CLIMATE CHANGE POLICY IN THE INTERNATIONAL CONTEXT: SOLVING THE CARBON LEAKAGE PROBLEM

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ABSTRACT

Under the Paris Agreement, nations set their own emissions goals and policies. As a result, climate policies vary widely across countries, with some countries imposing stringent emissions policies and others doing very little. A key problem when carbon policies vary across countries is that energy-intensive industries can relocate to places with few or no emissions restrictions. Relocated industries would continue to pollute but would be operating in a less desirable location. Moreover, the countries that imposed strict emissions reductions lose the benefit of having those industries located domestically. This problem, known as leakage, is one of the key reasons the United States has failed to enact substantial climate change policies. Without a solution to leakage, it may be much more difficult to prevent catastrophic climate change.

The most commonly proposed response to leakage is to impose border adjustments—tariffs on imports based on the emissions from the production of the imported good, and rebates for exports of prior taxes or other prices imposed on emissions. Border adjustments ensure that the same price is paid regardless of the location of production. Border adjustments, however, are complex to impose and are potentially incompatible with World Trade Organization (WTO) rules. Moreover, numerous studies show that border adjustments do not significantly improve the effectiveness of regional carbon policies.

We propose a better solution to the leakage problem. Our solution, the extraction-production tax (the EPT), combines a tax on domestic extraction with a conventional tax on emissions from domestic production. The core intuition behind this hybrid tax is that shifts in location due to carbon prices arise because of their effects on the price of energy seen by foreign actors. By reducing demand for fossil fuels, taxes on emissions from domestic production lower the global price of energy. In response, foreign actors increase their energy use, generating leakage. Border adjustments do not change this effect: carbon taxes on production with border adjustments also reduce the price of energy and increase energy use abroad. A tax on domestic extraction, however, raises the global price of energy because it

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reduces supply. A higher price of energy causes foreign users of energy to reduce their energy use, reducing leakage. Foreign extractors of energy, however, increase their supply. By combining a tax on the supply of energy and a tax on the demand for energy, the EPT sets these two forces against each other. A tax on the supply side of the market allows a lower tax on the demand side, with the two taxes set to minimize distortions in non-taxing regions.

The EPT not only better solves the economic problem of leakage than conventional approaches; it is also much simpler to implement. The EPT can be implemented by imposing a nominal tax on domestic extraction and border adjustments only on energy—but not goods in general—at a lower rate than the nominal extraction tax. Both an extraction tax and border adjustments on energy are easy to impose, which means that the EPT can greatly simplify the administration of carbon taxes. Finally, the EPT reduces concerns about WTO legality raised by traditional approaches. The EPT is a practical solution to the leakage problem and, therefore, can be a key piece to solving the global climate change problem.

INTRODUCTION

If some countries put a price on carbon but other countries do not, carbon-intensive industries may simply relocate to places with no restrictions on emissions. Relocated industries would continue to pollute, and the countries that attempted to address the problem of climate change would be effectively punished by losing those industries. This problem, known as leakage, is one of the central reasons that the United States has, so far, failed to act on climate change at a level anywhere near what is needed.[1] Leakage has been rightly called the "defining issue in the design. . . of regional climate policies."[2] If leakage is not solved, climate change may not be solved. In this article, we propose a new approach to solving the leakage problem, an approach that is simultaneously more effective, simpler

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[1] For example, the 1997 Kyoto Protocol would have imposed obligations to reduce emissions on most developed countries without imposing similar obligations on developing countries, including China and India. In response, the United States Senate unanimously passed what is known as the Byrd-Hagel Resolution. The Byrd-Hagel Resolution's key operative provision stated that the United States should not sign a climate agreement that included mandatory emissions reductions for developed countries (known as the Annex I parties) without also imposing limits on developing country parties. *See* Byrd-Hagel Resolution, S. Res. 98, 105th Cong. (1997). In announcing that he opposed the Kyoto Protocol, President Bush expressly invoked the Byrd-Hagel Resolution. For a history, *see* Susan Biniaz, *What Happened to Byrd-Hagel? Its Curious Absence from Evaluations of the Paris Agreement?* (Sabin Ctr. for Climate Change L., Working Paper, 2018), http://columbiaclimatelaw.com/files/2018/01/Biniaz-2018-1-Byrd-Hagel-article-Working-Paper.pdf.

[2] Meredith L. Fowlie, *Incomplete Environmental Regulation, Imperfect Competition, and Emissions Leakage*, 1 AM. ECON. J. 72, 73 (2009). As discussed below, there are several hundred published estimates of leakage, an indication of its importance to climate policy.

to implement, and more consistent with international trade law than standard approaches.

The standard approach to addressing leakage is to impose what is known as border adjustments.[3] Border adjustments are combinations of import tariffs and export rebates.[4] The import tariff is a tax on the emissions that arise from the production of imported goods, known as embodied emissions. The tariff ensures that imports face the same carbon price as goods produced domestically. The export rebate reimburses any taxes or other pricing mechanisms—such as the cost of permits in a cap and trade system—on emissions paid domestically when a good is exported. By removing taxes upon export, the rebate ensures that goods sold abroad face the same price as other goods sold in the destination country.[5] Every carbon-pricing proposal introduced in the United States Congress in recent years has included border adjustments.[6] The European Union (EU) has proposed a version of border adjustments known as the Carbon Border Adjustment Mechanism (CBAM) to prevent leakage caused by its Emissions Trading System.[7] Recently, 3,623 economists, including twenty-eight Nobel Laureates, signed a statement on carbon taxes that, among other things, stated that such taxes should include border adjustments.[8]

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3 *See infra* notes 6, 10.

4 *See* Erin Campbell, Anne McDarris & William A. Pizer, *Border Carbon Adjustments 101*, RES. FOR THE FUTURE (Nov. 10, 2021), https://www.rff.org/publications/explainers/border-carbon-adjustments-101.

5 *See id*.

6 For a summary of carbon tax bills, see Marc Hafstead, *Carbon Pricing Bill Tracker*, RES. FOR THE FUTURE (Oct. 1, 2020), https://www.rff.org/publications/data-tools/carbon-pricing-bill-tracker.

7 *See* Resolution Towards a WTO Compatible EU Carbon Border Adjustment Mechanism, EURO. PARL. DOC. (P9 TA(2021)0071) (2021). CBAM would impose an import tariff on carbon-intensive goods but would not offer an export rebate.

8 *See Economists' Statement on Carbon Dividends*, CLIMATE LEADERSHIP COUNCIL, https://www.econstatement.org (last visited March 4, 2023). The literature on border adjustments is vast. Citations to papers on the economic effects of border adjustments are found in note 37, on the implementation problems with border adjustments, in note 52, and on legal issues, in note 59. For recent surveys, *see* Aaron Cosbey et al., *Developing Guidance for Implementing Border Carbon Adjustments: Lessons, Cautions, and Research Needs from the Literature*, 13 REV. ENV'T ECON. & POL'Y 3, 3–22 (2019); *see also* Michael A. Mehling et al., *Designing Border Carbon Adjustments for Enhanced Climate Action*, 113 AM. J. INT'L L. 433, 433–81 (2019).

Border adjustments, however, pose serious legal and administrative problems. Measuring embodied emissions is difficult and expensive, and in many cases, embodied emissions will be unknowable.[9] Moreover, the import tariff may be an illegal barrier to trade under the World Trade Organization (WTO) and the export rebate may be an illegal subsidy, adding further uncertainty to the use of border adjustments.[10] On top of the implementation and legal challenges, border adjustments have limited impact. A large body of literature analyzing border adjustments suggests that they reduce leakage only by about one-third,[11] and the resulting tax is still not very effective at reducing emissions because of its regional nature.

Our approach, which we call the Extraction-Production Tax or the EPT, reduces emissions more effectively and at a lower cost than conventional approaches. There are three main advantages: it is simple to implement and enforce; it better complies with international trade law than standard border adjustments; and it largely solves the leakage problem, removing one of the major barriers to adopting an aggressive carbon policy in the United States or other countries.

The EPT, as its name suggests, combines a tax on domestic extraction of fossil fuels with a tax on emissions of CO_2 during domestic production.[12] For example, if the desired price on emissions

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9 *See infra* Part I.C.4. For an analysis of the administrative problems with imposing border adjustments, see Samuel Kortum & David Weisbach, *The Design of Border Adjustments for Carbon Prices*, 70 NAT'L TAX J. 421, 421–46 (2017).

10 *See infra* Part I.C.5. *See also* Joel P. Trachtman, *WTO Law Constraints on Border Tax Adjustment and Tax Credit Mechanisms to Reduce the Competitive Effects of Carbon Taxes*, 70 NAT'L TAX J. 469 (2017); *see generally* KATERYNA HOLZER, CARBON-RELATED BORDER ADJUSTMENT AND WTO LAW (2014). Note that border adjustments under broad-based VATs (as opposed to on carbon taxes) are almost universal, and are clearly legal under the WTO. A VAT with a border adjustment is known as a destination-based VAT, which is the form used in most of the world. Border adjustments under a carbon tax raise issues that are, for the most part, distinct from the issues they raise under a VAT. Border adjustments under a carbon tax are sometimes referred to as carbon border adjustments to avoid confusion with border adjustments under a VAT. Because our usage is clear here, we use the shorter terminology, border adjustments.

11 *See infra* Part I.C.3.

12 The term "production" is sometimes used in the fossil fuel industry to refer to what we call extraction. We use the term production to mean the manufacturing

is one hundred dollars per ton of CO_2, the EPT combines an extraction tax and a tax on emissions from production such that the two rates add up to one hundred dollars. The rates might be, for example, a forty dollar tax on extraction and a sixty dollar tax on production.

The EPT works by targeting the core channel for leakage: the effect of domestic climate policies on the price of energy in foreign countries. To illustrate, consider a conventional carbon tax, which falls on emissions from domestic production. Domestic producers of goods and services would substitute away from energy, and domestic consumers would purchase fewer energy-intensive goods, in both cases reducing the demand for energy. A reduction in demand lowers the price and this lower price gets transmitted, via trade, to foreign countries. Foreign producers, seeing a lower price, have an incentive to increase their energy use—and domestic producers have an incentive to relocate.

Adding border adjustments to a conventional carbon tax on production does not change the dynamic of leakage. Adding border adjustments, as we will show, shifts the tax to domestic consumption. A tax on domestic consumption still reduces the price of energy seen by foreign actors. As a result, a conventional carbon tax with border adjustments still increases energy use abroad and, therefore, fails to address the core problem.

Suppose instead that the United States taxed the domestic extraction of fossil fuels rather than the emissions that result from their use. A tax on domestic extraction *increases* the global price of energy rather than reduces it. The reason is that domestic extractors of fossil fuel, who must now pay a tax, reduce unprofitable extraction, which reduces supply and raises the price of energy. This higher price gets transmitted via trade to foreign markets. Because they raise the global price of energy, extraction taxes do not create an incentive to expand production abroad, so they do not cause conventional leakage. Instead, because foreign extractors can sell their output at a higher price, extraction taxes induce an increase in extraction outside of the taxing region. This expansion in foreign extraction partially offsets the reduction in domestic extraction in what we might call "extraction leakage."

of goods and services. The tax would fall on emissions from the combustion of fossil fuels during manufacturing.

