the production process used in the foreign country and the type of fuel.

Moreover, these taxes will change over time as the production processes, fuel sources, types of goods, and exporting countries change. Therefore, the 15,000 different tax rates would 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 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 requires knowing the underlying information, so aggregating products into larger categories may not reduce the informational demands significantly.

The problem with aggregating across products, however, is that it means that the actual emissions from the production of any particular good would no longer be relevant. 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 was set for the whole NAICS category. We could not allow the lower-emissions products within the category to prove that a lower tax should apply without effectively reverting to product-level taxes. We would therefore lose the incentives for emissions reductions that product-level taxes would create. Moreover, we would lose the information-forcing type equilibrium explored by Cicala et al. (In progress). The ability to prove out of a broad category is also central to some arguments about the legality of BAs, and those arguments would be similarly weakened. One possible way to thread this needle would be to use broad categories, allow individual producers to prove their emissions are lower than the estimates for their category, and hope that the costs of proving out limit the number of different tax rates that eventually have to be applied (which means hoping that the Cicala et al. equilibrium does *not* occur).

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.

Another problem with excluding final goods is that it requires a definition of final goods. Whereas for some goods it will be clear whether they are intermediates or final goods, for many others it may be less clear, as they can be both directly consumed and 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 avoids this complication by defining the category of covered goods by reference to what it is concerned about: whether the good is energy-intensive and trade-exposed.

3.2 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.

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

3.2.1 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.

A basic and, as far as we know, unrecognized problem with this approach is that actual emissions from the production of a good is not the correct base for BAs. Instead, the correct base is the additional (i.e., marginal) emissions that come from the production of the good.

To see why this is the case, start with a closed economy that imposes a production tax on the use of all fossil fuels according to their carbon content. For simplicity, assume that there are two types of fuels, hydro and coal, and that they are interchangeable. 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 consider an open economy, and suppose that only exports are subject to a tax (say, by the importing country). As opposed 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 is if coal is used entirely for exports and hydro is used entirely for domestic consumption. The tax would be on the amount of coal used. The second is the reverse: hydro is used entirely for exports and coal entirely for domestic consumption. There would now be no tax whatsoever even though there has been no change in emissions, production, or the types of goods that are exported.

What this example shows is that the actual fuel used in production is not the correct tax base. Instead, the correct tax is on the marginal source of energy.[25] We should ask what additional emissions are generated by producing the export good. The tax should be on these hypothetical additional emissions, not the actual emissions. 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.

[25] That the correct tax is not based on actual emissions will likely make little sense to most producers. The United States would be imposing BAs on a good that are not associated with the emissions from the production of that good. Although we do not consider legal issues here, we suspect that imposing a tax based on a hypothetical base not necessarily related to the emissions from the production of the good may raise legal questions.

The problem is that there is no easy way to compute the marginal source of energy. It requires determining the hypothetical additional fuel because of the production of an export. This is 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 source of power. Although it would be a rough proxy, it may be sufficient.

A simpler but less accurate alternative would be 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 than using the actual fuel source, however, because at least it eliminates the fuel switching problem.

3.2.2 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, 46–51) contains an extensive discussion of the production processes used around the world for the five categories of energy-intensive, trade-exposed goods. For example, cement can be produced using either wet kilns or dry kilns, and steel can be produced from scrap with an electric arc or a blast furnace using coal and coke to melt iron ore. In each case, the different methods involve substantial differences in energy use.

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.

As with fuel sources, the correct measure would look to the marginal 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. As 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 in 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) average emissions intensity of production for each product category in each exporting country; (2) 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 hybrid of these approaches, is best. The key is to note the trade-off: 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 trade-off requires knowing how difficult it would be to obtain the needed information and how much accuracy helps with incentives. Note also that the choice of a benchmark may itself determine how costly it is to obtain information. Choosing a benchmark that is too high relative to actual emissions creates an incentive for producers to reveal information so as to prove out of the benchmark. Choosing a benchmark that is too low destroys that incentive. Therefore, in thinking about the trade-off, it is better to choose a benchmark that is higher rather than lower.

3.2.3 Direct vs. Indirect Emissions

The final issue in estimating the emissions from the production of a good is determining which emissions count. In theory, BAs should include 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 others such as emissions from the production and transport of intermediates, waste disposal, and purchased 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, an incentive would exist to outsource electricity production. The remaining emissions, commentators argue, are too hard to measure and therefore should be excluded.[26]

Leaving out the remaining emissions, however, creates a number of problems. As 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 direct emissions, produced by the exporting firm, versus emissions 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 coownership to avoid whatever the rules are. US domestic tax law includes rules for treating firms as consolidated. Consolidation sometimes has benefits and sometimes has 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. The same is true for accounting rules.

For example, suppose that a “firm” produces an intermediate, which it then turns into a final good. However, a wholly owned subsidiary produces the intermediate and sells the good to its parent, which turns the intermediate 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 nonvoting common, or a 30 percent stake with put options to sell back some of that stake? Or what if the subsidiary were 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 that 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 easy to manipulate.

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[26] For example, Cosbey et al. (2012, 14).

As a result, including only direct and indirect emissions in BAs will not be as much of a simplification as it first appears.[27]

3.3 Which Countries

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

To understand the problems with all countries, consider a 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 tax removed at the border by H and an identical tax imposed by F. 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.

Suppose, however, that F has a carbon tax on production but no BA, while H has a carbon tax with a BA. Now 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 requires that all countries with a carbon price 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 above, it would take substantial coordination to make this work.

[27] Cosbey et al. (2012) would look to rules developed by the World Resources Institute to determine life-cycle 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 life-cycle emissions, however, because they were not developed in the context where there is a tax on being direct or indirect emissions but not on other emissions, and therefore a substantial incentive to manipulate the rules.

