Carbon Footprint Taxes[*]

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Abstract
We analyze whether a carbon consumption tax is logistically feasible. We consider a Carbon Footprint Tax (CFT), which would be modeled after a credit-method Value Added Tax. The basis for the tax would be a product's carbon footprint, which includes all of the emissions released during production of the good and its inputs as well as any greenhouse gases latent in the product. Our analysis suggests that a pure carbon footprint tax (CFT), requiring the calculation of the carbon footprint of every individual product, may be prohibitively costly. However a hybrid CFT seems economically feasible. The hybrid CFT would give firms the option to either calculate the carbon footprint of their outputs---and have their products taxed based on those footprints---or use product-class specific *default* carbon footprints as the tax basis, thereby saving on calculation costs. Because the CFT would be levied on all goods consumed domestically, the CFT would keep domestic firms on an even footing with those producing in countries without active climate policy, protecting competiveness and reducing leakage.

1. Introduction

Absent a binding international agreement capping global carbon emissions, countries wanting to slow climate change must proceed without enforceable commitments from much of the global community. Unilateral action carries costs that would not exist under global cooperation. If domestic policy raises production costs, local firms will be less competitive than rivals from unregulated economies. As market share shifts to foreign producers, overseas output---and emissions---will rise, offsetting some of the emission reductions achieved locally. Concerns over lost *competitiveness* and emission *leakage* have led many architects to include protections for energy intensive trade exposed (EITE) sectors in draft climate policies. For example, the third phase of the European Union's (EU) Emissions Trading System (ETS) provides a higher share of free allowances to EITE sectors (European Commission 2012). Similarly, the expired Waxman-Markey and Lieberman-Boxer bills included output-based allowance allocations for EITEs, as

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does Australia's EITE Assistance Program. Fine-tuning how allowances are allocated, though, doesn't force foreign producers to internalize the costs of their own carbon emissions, thus many draft policies also include provisions for border measures, such as tariffs on goods from unregulated economies and/or rebates to domestic exporters.

Most observers argue such border measures will prompt complaints to the World Trade Organization (WTO) and/or trade wars (Hufbauer, Charnovitz and Kim 2009, Low, Marceau and Reinaud 2011, Pauwelyn 2013). One reason for pessimism is that it will be hard to determine---and justify to a trade partner---what is the appropriate tariff. How should a country calculate the carbon embodied in imported goods, especially when production methods vary across firms? And what is the right import charge if domestic regulation comes in the form of permit trading with local firms receiving some of their permits free of charge? Moreover, the WTO may reject entirely the notion that the two most common price based instruments---carbon emission taxes and tradable carbon permits---are eligible for border adjustment in the first place; although *border tax adjustments* (BTAs) are allowed for taxes levied on products, they are not allowed for taxes or regulations levied on firms directly.

This paper examines whether a consumption-based carbon policy might solve the challenge of how to set domestic carbon policy that doesn't sacrifice the competitiveness of domestic firms in a WTO-consistent manner. We focus on a carbon footprint tax (CFT), which can be viewed as a tax on consuming *embodied* carbon[1]. The core idea is not new. Hufbauer, Charnovitz and Kim (2009) put forward embodied carbon taxes as an example of "a way to apply climate policies to imports that would probably comply with[General Agreement on Tariffs and Trade (GATT)] rules" (p.68). Courchene and Allan (2008) and Stiglitz (2009) go farther and propose that governments adopt carbon added taxes that are similar in design to a Value Added Tax (VAT). For Courchene and Allan the appeal lies in protecting domestic firms from "unfair competition in domestic and external markets from firms located in non-participating countries" (p.60). Stiglitz defends the idea on the grounds that the system would "provide strong incentives for each firm to make sure that its suppliers complied with the carbon tax regime" (p.5).

A further argument for taxing goods instead of direct emissions is that doing so focuses attention on patterns of embodied carbon consumption---patterns that are obscured by production data. For example, over the 1990-2006 period, the United Kingdom's territorial emissions fell by three to four percent, yet estimates suggest the UK's embodied carbon consumption rose by between sixteen and thirty percent (Peters et al. (2011 Supplementary Materials), Brinkley and Less 2010). Likewise, even though the production emissions of the 15 pre-2004 EU Member States fell during the 1990-2006 period, embodied carbon consumption rose by 47% (Brinkley and Less 2010). Conducting a differences-in-differences ex post analysis of Kyoto ratification, Aichele

[1] The CFT would differ substantially from carbon taxes currently in use world-wide. Most jurisdictions taxing carbon do so by taxing fossil fuel or electricity use, such as British Columbia, Canada, Montgomery County, Maryland, Germany, and Norway (Brewer, Greco, Pappas, & Schwartz 2011 p. 12; Flannery, Beale, and Hueston 2012 p. 38). In these systems, the emission tax is levied on purchases of fossil fuels or electricity according to the amount of carbon dioxide emitted by using said energy source. These taxes effectively tax *producers* according to their emissions from fossil fuel and electricity sources; the CFT would tax each *product* according to the full emissions embodied in its production. Detail on the design of the CFT is provided in the following sections.

and Felbermayr (2012) similarly find that ratifying nations had larger reductions in their territorial emissions than in their consumption of embodied carbon. They conclude that carbon emissions grew by seven percentage points less in Kyoto-ratifying nations than in their non-Kyoto ratifying counterparts, but that the growth rate of the embodied carbon consumption in Kyoto and non-Kyoto countries was not statistically different in the post-ratification period.