Neither tax alone—a tax on emissions from use in production or a tax on extraction—can solve the leakage problem. They both induce changes in foreign activity that partially offset their effects. Combining a tax on domestic extraction and a tax on emissions from domestic production, however, largely does solve the problem. The combination would allow the United States or a larger taxing coalition to control the net effects on the price of energy seen in foreign countries because the two taxes act on the price of energy in opposite directions. The mix of the two should be set based on how foreign actors respond to changes in the price of energy, as captured by the foreign supply and demand elasticities and the size of those markets. Set correctly, the combination of taxes, we will show, reduces emissions much more effectively than standard approaches at a lower cost.

The other key to the EPT is that it can be implemented simply and accurately, unlike carbon taxes with conventional border adjustments. To do so, the taxing region imposes a nominal tax on domestic extraction and a limited and narrow kind of border adjustment: a border adjustment only on the imports and exports of fossil fuels, but not other imports or exports—that is, not on goods and services more generally. As we explain below, border adjustments on energy shift an extraction tax downstream to production.

Rather than being imposed at the same rate as the underlying extraction tax, however, these border adjustments would be at the desired tax rate on emissions from domestic production. Using the numbers above, the nominal extraction tax would be at one hundred dollars per ton and the border adjustments on fossil fuels would be at only sixty dollars per ton. The border adjustments on energy at sixty dollars per ton shift only that portion of the tax downstream from extraction to production and leave the remaining forty dollars on extraction. The net effect is an effective tax on extraction at forty dollars per ton and an effective tax on emissions from production at sixty dollars per ton.

Implemented this way, the EPT is simple to impose. The base of the tax is an extraction tax, which, as prior work has shown, can easily be imposed by taxing only large, sophisticated entities that already carefully track fossil fuels.[13] These entities are already highly regulated and must keep careful books and records, which means that auditing and enforcement would also be simple. The border adjustments in the EPT are on energy, not on goods in general. Unlike border adjustments on goods, border adjustments on energy imports and exports would be easy to impose because we know with great precision the volume of imports and exports of each type of fossil fuel, and its carbon content.[14] This contrasts with border adjustments on goods more generally, where we have little way of knowing the carbon emitted from production in foreign countries.[15]

Finally, the EPT has fewer legal problems than conventional approaches. The problem with border adjustments imposed on goods generally is that the carbon itself does not cross the border. Instead, border adjustments are on the emissions from production in the foreign country. Taxes based on the process of production or the method of production, however, potentially run afoul of WTO rules because they have the potential to impose different taxes on like goods.[16] This is not true for border adjustments on energy. The tax would be on the carbon molecules that cross the border, substantially reducing concerns about WTO compatibility.

In short, the EPT works substantially better than conventional carbon taxes on domestic production, or conventional carbon taxes with border adjustments. It is easier to implement and is much more likely to be consistent with the WTO. It solves—or at least greatly reduces—the leakage problem and, therefore, removes one of the major barriers to the enactment of a carbon tax in the United States.

The remainder of this paper explores the arguments made above in detail. Part I provides background on carbon pricing, leakage, and border adjustments. Part II describes the EPT, starting with an explanation of why it performs better than conventional carbon taxes in an international setting and then turning to implementation and legal issues. It also includes results from a calibrated simulation

[13] *See generally* Gilbert E. Metcalf & David Weisbach, *The Design of a Carbon Tax*, 33 HARV. ENV'T L. REV. 499 (2009).

[14] The U.S. Energy Information Administration carefully tracks trade in energy. *See, e.g.*, *U.S. Energy Facts Explained, Imports & Exports*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/us-energy-facts/imports-and-exports.php (last visited Mar. 4, 2023).

[15] *See* Metcalf & Weisbach, *supra* note 13, at 502.

[16] *See* Trachtman, *supra* note 10, at 474.

of the global economy and trade, allowing us to compare the EPT to other approaches. Part III considers extensions of the analysis as well as limitations. Part IV concludes.

I. BACKGROUND

A. Carbon Pricing Basics

Climate change can be thought of as a global externality. People emit greenhouse gases which cause, or will cause, grievous harm to other people and other living things around the world, now and in the future.[17] Without a carbon price or some other policy, people will not fully consider the harm they cause to others when they pollute. In addition, they lack sufficient incentives to develop cleaner technologies.

While there are a number of greenhouse gases,[18] most carbon taxes focus on and are limited to emissions of CO_2 from fossil fuel combustion. There are two primary reasons. The first reason is that in developed countries, CO_2 emissions from the use of fossil fuels make up the overwhelming majority of emissions.[19] For example, in

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[17] There are two key features of greenhouse gases that make climate change different than a conventional pollution problem. The first is that greenhouse gases mix evenly in the atmosphere, which means that the harms are the same regardless of where the greenhouse gas was emitted. As a result, climate change is a global problem. Most other pollutants are local. Second, some greenhouse gases, notably CO_2, have very long atmospheric lives, which means that emission today will continue to cause harm long into the future. *See* DAVID ARCHER, THE LONG THAW: HOW HUMANS ARE CHANGING THE NEXT 100,000 YEARS OF EARTH'S CLIMATE (2008). These two features of greenhouse gases mean that emissions affect people in other countries and in the distant future, making conventional approaches to pollution, such as bargaining between injurers and victims or legal rules imposed from above, unworkable for climate change.

[18] The major greenhouse gases are carbon dioxide (CO_2), methane, nitrous oxide, and a number of highly potent gases used for refrigeration and related uses, such as hydrofluorocarbons. *See Energy and the Environment Explained*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases.php (last visited Mar. 4, 2023).

[19] In some developing countries, the most important source of emissions is deforestation. Forests take up and store carbon dioxide through photosynthesis. Deforestation reduces this carbon sink, and is categorized as an emission in most accounting methodologies. For comprehensive emissions data, by country, sector,

the United States, about 85 percent of net emissions are from fossil fuel combustion.[20] As a result, solutions to climate change necessarily, and primarily, involve transforming the fossil fuel sector of the economy.

The second reason is that emissions from fossil fuels are easier to tax than other emissions. Many non-fossil fuel emissions are from small, dispersed sources that are hard to measure and track, such as methane from enteric fermentation in livestock and nitrous oxide released from the soil by farmers when they till, plant, and harvest.[21] While we can estimate these in the aggregate, there is no available method of accurately tracing them to individual sources to be taxed. Emissions from fossil fuels, in contrast, can be taxed by imposing the tax on a relatively small number of large sources such as refineries, coal mines, and natural gas processors.[22] These sources, which already track inputs and outputs of fossil fuels and must keep careful records, are much more easily taxed.

We will follow that approach here, addressing only prices on emissions of CO_2 from the combustion of fossil fuels. We will occasionally refer to these carbon prices as prices on energy, with the understanding that carbon-free energy is exempt. Moreover, the three different fossil fuels—oil, gas, and coal—have different carbon content per unit of energy, and the carbon price must be adjusted to account for this. When we refer to a price on energy, we assume that it is adjusted appropriately to account for the actual carbon content of different types of energy.

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and year, *see ClimateWatch*, CLIMATEWATCH, https://www.climatewatchdata.org (last visited Mar. 4, 2023).

[20] *See* EPA, EPA 420-R-20-002, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS, 1990–2018, at ES-7–ES-9 (2020). The other major sources of emissions are methane emissions and nitrous oxide emissions from agriculture and hydrofluorocarbons from refrigeration. Land use change in the United States is a net sink (e.g., an increase in forested areas increased carbon sequestration in forests). Gross greenhouse gas emissions were 6,677 million metric tons of carbon dioxide equivalents (CO2e) in 2018, 5,032 of which were from fossil fuel combustion. Net emissions were 5,903 million metric tons of CO_2e.

[21] In 2018, methane from livestock in the United States resulted in 178 million metric tons of CO_2 equivalents, and nitrous oxide from agricultural soil management in the United States resulted in 338 million metric tons of CO_2 equivalents (out of a total of 5,903 million metric tons). *See id.* at ES-7 to -8, 5-3 to -10, 5-26 to -46.

[22] *See* Metcalf & Weisbach, *supra* note 13, at 501, 521–23.

We will generally refer to carbon prices as carbon taxes. Carbon prices can also be imposed through a cap and trade system, a liability system, subsidies, or implicitly through regulation. While there is a debate about which approach is preferable, to simplify the analysis, we consider only taxes. Our approach implicitly includes the possibility of subsidies—which are just negative taxes—and applies equally to cap and trade systems. Tort liability and regulatory approaches may raise distinct issues not considered here.

Because each ton of CO_2 causes the same harm regardless of who emits it, a carbon tax should be uniform across industries and locations. A uniform carbon tax ensures that emissions reductions occur where they are cheapest. A non-uniform tax, by contrast, would induce reductions where the tax is highest even if those reductions are more difficult or more expensive than reductions elsewhere.

To implement a carbon tax, it is useful to think of fossil fuels as moving through the economy in three steps.[23] Fossil fuels enter the economy when they are extracted from underground deposits. After processing and distribution, users of fossil fuels burn them to produce energy and use the energy to create goods or services. In the process, producers emit CO_2. Finally, people consume the goods or services created with that energy. We will refer to these three stages as extraction, production, and consumption.[24]

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[23] To see a visualization of energy flows in the U.S., see *U.S. Energy History Visualization*, RSCH. COMPUTING CTR. AT UNIV. OF CHI., https://us-sankey.rcc.uchicago.edu (last visited Mar. 4, 2023). According to the Energy Information Agency, about 20% of energy in the United States is carbon free. *See U.S. Energy Facts Explained, Consumption & Production*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/us-energy-facts (last visited Mar. 4, 2023). Just under half of that amount (8% of total energy) is from nuclear power, with renewable energy making up the rest (12%). *Id.* Biomass, wind, and hydroelectric power are the dominant sources of renewable energy (40%, 27%, and 19% of renewable power, respectively). *Id.* Fossil fuel energy is made up of petroleum (36% of total energy), natural gas (32% of total energy) and coal (11% of total energy). *Id.*

[24] In some cases, these stages are closely tied together. For example, if you use gasoline to power your vehicle, you are producing transportation services using a fossil fuel and also consuming those services as you are whisked to your destination. In other cases, production can be split between market production and home production: power plants burn coal and natural gas to produce electricity and

In a closed economy, that is, an economy without international trade, all fossil fuels that are extracted in a country are used to produce goods or services in that country, and all the resulting goods and services are consumed in that country. As a result, we can tax fossil fuels at any of the three stages, with the same result.[25]

There are, however, many fewer entities that extract fossil fuels than entities that use them in production or individuals who consume the resulting goods and services. According to one estimate, the United States can tax almost all emissions from fossil fuels by imposing the tax upstream on extraction—or nearly so, such as on refining—on only about 2,500 large, sophisticated entities.[26] As a result, in a closed economy, a domestic carbon tax can be imposed simply and effectively.