Suppose instead that we impose BAs only on countries without a carbon price. This might greatly simplify the system because a large percentage of US imports of carbon-intensive 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 goods. Table 2 reproduces their list. As can be seen, for most products, Annex I countries dominate the list of exporters.

Table 2. US Imports by Origin, 2005

	Steel		Aluminum		Chemicals		Paper		Cement	
	Source	%	Source	%	Source	%	Source	%	Source	%
1	Canada	18.6	Canada	51.0	Trinidad	41.6	Canada	66.9	Canada	16.1
2	EU	17.3	Russia	17.1	Canada	19.3	EU	16.8	China	14.0
3	Mexico	13.1	EU	6.2	Ukraine	7.3	China	3.5	EU	13.9
4	Brazil	8.2	OPEC	5.1	OPEC	6.6	S. Korea	2.2	OPEC	10.0
5	China	7.1	Brazil	3.8	EU	4.5	Mexico	2.2	Thailand	8.6

Source: Houser et al. (2008)

While such a system is possibly an improvement, there are two serious problems. The first is determining the set of countries subject to BAs. Most commentators suggest using something like "comparable carbon price" as the standard: if a country does not have a comparable carbon price, then imports from (and exports to) that country are subject to 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 do this.

For example, countries can impose carbon taxes at varying prices, cap and trade at varying emissions levels and trading prices, hybrid systems, flexible command-and-control systems that allow some trading, and traditional command-and-control systems that impose technology requirements. Many countries or regions have a mix of all of these. For example, countries in the 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 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 that 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. As noted in the introduction, however, the Paris Agreement does not eliminate concerns about leakage 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 border adjustments.

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 US 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 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 tries yet a different approach to determining which countries are subject to BAs. First, it limits BAs to industrial sectors where less than 85 percent of US imports are from what we might call "good" countries (1120). 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 are only from countries that are not part of a treaty and countries with greenhouse gas emissions intensity for the sector higher than that of the United States for that sector. There are also exceptions for least-developed countries and countries with very low emissions (1129).

While this approach has the advantage of seeming to be objective, it does not track the reason why the bill includes border adjustments 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 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 percentage (or total) of 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, no straightforward criterion appears to exist for determining which countries are subject to BAs and which ones are not. Without a straightforward criterion, 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.

A second problem with exempting a broad group of countries, beyond defining the exempt countries, is transshipping. The simple 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, F, G, and H. 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, however, and H imposes BAs on imports from G. 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 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 the 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. No change has occurred in the patterns of production or consumption, but the tax has been eliminated.

There is, of course, an observable difference between 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 no actual transshipping has occurred. 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 it would have no way to determine this, particularly 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.

4. Conclusion

Each of the design issues—which goods, which emissions, and which countries—raises significant problems. In combination, implementing BAs will be complex. 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. We do not know whether BAs improve welfare, either of the taxing country or globally. Leakage measures are not directly related to welfare, so they are not reliable indicators of the need for BAs. Even if they were, whether BAs increase or reduce leakage depends on a number of parameters, and extraction taxes may in fact have lower leakage than the production or consumption taxes resulting from the use of BAs. Similarly, notions of competitiveness are poorly defined or even incoherent and do not provide a justification for BAs.

Finally, the recent agreement in Paris at COP21 reduces the need for BAs. After the Paris Agreement, all countries will have some implicit carbon price. While these prices are not likely to be equal, concerns about leakage arose in a Kyoto Protocol world where some countries had carbon prices or other emissions policies and others had no policies at all.

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 provide all the benefits of actually imposing BAs without the cost.

The Waxman-Markey bill takes 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.[28] Under this system, importers of covered goods would have to buy permits in much the same way that the Waxman-Markey permit system would have worked for domestic emissions (1087–115).

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 emissions 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. 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 lower energy costs for domestic use. Nordhaus wants to impose tariffs as a way of preventing free riding.

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 nonpricing 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 as a simpler method than BAs to reduce leakage. Output-based rebates are rebates or subsidies paid to exporters based on the industry average level of emissions per unit. Domestic and foreign producers of the same good, selling in the foreign market, would face the same average carbon price, zero. Output-

28 Because Waxman-Markey is a cap-and-trade bill, it would have required importers to purchase permits much in the same way as domestic producers, but from a separate pool. It is not clear why this approach is taken, because it can mean that the prices in the two markets differ. The bill states that the administrator (of EPA, who runs the program) should 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 does not include rebates on export, so it does not impose full border adjustments. It does contain a rebate program for EITE industries, but this is not based on exports. Instead, it is a general subsidy.

based rebates, therefore, help domestic producers compete in foreign markets. Because they are based on an industry average, however, the size of the rebate does not depend on the emissions intensity of the particular exporter. Exporters can still reduce their taxes by switching to less-carbon intensive production methods. Output-based rebates, therefore, create the right incentives on the margin for domestic producers to substitute toward lower-emitting production methods.

A domestic carbon tax with output-based rebates is neither a tax on domestic production nor a tax on domestic consumption. It is not a tax on production because the rebate, on average, eliminates the tax on goods produced domestically but consumed abroad. It is not a tax on domestic consumption because there is no tax on goods produced abroad that are consumed domestically. We can think of it as, on average, a tax on domestic production consumed at home. The tax base, therefore, is smaller than the base of a consumption or production tax

Fischer and Fox (2012b) compare output-based rebates, BAs (i.e., consumption taxes), and BAs just for imports or just for exports. They estimate the effectiveness of each policy in reducing emissions (though 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, apply only to domestic producers and use industry averages rather than the emissions of any particular polluter. While they seem clearly second best, in that they eliminate one of the benefits of a carbon tax—foreign consumers would not see 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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