To our knowledge, however, all existing carbon prices are imposed on emissions from production.[27] They are imposed where the smokestack or tailpipe is located, that is, where the emissions actually take place. For example, the cap and trade system in the European Union is imposed on industrial use of fossil fuels. Only industries operating in the EU are required to have a permit. Industries located outside the EU are not subject to their permit system even if their products are ultimately imported into the EU and consumed there. If an industry in the EU exports its products, it still must pay a carbon price because the emissions occurred in the EU.[28] The same

individuals use that electricity to produce light and heat, which they consume. There may also be links in the chain of production that fall between these stages. For example, refining may be thought of as part of extraction (preparing deposits for use in the market) or as part of production (making an intermediate good). As we will discuss, what matters for tax system design is the effect of a tax at that step on the price of energy.

[25] A tax on extraction can also work in reverse, as a subsidy to sequestered carbon. *See* Metcalf & Weisbach, *supra* note 13, at 501, 537–40.

[26] *See id.*

[27] *See* Hafstead, *supra* note 6.

[28] *See* EUR. COMM'N, EU ETS HANDBOOK 20 (2015) (because there is no rebate of taxes on export, EU-based exporters are still subject to the tax).

is true of California's cap and trade system[29] and the northeast's Regional Greenhouse Gas Initiative.[30]

Existing systems impose a tax directly on production, in the sense that producers must remit the tax. Recent carbon tax bills in the United States Congress would impose a tax on emissions from domestic production but get there in a different way. These bills propose starting by imposing a tax on domestic extraction. They would then impose a tax on all imported fossil fuels and rebate taxes on all exported fossil fuels.[31] The net result would be a tax on emissions from domestic production. To see why, consider a unit of fossil fuel extracted domestically. A tax is imposed on its extraction. If the unit of fuel is used domestically, the tax remains. If it is exported, the tax is rebated. Suppose instead that the unit of fossil fuel is extracted abroad. If it is imported and used within the United States, a tax is imposed, while if it remains abroad and is used there, no tax is imposed. The net result is a tax on emissions from fossil fuels used in domestic production. The advantage of this newer approach is that it requires large domestic extractors to remit the tax, along with any importers, while exporters get a rebate. This simplifies the operation of the tax. As we will discuss in Part II, the EPT takes advantage of this same mechanism, but with a different goal.

In Part II, we will turn back to how to use the location of the tax—on extraction, production, or consumption—to design carbon taxes in an open economy setting. For now, we follow the conventional approach and assume the tax is on emissions during production.

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[29] *See* CAL. ENV'T PROT. AGENCY AIR RES. BD., OVERVIEW OF ARB EMISSIONS TRADING PROGRAM 1 (2015), https://ww2.arb.ca.gov/sites/default/files/cap-and-trade/guidance/cap_trade_overview.pdf (noting emissions trading applies to in-state electricity generators and large industrial facilities).

[30] *See* REG'L GREENHOUSE GAS INITIATIVE, ABOUT THE REGIONAL GREENHOUSE GAS INITIATIVE 1 (2021), https://www.rggi.org/sites/default/files/Uploads/Fact%20Sheets/RGGI_101_Factsheet.pdf (noting RGGI applies to in-state powerplants).

[31] *See, e.g.*, America's Clean Future Fund Act, S. 685, 117th Cong. § 4695 (2021–22), introduced by Majority Whip, Richard Durbin. This bill also imposes border adjustments on goods, which (as discussed below) shifts the tax to domestic consumption.

B. Leakage

In an open economy—one where there is trade—domestic carbon taxes on production can be avoided by moving production to a country without a carbon tax. For example, an American steel producer who sells its steel domestically can avoid a carbon tax imposed by the United States by moving abroad to a jurisdiction without a carbon tax and exporting the steel to the United States. As long as any increase in production costs plus the cost of shipping is less than the tax, the formerly domestic and now foreign producer of steel selling in the United States can do so at a lower cost than a domestic producer who must pay the tax. The same holds for sales in foreign markets: domestic producers facing a carbon tax are at a disadvantage relative to foreign producers selling in foreign markets. They can eliminate that disadvantage by moving abroad and avoiding the tax. As a result, a carbon tax on production creates an incentive to shift production abroad.

This shifting of domestic activities to low-tax regions is known as leakage. Leakage is usually defined as the increase in emissions outside of the taxing region, measured as a fraction of the emissions reductions in the taxing region.[32] For example, if the United States imposed a carbon price that reduced domestic emissions by one hundred units, and as a result, foreign emissions went up by twenty units, leakage would be 20 percent. The net global emissions reduction from the tax would be eighty units.

Leakage threatens to make domestic carbon pricing futile because emissions reductions at home are replaced by emissions increases abroad. If leakage were 100 percent, a domestic carbon price would achieve nothing other than causing producers to operate in a less-preferred location. Whatever benefits there were to the United States of having production occur domestically, such as supply chain security, would be lost. For this reason, leakage has been called the defining problem in the design of regional climate policies.[33]

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[32] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE (2007), https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf.

[33] *See* Fowlie, *supra* note 2, at 73.

To understand the size of the problem, researchers use large-scale, computable general equilibrium (CGE) models.[34] These models include detailed representations of the economy, most often with a high level of detail in the energy sector.[35] The researchers calibrate the inputs and outputs of each sector, and how those inputs and outputs feed into other sectors. Sectors in the models adjust their behavior in response to prices based on calibrated response functions. For example, a sector may reduce its energy use when energy prices go up, with the extent of its response depending on available technology. The models attempt to represent the response elasticities of different sectors, enabling the model to simulate how each sector, and the economy as a whole, would respond to a carbon tax.[36]

By our count, since the turn of the century, there have been over fifty CGE studies of the general problem of differential carbon prices published in the peer-reviewed literature, many more in the gray literature, and yet still more of specific industries or countries. Each study considers multiple different scenarios. Combined, there are hundreds of simulations of the effects of a carbon price on leakage.[37]

[34] *See infra* note 37 and accompanying discussion.

[35] For an overview of the use of CGE modeling for environmental problems, see Lars Bergman, *CGE Modeling of Environmental Policy and Resource Management*, *in* 3 HANDBOOK OF ENVIRONMENTAL ECONOMICS 1273, 1273–306 (Karl-Göran Mäler & Jeffrey R. Vincent eds., 2005).

[36] *See, e.g.*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 32, at 665–66.

[37] For example, a 2014 meta-study of carbon leakage papers examined 25 studies (20 of which were CGE studies, 5 of which were partial equilibrium studies). *See* Frédéric Branger & Philippe Quirion, *Would Border Carbon Adjustments Prevent Carbon Leakage and Heavy Industry Competitiveness Losses? Insights from a Meta-Analysis of Recent Economic Studies*, 99 ECOLOGICAL ECON. 29 (2014). These 25 studies, which make up only a portion of the literature, had 310 different modeled scenarios. Since that meta-study in 2014, there have been a number of additional studies of the issue. *See, e.g.*, Christoph Böhringer et al., *Robust Policies to Mitigate Carbon Leakage*, 149 J. PUB. ECON. 35 (2017) [hereinafter Böhringer et al., *Robust Policies*]; Warwick J. McKibbin et al., *The Role of Border Carbon Adjustments in a U.S. Carbon Tax*, 09 CLIMATE CHANGE ECON. 1840011-1 (2018); Xiujie Tan et al., *Assessment of Carbon Leakage by Channels: An Approach Combining CGE Model and Decomposition Analysis*, 74 ENERGY ECON. 535 (2018). For surveys of this literature, see SUSANNE DROGE, CLIMATE STRATEGIES, *Tackling Leakage in a World of Unequal Carbon Prices* 1 (2009),

The majority of studies find leakage to be within a broad but relatively consistent range: carbon prices in the developed world[38] that produce global emissions reductions in the range of ten percent have leakage rates between five percent and 30 percent.[39] That means that for every hundred tons of emissions reductions from a carbon price in the developed world, there is an increase of between five and thirty tons in other parts of the world, such as in China or India.

Whether this is large or small depends on one's point of view. On one hand, it is not so large as to make a carbon tax futile. On the other hand, 30 percent is hardly insignificant. Moreover, leakage is likely to be concentrated in a small set of industries, those that are energy intensive and exposed to trade. A leakage rate of 20 percent nationally may mean that for some industries, leakage is quite high. The effects in those industries could be substantial. Moreover, CGE models tend to use short-run or medium-run response elasticities, and if a unilateral carbon tax were to persist in the long run, leakage could be much higher—because long-run responses will be larger than short-run responses. Furthermore, leakage would likely be higher when policies aim to achieve greater emissions reduction than just the ten percent mentioned above. In any event, these numbers are large enough, or are concentrated enough, that leakage is

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https://climatestrategies.org/wp-content/uploads/2014/11/cs-leakage-exec-sum-oct09.pdf; Zhong Xiang Zhang, *Competitiveness and Leakage Concerns and Border Carbon Adjustments*, 6 INT'L REV. ENV'T & RES. ECON. 225 (2012). An important series of studies on carbon leakage and border adjustments was undertaken by Stanford's Energy Modeling Forum. For a summary of these studies, see Christoph Böhringer et al., *Introduction to the EMF 29 Special Issue on the Role of Border Carbon Adjustment in Unilateral Climate Policy*, 34 ENERGY ECON. S95 (2012).

38 Most models use the set of countries that had, or would have had, obligations to reduce emissions under the Kyoto Protocol as their taxing region. These countries are referred to as the Kyoto Protocol Annex B countries. The countries listed in Annex B do not correspond precisely to today's definition of developed countries. For example, South Korea is not an Annex B country, but some countries that were formally part of the Soviet Union but that are today quite poor are. *See* Kyoto Protocol to the United Nations Framework Convention on Climate Change Annex B, Dec. 10, 1997, 2303 U.S.T. 162.

39 *See* Branger & Quirion, *supra* note 37, at 29; Joshua Elliott et al., *Unilateral Carbon Taxes, Border Tax Adjustments, and Carbon Leakage*, 14 THEORETICAL INQUIRIES L. 207 (2013); Böhringer et al., *Robust Policies*, *supra* note 37, at 36.

viewed as the central problem in the design of carbon taxes in an international setting.

C. Border Adjustments

Border adjustments, also called carbon border adjustments or border adjustment taxes, are the most prominently proposed solution to leakage by a substantial margin.[40] As noted, every carbon tax bill introduced in the current and the previous Congress has included border adjustments.[41] As part of the EU Green Deal, the EU is expected to implement a version of border adjustments, the Carbon Border Adjustment Mechanism, for its emissions trading system in the near future.[42] Over 3,600 economists, including twenty-eight Nobel Prize winners and the current Secretary of the Treasury, signed a statement endorsing border adjustments.[43] Major environmental groups have devoted substantial resources to their design and implementation.[44] Border adjustments are a central element of climate change policy in an international setting.

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40 *See infra* notes 41–44. The EU cap and trade system, the Emissions Trading System, currently uses a free allocation of permits to vulnerable industries to address leakage. As part of the EU Green Deal, however, the EU has recently proposed shifting to border adjustments, in a system known as the Carbon Border Adjustment Mechanism. *See EU Green Deal – Revision of Energy Taxation Directive,* EUR. COMM'N, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227 (last visited Mar. 4, 2023).

41 For a list of carbon pricing bills, *see* Hafstead, *supra* note 6.

42 *See* Proposal for a Regulation of the European Parliament and of the Council Establishing a Carbon Border Adjustment Mechanism, EUR. PARL. DOC. (COM (2021) 564) (2021). For a summary, *see Carbon Border Adjustment Mechanism*, EUR. COMM'N, https://ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en (last visited on Mar. 4, 2023).

43 *See Economists' Statement on Carbon Dividends*, *supra* note 8.

44 For example, Resources for the Future has devoted significant resources to a project on the design of border adjustments. *See* BRIAN FLANNERY ET AL., RES. FOR THE FUTURE, FRAMEWORK PROPOSAL FOR A U.S. UPSTREAM GREENHOUSE GAS TAX WITH WTO-COMPLIANT BORDER ADJUSTMENTS (2018). *See also* Rob Bradley et al., *Leveling the Carbon Playing Field*, WORLD RES. INST. (2009), https://www.wri.org/research/leveling-carbon-playing-field; Martin Dietrich Braunch et al., *Event Highlights: Carbon Border Adjustments in the E.U., the U.S., and Beyond*, COLUM. CTR. ON SUSTAINABLE INV. (2021), https://ccsi.columbia.edu/content/event-highlights-carbon-border-adjustments-eu-us-and-beyond. As an illustration of the prominence of the issue, a Google Scholar search (on July

Unfortunately, as we document below, border adjustments only modestly improve the effectiveness of carbon prices, are nearly impossible to implement accurately, would be costly to impose and easy to avoid, and raise significant problems under international trade law.

1. Border Adjustment Basics

Border adjustments are taxes on imports and rebates of prior taxes paid on exports. We will differentiate between border adjustments on energy and border adjustments on goods. For energy, the border adjustment on imports is based on the carbon content of the energy—plus any emissions from extraction of the energy. For example, if the United States imported a barrel of oil, the border tax would be on the carbon content—the number of carbon molecules—in the oil. If the United States exported a barrel of oil, the rebate would be of the taxes paid on extraction, if any.

For goods—other than energy—the tax on imports is based on the emissions from the production of the good, known as embodied emissions. Consider, for example, a piece of steel imported into the United States from South Korea. When the steel was produced in South Korea, the producer emitted CO_2 because of the energy required during manufacturing. When the steel crosses the border, a tax would be imposed on those emissions as if the emissions arose in the United States. For example, if production of the unit of steel produced one ton of CO_2 in South Korea, when the steel is imported into the United States a tax on one ton of CO_2—for example, one hundred dollars per ton—would be imposed. The rebate on exports of goods is of carbon taxes paid during the production of a good. For example, if the United States produced the steel domestically and exported it, the rebate would be of any taxes paid domestically from the production of that steel.

If the United States were to impose a tax on extraction, border adjustments on energy would shift the tax downstream to production. To illustrate, consider a tax on domestic extraction with a border adjustment on imports and exports of energy—but not goods. Any energy that is extracted within the United States and used in production domestically bears a tax. Any energy that is extracted

9, 2021) for "carbon border adjustment" turned up 19,100 articles mentioning the term since 2010.

domestically and exported for use in production abroad does not bear a tax because of the rebate of the extraction tax on export. And any energy that is imported and used here in production is taxed on import. Therefore, an extraction tax plus border adjustments on energy is just a tax on emissions from domestic production, or what we call a production tax.[45] The nominal tax is on extraction, but the effective tax is on production.

Border adjustments on goods shifts the tax further downstream, to consumption. Any goods produced and consumed domestically bear a tax because the border adjustment does not apply to purely domestic items. Exported goods do not bear a tax because the production tax is rebated at the border. Goods that are imported and consumed domestically have a tax imposed at the border. Therefore, adding border adjustments on goods to a tax on domestic production shifts it to a tax on domestic consumption. Combining these steps, an extraction tax with a border adjustment on both energy and goods is a consumption tax.

We will use the terms "extraction tax," "production tax," and "consumption tax" to refer to a tax on the carbon content of fossil fuels when extracted, a tax on emissions from the use of fossil fuels in production, and a tax on the emissions associated with, or the emissions "embodied in" goods when consumed respectively. We will refer below to both the effective taxes (extraction taxes, production taxes, and consumption taxes) and nominal taxes (an extraction tax plus border adjustments on energy) depending on the context. For example, in Part III.A, we will use effective taxes because we focus there on the effects of these taxes, not on how they are implemented. In Part III.B, we consider implementation, and there discuss how the effective taxes can be implemented via simple nominal taxes. The context should make our reference clear.

2. The Argument for Border Adjustments Under a Production Tax

As noted, conventional carbon taxes are imposed on production. Production taxes creates an incentive to shift production abroad, creating leakage. The argument for imposing border

[45] As noted, recent carbon tax proposals in the United State often use this structure to impose a tax on domestic production while requiring fewer entities to remit taxes.

adjustments on a production tax is that border adjustments eliminate the incentive to relocate production, reducing leakage.

To illustrate, consider a country with a tax on emissions from domestic production that trades with the rest of the world, which does not impose a carbon tax. Compared to the situation with no tax, producers in the taxing country have higher costs than producers in the rest of the world. Consider, for example, domestic producers exporting to the rest of the world that have about equal costs to producers elsewhere before a carbon tax is imposed. After the carbon tax, their costs will be higher than their competitors, reducing exports. Similarly, if without tax, domestic producers selling domestically have equal costs to importers, adding a tax will raise their costs, increasing imports. Stated in terms of comparative advantage, a domestic carbon tax on production reduces the comparative advantage of domestic producers, shifting trade shares in favor of foreign producers.

Border adjustments on goods eliminate this distortion. Because they shift the tax to domestic consumption, the tax does not depend on where a good is produced. Domestic producers exporting to foreign markets have the tax rebated, thus their comparative advantage in those markets is the same as it was without the tax. Similarly, foreign producers selling to the domestic market have a tax imposed on import, which means all producers—domestic and foreign—selling domestically see their costs increase equally. Comparative advantage is maintained. Because it eliminates distortions in trade patterns, a consumption tax, or equivalently, a production tax with border adjustments, is more efficient than a production tax.

3. The Size of the Effects

While border adjustments improve the efficiency of a domestic production tax, to decide whether they are desirable, we need to compare the benefits of improving the operation of the tax to their costs. To do this, we need to estimate the size of the effects. Most studies of leakage also estimate the effects of adding border adjustments,[46] thus we may review the results from those studies to get a sense of the likely magnitude.

The consensus from these studies is that border adjustments offer some, but modest, gains. They reduce leakage by about a third,

[46] *See, e.g.*, Branger & Quirion, *supra* note 37, at 35.

and they result in modestly greater emissions reductions for any given tax rate.[47]

Figure 1 illustrates the effect of carbon taxes on emissions. It depicts the results of a simulation of leakage and border adjustments from a typical CGE model.[48] The x-axis is the carbon tax in dollars per ton of CO_2 and the y-axis is the percent reduction in global emissions relative to the business-as-usual (BAU) estimate—the emissions expected under current policies, without a new tax. The simulation focuses on the effect of taxes in what are known as Annex B countries, effectively most of the developed countries.[49] The top three lines are those relevant for understanding leakage and border adjustments as they illustrate that global reductions in emissions from Annex B carbon taxes are significantly less than reductions in emissions in the Annex B carbon taxes themselves, even accounting for border adjustments. The bottom line is intended to give a sense of scale and shows the simulated reductions that would arise with a global tax rather than a tax in Annex B countries alone.

The top line shows the global emissions reductions from a standard production tax in Annex B. The line labeled "Annex B Reductions-Annex B tax" shows the emissions reductions in just the Annex B countries from that tax. Note that the global emissions reductions from a tax in Annex B are less than the Annex B emissions reductions—that is, the global line is above the Annex B line. The reason is that emissions increase outside of Annex B because industries relocate offshore. This increase—the vertical distance between the two lines—is leakage. As can be seen, leakage increases with the tax rate. The higher the tax, the greater the incentive to shift production offshore. Leakage in this simulation is less than 20 percent, which is consistent with much of the literature.[50]

47 *See* Joseph E. Aldy, *Frameworks for Evaluating Policy Approaches to Address the Competitiveness Concerns of Mitigating Greenhouse Gas Emissions*, 70 NAT'L TAX J. 395, 402 (2017).

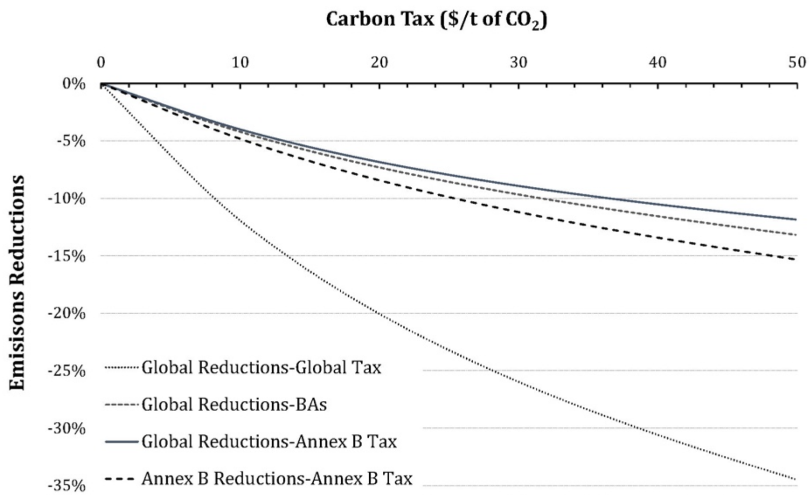
48 For a description of the model and results, see Elliott et al., *supra* note 39; Joshua Elliott et al., *Trade and Carbon Taxes*, 100 AM. ECON. REV. 465 (2010); Joshua Elliott et al., *CIM-EARTH: Framework and Case Study*, 10 B.E. J. ECON. ANALYSIS & POL'Y 1 (2010).

49 For a discussion of Annex B countries, see note 38.

50 *See* note 39 and accompanying discussion.

The effects of adding border adjustments are illustrated with the line labeled "Global Reductions-BAs." This shows global emissions reductions when the Annex B countries add border adjustments to the tax, converting the tax to a consumption tax. Global emissions decrease when Annex B countries add border adjustments. Border adjustments help,[51] but the effects are modest at best. Adding border adjustments is not a panacea as they only marginally reduce emissions.

Figure 1: Effects of Border Adjustments



4. Implementation Problems

If border adjustments on goods were simple to impose—and raised no legal problems—the modest gains that they generate might be worth it. But, in fact, they are a nightmare to impose. We have previously explored the implementation problems with border adjustments at length.[52] Rather than repeat this analysis, we provide a brief overview.

51 Although we do not show the relevant line, the Annex B reductions, with an Annex B consumption tax, reduce leakage as well.

52 *See* Kortum & Weisbach, *supra* note 9. For other analyses of the implementation issues, see Branger & Quirion, *supra* note 37; Charles E. McLure Jr., *Selected International Aspects of Carbon Taxation*, 104 AM. ECON. REV. 552, 553 (2014); AARON COSBEY, INT'L INST. FOR SUSTAINABLE DEV., BORDER CARBON ADJUSTMENT (2008), https://theasiadialogue.com/wp-content/uploads/2017/05/cph_trade_climate_border_carbon.pdf; AARON COSBEY ET AL., INT'L INST. FOR

The key problem with imposing border adjustments is that there is no straightforward way to determine the emissions associated with an imported good. Consider a shipload of automobiles arriving in Los Angeles. Each automobile will have parts from many different countries with the parts assembled in yet another set of countries. Those parts may have been produced using various technologies and fuel sources under a number of environmental regimes. The mix of parts, countries, and fuel sources will be different for each type of vehicle and different for various model years of the same vehicle. Customs agents would be at a complete loss if they were required to impose a tax on each automobile based on its emissions during production, let alone impose a similar charge for each and every other good crossing the border. In 2019, the United States imported about $2.37 trillion of goods, including $354 billion in transportation equipment such as automobiles and trucks.[53] Imposing accurate border adjustments at this scale is infeasible.

Because of this problem, border adjustment proposals, including the border adjustments proposed in every carbon tax bill in the current and previous United States Congress, are limited to a narrow set of goods, most often raw materials such as steel and chemicals. They exclude complex final goods such as automobiles. Moreover, even within this narrow set of goods, they aggregate goods into

SUSTAINABLE DEV., A GUIDE FOR THE CONCERNED: GUIDANCE ON THE ELABORATION AND IMPLEMENTATION OF BORDER CARBON ADJUSTMENT (2012), http://papers.ssrn.com/abstract=2178312; TREVOR HOUSER ET AL., LEVELING THE CARBON PLAYING FIELD (2008); Roland Ismer & Karsten Neuhoff, *Border Tax Adjustment: A Feasible Way to Support Stringent Emission Trading*, 24 EURO. J.L. & ECON. 137, 153 (2007); Catherine F. Izard, Christopher L. Weber & H. Scott Matthews, *Primary and Embedded Steel Imports to the U.S.: Implications for the Design of Border Tax Adjustments*, 44 ENV'T SCI. TECH. 6563, 6563 (2010); Stéphanie Monjon & Philippe Quirion, *How to Design a Border Adjustment for the European Union Emissions Trading System?*, 38 ENERGY POL'Y 5199, 5199 (2010).

53 *See United States*, Observatory of Econ. Complexity, https://oec.world/en/profile/country/usa?yearSelector1=exportGrowthYear25&yearlyTradeFlowSelector=flow1 (last visited Mar. 4, 2023).

broad categories and assume, counterfactually, that all goods in each category generate the same emissions when produced.[54]

This approach is both narrow and inaccurate. Different types of raw materials in the same category can have widely different emissions profiles.[55] Even raw materials of the same type are produced using a variety of production methods and fuel sources, resulting in different emissions profiles.[56] Consequently, the border adjustment on any given raw material may bear little relationship to the emissions associated with its production.

On top of these problems, many border adjustment proposals also would not apply to countries with comparable carbon prices.[57] The reason is that if emissions are already taxed during production in their country of origin, there is no need to impose a second tax when the resulting good is imported to the United States. While this idea makes sense, it would be hard to implement because there is no easy way to determine which countries have comparable carbon prices. Climate policies in any single country are likely to be complex, combining regulations, subsidies, pricing, and other mechanisms imposed differentially on different parts of the economy. There is no straightforward way to translate these complex mixes of policies to a comparable carbon price to determine if imports from that country should be subject to a border tax. Any determination of which goods from which countries are exempt would likely be political in nature.

Even if an appropriate import charge were determined, these narrow border adjustments would be easy to avoid. Rather than selling raw materials, exporters could shift to selling final goods or partially finished goods which would not be subject to the border tax. The result is perverse. Border adjustments would end up encouraging the very thing that they seek to avoid: shifting production abroad.

54 For example, the border adjustments proposed in a major study by Resources for the Future, a prominent environmental think tank, are limited in this way. *See* FLANNERY ET AL., *supra* note 44, at 7.

55 *See* Kortum & Weisbach, *supra* note 9.

56 *See* HOUSER ET AL., *supra* note 52, at xviii.

57 *See*, *e.g.*, Save our Futures Act, S. 2085, 117th Cong. § 4695 (2021), Consumers REBATE Act, H.R. 8175, 116th Cong. § 9902 (2020).

If exporters from low tax countries wish to continue exporting raw materials rather than finished goods, they could switch fuel sources, using clean sources of fuel for exports to the United States and dirty sources to produce goods for their own consumption. They could also transship goods through countries with high carbon taxes but no border adjustments, making the goods appear as if they were from the high-tax country rather than the low-tax country. The opportunities for mischief would be legion.[58]

To implement this regime, the United States would need a vast new bureaucracy. This bureaucracy would have to classify goods, determine their carbon content, police avoidance schemes, and resolve disputes. For example, setting the import taxes and adjusting them regularly would require a large amount of data on how goods are produced in foreign countries and the relevant fuel source. Actors would argue about the classification of goods or the method of attributing emissions to their production technology and fuel source. Such disputes would have to be adjudicated. Detecting illegal transshipping would require policing and investigative work. Imposing even a narrow, inaccurate, and easily avoidable set of border adjustments would not be a casual undertaking. In short, implementing border adjustments on goods would require engaging in a costly and largely hopeless task to achieve modest gains.

5. Legality: The WTO

A final problem with border adjustments is that they may not comply with international trade law. The World Trade Organization has never considered a close analogy to border adjustments under a carbon tax, thus there is considerable uncertainty about whether such adjustments are allowed. There are a number of thorough analyses of the legal issues, therefore we provide only a brief overview.[59] WTO law is archaic and legalistic. Many of its terms often

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[58] None of these effects are captured in CGE modeling efforts, which means that the models may substantially overestimate the effectiveness of border adjustments.

[59] For a more complete analysis, see Trachtman, *supra* note 10. *See also* Ismer & Neuhoff, *supra* note 52; Javier de Cendra, *Can Emissions Trading Schemes be Coupled with Border Tax Adjustments? An Analysis Vis-A-Vis WTO Law*, 15 RECIEL 131 (2006); Holzer, *supra* note 10; Stéphanie Monjon & Philippe Quirion,

do not comport with their economic or commonsense meanings. Therefore, what makes sense from a policy perspective may not be consistent with the WTO and straightforward intuitions about results may be wrong.

The WTO rules apply separately to duties on imports and to rebates on exports. Duties on imports cannot discriminate between goods that are produced domestically and goods that are imported or exceed the tariff bindings agreed to by a nation. Rebates for exports cannot be an illegal subsidy.[60] We limit our discussion to selected issues regarding import charges.

Under the General Agreement on Tariffs and Trade (GATT) Article III—the agreement's national treatment clause—foreign producers must be treated with no less advantageous terms than domestic producers. To determine this, the WTO will examine the treatment of "like" products and "directly competitive and substitutable" products.

Under the WTO definition of "like," the method of production appears to be irrelevant.[61] For example, steel produced using one method of production, such as a blast furnace, may be functionally the same as steel made using a different method, such as an electric arc furnace. The two types of steel are "like" one another and, therefore, must be treated the same way. However, the emissions from these two methods are quite different. Accurate border adjustments would treat the two types of steel differently. If the "likeness" rule prevents them from being treated differently, it would effectively prohibit accurate border adjustments.

Once "like" products have been identified, we must determine the nature of their domestic treatment and whether a border

A Border Adjustment for the EU ETS: Reconciling WTO Rules and Capacity to Tackle Carbon Leakage, 11 CLIMATE POL'Y 1212 (2011); WTO & UNEP, TRADE AND CLIMATE CHANGE (2009); Jagdish Bhagwati & Petros C. Mavroidis, *Is Action Against US Exports for Failure to Sign Kyoto Protocol WTO-Legal?*, 6 WORLD TRADE REV. 299 (2007); Robyn Eckersley, *The Big Chill: The WTO and Multilateral Environmental Agreements*, 4 GLOB. ENV'T POL. 24 (2004); Jeffrey Frankel, *Climate and Trade: Links Between the Kyoto Protocol and WTO*, 47 ENV'T SCI. & POL'Y FOR SUSTAINABLE DEV. 8 (2005); Jacob Werksman, *Greenhouse Gas Emissions Trading and the WTO*, 8 REV. EUR. CMTY. & INT'L ENV'T L. 251 (1999).

[60] *See* Trachtman, *supra* note 10, at 486–90.

[61] The WTO determines whether products are "like" by examining whether they are in competition with one another. Trachtman, *supra* note 10, at 474.

adjustment is allowed to match that treatment. GATT Article II.2(a) allows countries to impose "at any time on the importation of any product a charge equivalent to an internal tax . . . in respect of the like domestic product." This means that if a carbon tax is an internal tax on a product, nations can impose an equivalent import charge—that is, a border adjustment.

Unfortunately, there is no clear definition of an internal tax on a product. The WTO distinguishes between direct and indirect taxes, and only indirect taxes count as a tax on a product.[62] For example, Value-Added Taxes (VATs) count as internal taxes on products and taxes on profits do not.[63] There is, however, no guidance on how to characterize a carbon tax. Because we neither know what it means for a product to be "like" another nor when a product is subject to an internal tax, there is considerable uncertainty on whether the import charge component of border adjustments is WTO compliant.

Commentators typically suggest, therefore, that nations seeking to impose border adjustments rely on two exceptions found in Article XX in subsections (b) and (g). Article XX(b) allows measures "necessary to protect human, animal or plant life or health."[64] Arguably a border adjustment meets this requirement. A key issue, which we return to below, is whether an import charge is "necessary." A charge is necessary only if there are no less restrictive alternatives. If one views border adjustments as the best means of controlling leakage, and therefore, of implementing a carbon tax and reducing the harms from climate change, they may be necessary. But if other means are available, they are not.

Article XX(g) creates an exception for measures that relate to the "conservation of exhaustible natural resources…made effective in conjunction with" domestic restrictions.[65] The ability of the atmosphere to absorb CO_2 is most likely an exhaustible natural resource. There is no "necessity" provision in Article XX(g), thus on

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[62] *See id.* at 472.

[63] *See* Amelia Porges et al., Guide to GATT Law and Practice: Analytical Index 145–46 (6th ed. 1995).

[64] General Agreement on Tariffs and Trade, art. XX(b), Oct. 30, 1947, 61 Stat. A-11, 55 U.N.T.S. 194.

[65] *Id*. art. XX(g).

its own terms, Article XX(g) seems more promising than Article XX(b).

Measures that satisfy Articles XX(b) and XX(g), however, must also satisfy the chapeau of Article XX. This requires that there be no "arbitrary or unjustifiable discrimination between countries where the same conditions prevail" and no "disguised restriction[s] on international trade."[66] These requirements have been interpreted to necessitate meeting a "least trade restrictive alternative" test.[67] As we will discuss below, because there are alternatives that are less trade restrictive than border adjustments on goods, notably the EPT, there is some issue of whether border adjustments can survive either Article XX(b) or Article XX(g).

There is a large amount of additional detail. The majority view appears to be that the WTO would not hold border adjustments under a carbon tax to be illegal. The WTO would, it is hoped, be hesitant to interfere with policies designed to address climate change. There are enough exceptions and nuances in WTO law that there is room to uphold border adjustments if the WTO so desired.[68] Nevertheless, there is considerable uncertainty.

6. Summary

Border adjustments to conventional carbon taxes on production are designed to reduce or eliminate the trade distortions introduced by those taxes. They only modestly improve the performance of a production tax, however, reducing leakage by about one-third. With or without border adjustments, the emissions reductions from conventional approaches are modest. Border adjustments are also difficult to administer, inaccurate, and avoidable. Moreover, although most likely consistent with the WTO, they raise considerable legal uncertainty.

As shown above, there are good reasons why border adjustments are controversial. Below, we explore a better way to impose a regional carbon price.

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[66] *Id.* art. XX.

[67] *See* Trachtman, *supra* note 10, at 481.

[68] *See id*. at 469.

II. A BETTER ALTERNATIVE

This section of the Article demonstrates how to design a better regional carbon price. Our approach reduces global emissions more effectively and at a lower cost than traditional approaches. It is also simpler to implement and raises fewer legal problems.

Our reasoning is based on a formal model of the problem, and we show some results here from a calibrated version of the model. Rather than presenting the model here, we describe the results and underlying reasoning that comes out of the model. We describe the basic structure of the model in the Appendix. The full model, its solution, and the details of our calibration, are available elsewhere.[69] Our code is freely available and can be run using open source software.[70]

A. The Root of the Leakage Problem

To understand how to design a better regional carbon tax, we start by clarifying why carbon taxes generate leakage. Carbon taxes affect the price of energy in other parts of the world. Leakage is caused when foreign actors who are not subject to the tax respond to that changed price. The key idea is that different methods of imposing a carbon tax, all of which would be equivalent in a world without trade, have different effects on the price of energy in other parts of the world when there is trade, and therefore, different leakage effects.

We begin with the standard explanation of how taxes affect prices and quantities.[71] The analysis applies to an arbitrary good, service, or type of fuel but, because we are focused on energy, we will apply it to the market for oil.

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69 *See* Samuel Kortum & David Weisbach, *Optimal Unilateral Carbon Policy* (CESifo, Working Paper No. 9409, 2021), https://www.cesifo.org/en/publikationen/2021/working-paper/optimal-unilateral-carbon-policy.

70 *See* David Weisbach (dweisbach), *Code for Optimal Unilateral Carbon Policy*, GITHUB https://github.com/dweisbach/Optimal-Unilateral-Carbon-Policy (last visited Mar. 3, 2023).

71 This analysis mirrors that found in in basic public finance textbooks. *See, e.g.*, JONATHAN GRUBER, PUBLIC FINANCE AND PUBLIC POLICY 588–89 (7th ed. 2019).

Figure 2 is a supply-demand diagram for oil. The dark lines represent the pre-tax supply and demand curves. Without taxes, the market clearing quantity of oil would be Q_0 and it would sell at price p_0.

Suppose that we want to impose a tax of *t* per unit on oil. We can alternatively require sellers or buyers to remit the tax. The sellers, we will assume, are the extractors of the oil. The buyers are either producers who use oil to make things, or consumers of oil, who buy products made with oil. In Part II.B, we will more carefully differentiate between these different types of buyers. For now, we treat producers and consumers as the same.

As noted in Part I, current carbon taxes—or equivalently, cap and trade systems—require users or buyers of energy to remit the tax. The tax is on the demand side. If the buyers must pay a tax on oil, their willingness to pay for oil will decline because they must now pay the tax on top of what they pay the seller. The demand curve shifts downward and inward, as reflected in the dashed, downward-sloping line in Figure 2. The after-tax equilibrium is where the new demand curve intersects the supply curve. The market price goes down to p_t, but including the taxes, buyers pay p_t+t. With a tax on demand, p_t is *lower* than the pre-tax price and the equilibrium quantity goes down to Q_t.

Figure 2: Tax on Demand

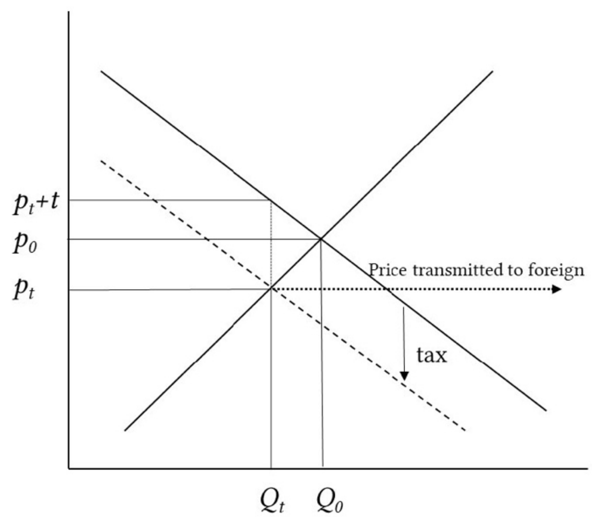
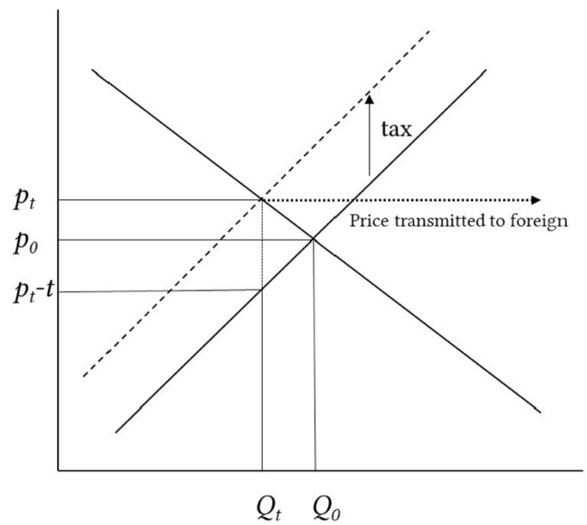


Figure 3 shows the same tax, but now with the tax remitted by extractors. If extractors remit the tax, their costs go up. They must charge more per unit to cover their costs, which now include taxes. As a result, sellers producing the same total quantity will charge higher prices, and the supply curve shifts upward and inward, as reflected in the dashed, upward-sloping line in Figure 3. The market clearing quantity that is sold goes down to Q_t, where the new supply curve and the original demand curve intersect. The market price of oil will go up to p_t. Extractors will receive p_t and pay a tax of t, leaving them with p_t-t. Relative to when there is no tax, buyers pay more and sellers receive less.

Figure 3: Tax on Supply



With no trade, it makes no difference whether the tax is remitted by buyers of oil or sellers (extractors) of oil. In both cases, the market-clearing quantity is the same, Q_t, and the difference between what buyers pay and sellers receive is the tax, t. That is, regardless of who remits the tax, there is a wedge of t between what buyers pay and sellers receive. As a result, the standard view in tax policy is that it does not matter whether the government imposes a tax on sellers or buyers.[72] A consequence of this conclusion is that in a world without trade, we can impose remittance obligations where they are most convenient, such as on larger, more sophisticated entities.[73]

With trade, this equivalence no longer holds. The reason is that taxes on demand and taxes on supply have different effects in

[72] *See id.* at 589. This view is reflected in the incidence of Social Security taxes. They are remitted half by workers and half by employers, but the incidence is thought to fall entirely on workers. It would not matter if they were remitted entirely by employers or by workers.

[73] *See* Metcalf & Weisbach, *supra* note 13, at 523. The standard conclusion does not hold if one side of the market is more likely to evade taxes than the other. If, for example, sellers are more likely to evade taxes than buyers, taxing sellers is not the same as taxing buyers.

foreign markets in which carbon taxes are absent. To see this, return to Figure 2, showing a tax on demand. In this case, buyers pay p_t+t for oil and sellers receive p_t. The after-tax price, p_t, goes down. With trade in oil, p_t is the price that is seen in international markets—indicated by the dashed arrow. A tax on domestic demand for oil suppresses the global price of oil. A lower price of oil in foreign markets generates an increase in the demand for oil in those markets, which is what causes leakage. Note, however, that there is a second effect of a tax on the demand side: a lower global price of oil will cause a reduction in extraction in foreign markets because extractors will receive less for the oil that they extract. Marginal oil fields will go offline. This effect partially offsets demand-side leakage. That is, a tax on domestic demand increases foreign demand but reduces foreign supply.[74]

The reverse holds for a tax on domestic supply. As Figure 3 illustrates, a tax on domestic supply makes the after-tax global price, p_t, go *up* rather than down. Foreign users of oil will consume less because they face a higher price. Foreign suppliers of oil, however, will extract more because the price they can charge has gone up, making previously unprofitable oil fields profitable at the new price. This illustrates how taxes on supply generate what we might call "extraction leakage," which is an increase in the supply of energy in other parts of the world in response to a domestic tax—as opposed to conventional leakage, which is an increase in the demand for or use of energy in another part of the world. That is, a tax on the supply of oil causes foreign demand to go down and foreign supply to go up.

Neither tax on its own is able to control the responses in other parts of the world. They both transmit price changes to foreign markets, which respond by offsetting the tax at least in part.[75] With a

[74] In addition, the equilibrium supply and demand shown in Figure 2 (as well as in Figure 3) cannot be the equilibrium with trade. The reason is that at the price shown, there is excess demand in foreign countries, which means that global supply does not equal global demand. In equilibrium, the price would go down less than is shown, generating excess supply in the taxing regime sufficient to meet the excess demand elsewhere.

[75] A second reason the equivalence no longer holds when there is trade is that the tax base of a tax based on extraction need not be the same as the tax based on energy used production or the energy embodied in goods that are consumed. The

tax on demand, foreign users of oil increase their use, offsetting domestic reductions. With a tax on supply, foreign suppliers of oil increase their extraction, offsetting domestic reductions.

B. Designing a Better Alternative

The key to designing a better regional carbon policy is to exploit the difference between taxes on supply and taxes on demand. Exploiting this difference allows the taxing region to better control the effects of its policy elsewhere in the world and, by doing so, control leakage. This strategy also makes the tax easier to implement and more likely to be compatible with the WTO. We start by showing how to combine taxes on supply and demand to control leakage. We then consider how to impose a tax on the demand side, either on emissions from production, emissions embodied in consumption, or some combination of the two.

1. Hybrid Taxes: Combining Taxes on Supply and Demand

Recall that taxes on the demand side of the market lower the price seen in foreign markets, and taxes on the supply side of the market increase the price seen in foreign markets. The key insight is that by imposing part of the tax on both sides of the market, the taxing region can choose how its taxes affect foreign prices.[76] If, for example, half the tax was imposed on the demand side and half the tax was imposed on the supply side, the two would push in opposite directions, the demand side tax pushing the foreign price down and the supply side tax pushing it up—although, depending on how foreign markets respond, possibly not by the same amount the demand side tax pushes the price down. By selecting the right mix, the taxing region can choose the effects of its tax abroad.

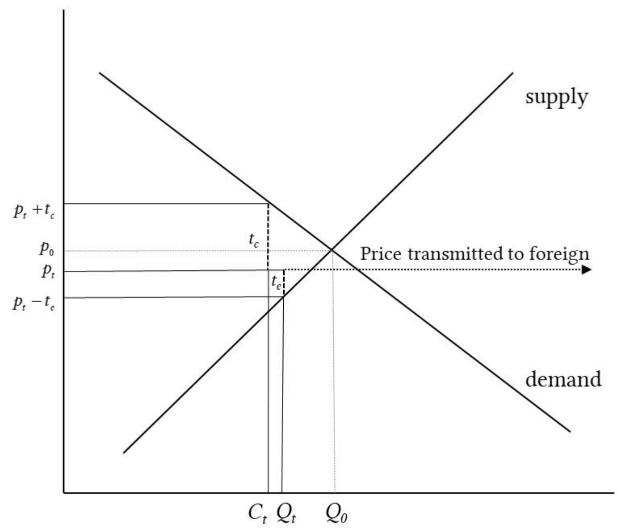
Figure 4 illustrates how the mix of domestic taxes affects the price seen in foreign markets. To be concrete, suppose that the desired tax is ten dollars per unit of oil. Rather than a ten dollar tax on

reason is that with trade, domestic extraction may be larger or smaller than energy use in production if energy is exported or imported, respectively. The same holds for energy used in production compared to the energy embodied in goods that are consumed domestically. Changing who remits the tax changes the tax base.

[76] This insight dates back to a paper published in 1975. *See* James R. Markusen, *International Externalities and Optimal Tax Structures*, 5 J. INT'L ECON. 15 (1975). Nevertheless, it does not seem to have been appreciated in the literature on the design of carbon taxes.

buyers or a ten dollar tax on sellers, Figure 4 shows a combination of a three dollar tax on the supply side and seven dollar tax on the demand side. There is still a ten dollar difference between what buyers pay and sellers receive in the taxing jurisdiction, so the effective tax is the same. This combination lowers the price seen in foreign markets relative to the price before the taxing region imposes the tax but does so less than a tax imposed entirely on the demand side.[77]

Figure 4: Combining Taxes on Supply and Demand



The choice of a demand-side tax of seven dollars and a supply-side tax of three dollars is merely illustrative. The taxing region can choose any combination of the two that equals the total tax that it

77 In Figure 4, the after-tax amount supplied, Q_t, in the taxing region and the after-tax amount demanded in the taxing region, denoted by C_t, are not equal. This is because if the price is lower in foreign countries, their extraction will go down but demand will go up, generating a net demand for exports from the taxing region, similar to the effect discussed in note 74. Figure 4 is drawn to show an excess of supply in the taxing region to meet that demand for exports. The equilibrium price of oil sets the demand for exports in foreign countries equal to the excess supply in the taxing region. Note that this would also be true in Figures 2 and 3, but we have omitted this feature for simplicity.

seeks to impose. By choosing the mix, the region determines the price p_t, and therefore, the effects seen in foreign markets.

The optimal mix minimizes market distortions, which means that the optimal mix depends on how foreign markets respond to price changes. If foreign supply is highly responsive to price changes, the taxing region will not want to impose taxes on the supply side because doing so induces large responses. Similarly, if foreign demand is highly responsive to price changes, the taxing region will want to avoid demand-side taxes. The optimal mix balances these effects.[78]

To illustrate the logic, suppose that the taxing regime begins with a tax only on supply which, in the case of oil, is an extraction tax. Ideally, the rate would be set equal to the marginal harm from emissions. This tax increases the global price of oil, resulting in an increase in foreign extraction. Increases in foreign extraction cause harm because that extracted energy ultimately produces atmospheric CO_2, causing an increase in climate change. The size of this effect—what we call extraction leakage—is determined by the elasticity of energy supply in foreign markets multiplied by the size of those markets.

To offset this effect, the taxing region can lower the extraction tax and impose an offsetting tax on the demand for energy, leaving the sum of the two taxes the same as the original extraction tax and equal to the marginal harm from emissions. For example, if the original extraction tax were ten dollars per ton, the taxing region could lower it to nine dollars per ton and impose a one dollar per ton tax on demand, leaving the sum of the two taxes the same. This change reduces extraction leakage by lowering the price of energy. A lower price of energy, however, increases foreign demand—relative to what it would be with the pure extraction tax—resulting in more energy use and therefore, more harm from climate change. The size

[78] In fact, the taxes are set so that the two tax rates multiplied by the relevant change in foreign markets are equal, or in notation:

$$t_e \varepsilon_e Q_e^* = t_d \varepsilon_d C_e^*,$$

where t_e is the tax on extraction, ε_e is the foreign elasticity of extraction, Q_e^* is the amount of foreign extraction, and t_d, is the tax on consumption, ε_d is the foreign elasticity of demand, and C_e^* is the amount of (demand for) foreign consumption. In addition, the two taxes sum to the marginal harm from emissions, thereby giving us two equations for two unknowns.

of the demand-side effect is determined by the foreign demand elasticity and the size of that market.

The optimal policy trades off these two effects: the harm of an increase in foreign extraction due to an increase in the price of energy and the harm of an increase in foreign demand due to a decrease in the price of energy. The combination of the two smaller distortions, one on the supply side and one on the demand side, will typically be less than one larger distortion in either supply or demand alone, which means that combining taxes on supply and demand produces superior outcomes compared to taxing only one side of the market.[79] Because these two effects may not be equal—the supply and demand elasticities and the size of the markets may be different—the optimal policy may not leave energy prices fixed at their pre-tax price level. The taxing region may be more concerned about conventional leakage than extraction leakage, or vice versa.

2. Choosing the Demand-Side Tax

We have so far elided the difference between various taxes on demand, namely taxes on production and taxes on consumption. As discussed, the demand side may be framed as two distinct steps: the use of fossil fuels in production and the consumption of goods produced using fossil fuels. The question is where to place the demand-side tax, on emissions from production or emissions associated with consumption. Border adjustments on goods shift the tax from production to consumption; thus the question is equivalent to whether, or to what extent, to have border adjustments on goods. We discuss this choice here. We start by discussing the effectiveness—how well different choices reduce emissions—and then turn to implementation and WTO compatibility.

Note that while the considerations are similar to those discussed in the literature on border adjustments, we are considering here a demand-side tax that is part of a hybrid system that also taxes the supply side or extraction. The demand-side tax is smaller in a

[79] One intuition for this is that the costs of a tax go up with the square of the tax rate. One $10 tax produces much greater costs than two $5 taxes. *See* GRUBER, *supra* note 71, at 617–18. If either supply or demand were perfectly vertical, then the taxing region would choose to tax only one side of the market, but in all other cases, it should tax both sides.

hybrid system than in a pure demand-side system. As a result, the costs and benefits of different choices will not be the same as in the general literature. In fact, we will argue that because of the extraction tax (a simpler demand-side tax), the extraction production hybrid (EPT) should be preferred.

Effectiveness. There are three salient possibilities for the demand-side tax: the two previously mentioned—taxing production or taxing consumption—and a combination of the two.[80]

The key problem with taxing emissions from domestic production is that doing so creates an incentive to shift production abroad, generating leakage. The incentive to shift production abroad arises both for goods potentially produced abroad but consumed at home—the import margin—and for goods currently produced at home but consumed abroad—the export margin. A tax on production causes shifts along both margins, increasing imports and reducing exports.

As discussed in Part I.C.2, shifting the tax downstream to domestic consumption—for instance, by adding border adjustments—eliminates these incentives because the tax is the same regardless of the location of production. As a result, a consumption tax is, all else equal, a more effective tax than a production tax.[81]

However, in the hybrid tax environment we are considering here—one with the addition of a tax on extraction—the advantage of a consumption tax over a production tax is reduced, perhaps

[80] In fact, there are a number of other possibilities, including only taxing goods that are both produced and consumed at home, taxing only imports or only exports, and taxing imports and exports but not goods both produced and consumed at home. Our modeling shows that none of these possibilities turns out to be desirable.

[81] If taxing region is constrained to imposing the demand-side tax on production (say for political or legal reasons), it can account for leakage by lowering the tax rate. In particular, if leakage is 100%, the optimal production tax would be zero because any positive tax would result in completely offsetting shifts in production, resulting in no emissions reductions but distortions in the location of production. The hybrid tax would fall purely on extraction. If leakage were zero, the optimal production tax would be the same as the optimal consumption tax (e.g., the marginal harm from emissions) because leakage would not be a consideration. For leakage rates between 0% and 100%, the optimal production tax rate scales with the leakage rate. In effect, because of leakage, a production tax cannot be imposed at as high a rate as a consumption tax.

significantly, as our simulations in Part III.C demonstrate. A key reason is that when the taxing region imposes a hybrid tax, the tax is split between demand and supply, resulting in a lower rate on the demand side. A lower tax on the demand side generates less leakage. In addition, if the taxing region chooses to tax production rather than consumption, the taxing region can shift more of the tax to extraction to further limit leakage. Because there is less leakage to begin with, the benefits of border adjustments on goods to shift the production portion of the tax to consumption are lower in hybrid systems.

While a consumption tax is more effective than a production tax, our model finds that the combination of both is more effective than either. This should not be surprising because the combination is less restrictive than a tax that must fall only on one or the other. That is, of the three possibilities, taxing both production and consumption is the most effective.

A tax on both production and consumption can be thought of as falling on (1) all goods consumed at home, regardless of whether they are produced at home or abroad, and (2) goods produced at home and exported. The potential third category—goods produced at home that are consumed at home—does not need a separate tax because those goods are already taxed under the consumption portion of the tax. That is, if the consumption portion of the tax covers all goods consumed at home, then the production portion of the tax need only cover exports. Because the consumption portion of the tax picks up imports, there is no incentive for leakage along that margin. As a result, with a tax on both production and consumption, we only need to worry about leakage on the export side.

One way to think about the benefit of taxing both production and consumption is that it has a larger base than either production or consumption alone. It taxes all domestic consumption plus exports. A pure consumption tax would remove the tax on exports—via a border adjustment—allowing exports to be produced with greater emissions than if the tax were not removed. The broader base of a tax on both production and consumption helps ensure that exports face a carbon tax and thus, that exporters take climate change externalities into account.

To account for the possibility of leakage, the tax on exports should be lower than the tax on domestic consumption. The proportion of the export tax to the tax on domestic consumption should scale inversely with the degree of leakage. For example, if leakage were 100 percent, it would not make sense to try to tax exports because doing so would result in a shift of that production abroad. The tax on exports in this case should be zero. If leakage were zero, the tax on exports would be the same as the tax on domestic consumption.

Implementation. While the production tax hybrid, the EPT, is the least effective tax on the demand side, it has a substantial advantage in its cost of implementation. The reason is that hybrids involving consumption taxes need to impose border adjustments on goods. This means that the extraction-consumption hybrid—and similarly, the extraction-production-consumption hybrid—faces all of the implementation problems with border adjustments on goods that were discussed in Part I.C.4., while the EPT can be implemented in a simple and accurate manner.

There are two observations that allow the EPT to be implemented simply and accurately. First, as we observed in our discussion of current production tax proposals in Congress, an extraction tax with border adjustments on energy but not goods is equivalent to a production tax. The border adjustments on energy shift the tax downstream to production. To illustrate, suppose that the taxing region imposes a forty dollar tax on extraction, imposes a forty dollar tax on imports of energy, and rebates the forty dollar tax previously paid if energy is exported. Any energy used domestically bears the tax: if it was extracted domestically the tax is imposed on extraction and if it was extracted abroad and imported, the tax is imposed at the border. Any energy used abroad does not bear a tax: if it was extracted domestically, the tax is rebated when the energy is exported and if it was extracted abroad, no tax is imposed. Therefore, border adjustments on energy, but not goods, shift an extraction tax to domestic production.

Second, if the border adjustments on energy are imposed at a lower rate than the underlying extraction tax, only that portion of the extraction tax is shifted to production. For example, suppose that the desired set of taxes is a sixty dollar tax on extraction and a forty dollar tax on production. To implement this tax, the taxing region would impose a nominal extraction tax of \$100 per ton of CO_2 and a border adjustment on imports and exports of energy—but not goods—at forty dollars per ton. The border adjustment shifts forty dollars of the tax downstream to production, leaving an effective sixty dollar tax on extraction. Therefore, this combination is equivalent to imposing a sixty dollar per ton extraction tax and a forty dollar per ton tax on production.

This combination—an extraction tax and border adjustments on energy—can be implemented easily and accurately. As noted, the United States can impose a tax on all extraction of fossil fuels by taxing only about 2,500 large, sophisticated entities.[82] Border adjustments on energy are also easy to implement. To implement them, we only need to know the carbon content of imported or exported fuels, which are already tracked in great detail.[83] And compared to imports and exports of goods, the volumes are smaller.[84] Therefore, the EPT, implemented this way, is simple to impose and hard to avoid.

The hybrids that involve a consumption tax, by contrast, require border adjustments on goods. For example, to implement the extraction-consumption hybrid, the taxing coalition would start with an extraction tax and then apply the border adjustments—at a lower rate than the nominal extraction tax—to energy *and goods*. Applying border adjustment to goods shifts the demand-side component of the tax all the way downstream to consumption, generating a hybrid of an extraction tax and a consumption tax.

Applying the border adjustments to goods, however, invokes all of the implementation and legal problems discussed above. Those problems did not depend on starting with a nominal production base and adding border adjustments. They arise if we start with a nominal extraction base as well, in exactly the same fashion. As a result, unless the gains from adding border adjustments on goods are substantial—which they are not in our simulations using our

82 *See* Metcalf & Weisbach, *supra* note 13, at 501, 537–40.

83 This is done in the United States by the Energy Information Agency. It is done globally by the International Energy Agency.

84 The Energy Information Agency already carefully tracks energy imports and exports. *See generally U.S. Total Energy Exports Exceed Imports in 2019 for the First Time in 67 Years*, U.S. ENERGY INFORMATION ADMINISTRATION (Apr. 20, 2020), https://www.eia.gov/todayinenergy/detail.php?id=43395#.

preferred calibration—it is preferable to simply impose them on energy, or in other words, to use the EPT.[85]

The same is true for the hybrid of all three taxes: extraction, consumption, and production taxes. This hybrid would be implemented by imposing the same nominal tax on extraction, partial border adjustments on energy, and partial border adjustments on imports of goods. The rebate on exports, however, would be at an even lower rate—possibly zero—to keep some fraction of the tax on exports. As noted, the fraction depends on the leakage rate. If leakage were zero, the tax on exports should be at the same rate as on domestically consumed goods, which means that the rebate should be zero. If leakage were 100 percent, the tax on exports should be zero, which means that the entire demand-side tax should be rebated on export. For leakage rates between zero and 100 percent, the border adjustment on exports would scale accordingly.

This system has the same administrative costs as the extraction-consumption hybrid. The taxing region would still need to estimate the emissions associated with imports of goods. As a result, the administrative considerations for this system, as compared to the EPT, are the same. As between the hybrid of all three taxes compared to the extraction-consumption hybrid, there is little reason to prefer the more limited extraction-consumption hybrid. The only implementation difference is that the rebate on exports of goods is lower for the hybrid of all three. While, as seen below in our simulations, it generates only modest gains, imposing the hybrid of all three would add no additional implementation costs relative to the extraction-consumption hybrid.

The WTO. As discussed above, while it is likely that border adjustments on goods would be held to be consistent with WTO law, uncertainties remain. Shifting to border adjustments on energy but not goods—to the EPT—reduces those uncertainties. The reason is that border adjustments on energy would not be on the production process or method. They would be on the actual carbon molecules that cross the border. To the extent that the legal determination

[85] If the taxing coalition is such that there remains a benefit to the extraction/consumption hybrid, a possible middle ground might impose border adjustments on energy and on a subset of goods that are particularly energy intensive and trade exposed. This approach is the approach taken in most proposed border adjustments in bills introduced in Congress.

depends on problems with taxing production processes or methods, the EPT is more likely to be allowable than the extraction-consumption hybrid or the combination of all three taxes.

A second consideration for the legality of the various taxes is that the EPT would be accurate while the extraction-consumption hybrid and the hybrid of all three would not. An inaccurate tax generates easy opportunities for complaints: litigants would be able to show to the WTO that they are over-taxed relative to their domestic competitors, generating what looks like a trade barrier. The EPT eliminates this concern.

A final note is that the effectiveness of the EPT makes it more difficult for countries to make the "necessity" showing required for the Article XX(b) exception in the GATT. It is not necessary to impose border adjustments on goods for environmental reasons if the EPT is available as an alternative. An implication is that pure consumption taxes, the extraction-consumption hybrid, and the hybrid of all three taxes are more likely to violate the WTO than otherwise. That is, the effectiveness of the EPT makes the legal case for the EPT stronger.

3. Summary

Hybrid taxes—combinations of taxes on the supply of energy and the demand for energy—work better than pure taxes on either supply or demand. The reason is that hybrids can be designed to control the price of energy seen in foreign markets and therefore, the responses to the tax in those markets. Of the three hybrids, the EPT seems the most promising. Although it may be somewhat less effective than the other hybrids, it is much easier to implement and is less likely to raise legal problems.

Ultimately, the trade-offs between the three hybrid taxes depend on how much better the extraction-consumption hybrid or the hybrid of all three perform relative to their higher administrative cost. We explore this issue below using a calibrated simulation of our model.

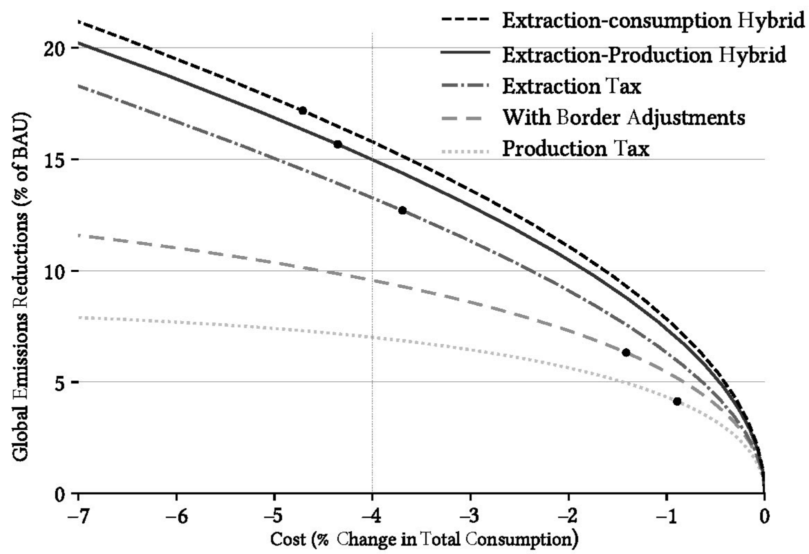
C. Simulations

To get a sense of the quantitative benefits of the various hybrid taxes and to compare them to one another, we present a number of simulations of our formal model of the problem. Details of our calibration are in the Appendix. Briefly, we assume for these simulations that a tax is imposed in the Organization for Economic Cooperation and Development (OECD) countries and that the rest of the world does not impose any climate policy. We consider the effects of changing the taxing coalition in Part III. We assume that the economy has three stages: extraction of energy, which is traded; the use of energy in production to manufacture goods, also traded; and consumption of those goods. We calibrate the model to trade shares in extraction, production, and consumption and estimate the elasticities based on the relevant data.

We start with a comparison of the EPT to conventional taxes—a tax on domestic production, the same tax with full border adjustments, and a tax on domestic extraction—and to a hybrid of an extraction tax and a consumption tax. Figure 5 illustrates the emissions reductions achievable under each policy (y-axis) for a given cost (x-axis), measured in terms of a reduction in current consumption. It is similar to a standard Production Possibilities Frontier graph that shows the tradeoffs available between two goods. Rather than goods such as wine and beer, Figure 5 shows the tradeoff between emissions reductions and consumption—measured in terms of costs as a percent of goods consumption. The dots indicate the emissions reductions that the OECD would optimally choose with each policy if we assume a particular level of global marginal harm from climate change.

As can be seen, the EPT vastly outperforms both a conventional tax on emissions from production and a tax on emissions associated with consumption—a production tax along with border adjustments on goods. At any given cost, the EPT reduces emissions more than conventional approaches, and increasingly so as the OECD spends more to reduce emissions. For example, at a cost of four percent of consumption—shown with a vertical line—a traditional production tax reduces global emissions by about seven percent. Adding border adjustments improves that to 9.5 percent. The EPT reduces emissions by 15 percent at the same cost. As expected, the extraction-consumption hybrid outperforms the EPT, but in this simulation, the difference is small. This confirms the argument above that the simplification benefits of the EPT make it the better choice.

Figure 5: Comparison of the EPT to Conventional Taxes



In Part III.B we argued that the reason the EPT performs better than conventional approaches is that by combining a tax on the supply of energy—an extraction tax—with a tax on the demand for energy—a production tax—the EPT allowed the taxing region to control the effects of its policy on the price of energy transmitted to other parts of the world. Figure 6 illustrates this within our simulation.

Figure 6 shows the change in price of energy in non-taxing regions—non-OECD countries—for the same five policies considered in Figure 5. The x-axis is the marginal harm from climate change, set in units relative to the price of the carbon content of energy. A marginal harm of one indicates that the marginal harm, and therefore, the optimal tax rate, is about equal to the price of the carbon content in each unit of energy. For example, if a gallon of gas costs four dollars, and half of that (two dollars) is for the actual carbon molecules in that gallon, and the other half is due to the costs of renting the land for the gas station, paying employees, profits to the oil company, and so forth, a value of one on the x-axis would mean that the harm from burning a gallon of gas is two dollars. The y-axis is the change in the price of energy relative to its no-tax value, which is normalized at one.

As discussed above, the two demand-side taxes—the production tax and that same tax with border adjustments on goods—decrease the price of energy in the rest of the world, an effect that gives rise to leakage.[86] A pure extraction tax increases the price of energy in the rest of the world. This increase in the price of energy will induce more extraction abroad but will not create conventional leakage.

The EPT moderates these effects. Under the calibration in this scenario, the OECD chooses a mix of extraction and production taxes that still lead to an increase in the price of energy, but a smaller increase than a pure extraction tax. The reason the OECD would want to choose this mix of taxes and this effect is that the elasticity of energy supply is relatively low in this calibration. As a result, a large increase in the price of energy abroad does not induce a large increase in extraction. The OECD, therefore, can set the mix of taxes without having to worry too much about an increase in extraction abroad. When we consider robustness checks in Part III, we will see that with different calibrations, the effects of the EPT on the price of energy look different.

[86] *See infra* part II.B.1.