McLure (2010) rejects carbon added taxes on the simple grounds that the transaction costs would be too high; he argues that tracking the carbon intensity of every good consumed in an economy would be "a truly gargantuan undertaking that would not be cost-effective" (p.255). Parties on neither side of the debate, however, give much detail as to how a footprint tax would operate[2], and so it is hard to know whether a carbon footprint tax is indeed a viable policy option. This paper aims to fill in some of the missing details. We offer specifics as to how a CFT would work. We consider first a pure CFT in which a carbon footprint (CF) is calculated for every good. Because a pure CFT may be prohibitively costly, we also consider a hybrid CFT scheme in which, for each product class[3], the government publishes a *default* footprint that a firm can use as the basis for taxation in lieu of calculating the idiosyncratic footprint of each good it produces. We also lay out the merits and disadvantages of *exempting* some sectors and producers from the CFT system.

2. Policy Design of a Pure CFT

In this section we outline how a Carbon Footprint Tax (CFT) would be implemented in its purest form, with each good being taxed according to its full carbon footprint; in Section 3 we will discuss a hybrid version of the tax, designed so as to reduce implementation costs. The footprint tax would be *destination-based*, meaning the tax would target consumers, rather than producers. The tax would be a product tax, levied on all products at the point of purchase by the final end-user, regardless of where the goods were produced. It would be levied using the c*redit-method*, meaning each buyer would pay taxes on the full carbon footprint of items purchased, and each producer would receive rebates on taxes paid for intermediate goods. The tax basis would be the sum of a product's *embodied* carbon as well as any latent emissions associated with the product. A good's *embodied* emissions would be all the greenhouse gases released during that good's production, including the production of its inputs. In the remainder of this paper we will regularly refer to greenhouse gasses as CO2 equivalents (CO2e).

Using Life Cycle Analysis (LCA) terminology, this would include all of a product's Scope 1, 2 and 3 emissions: emissions released by the manufacturer directly (Scope 1), those released when generating the electricity, heat or steam used by the manufacturer directly (Scope 2), and all emissions from upstream or parallel activities by third-parties, e.g. emissions from resource

[2] McLure (2012) provides an exception, contrasting how a carbon-added tax might work if applied using a credit-, subtraction- or addition-method; he does not, however, consider emissions from sources other than fossil-fuel combustion, third-party certification, or the use of baselines.

[3] By "product class" we mean any convenient way of grouping similar products. These product classes could be defined by the North American Industry Classification System (NAICS) or another similar industry classification system. For example, the US Census has developed a system that extends the NAICS mining and manufacturing codes to the ten digit level. One sample product class from this system is "Candles, including tapers" (NAICS-based code 3399994100). We discuss this further in section 4.1.

extraction, upstream intermediate good production, business travel and transport using non-owned vehicles, and non-owned waste disposal (Scope 3).[4] *Latent* emissions would be those released when the good is consumed under typical conditions; for example, if the product in question is a fossil fuel, its latent emissions would be the greenhouse gasses typically released during fuel combustion.[5]

To illustrate how the CFT would work, we begin with a stylized example of two industries producing goods U and D (for "upstream" and "downstream"), respectively. U-type firms produce good U using a_{UY} units of a clean numeraire input Y and release e_U CO2e emissions per unit of output. D-type firms produce good D using *1* unit of *U*, a_{DY} units of *Y* and generate e_D units of additional emissions. In an Appendix we work through a more detailed example to illustrate how a CFT would be implemented.

Assume input and output markets are competitive. If we also assume--for now--that neither U nor D-type products carry latent emissions then the carbon footprint of good U is e_U and the footprint of D is e_U+e_D.

Suppose the tax rate on CO2e emissions is *t. U* producers would post prices of $p_U = a_{UY}$ and buyers would face tax inclusive price $a_{UY} + te_U$. If the item was to be used as an input into downstream production, the purchaser would submit its receipt to the revenue agency and be reimbursed the CFT-paid; its net cost for a unit of U would thus be $p_U = a_{UY}$. The D-producer would in turn post a retail price of

$$p_D = p_U + a_{DY} = a_{UY} + a_{DY}$$

and consumers would face a tax-inclusive price for good D of

$$p_D + t[e_U + e_D] = a_{UY} + a_{DY} + t[e_U + e_D].$$

Now we introduce latent emissions into the analysis. Suppose, for example, that U is a refined fossil fuel; when U is ultimately combusted there will be additional emissions that we label L_U. Given our earlier definition, the tax basis for U should be e_U+L_U, such that the tax-inclusive price of U will be

$$p_U + t[e_U + L_U]$$

with e_U+L_U equaling the good's *carbon footprint*. Any firm purchasing *U* would be eligible for a CFT-rebate of

$$t[e_U + L_U].$$

[4] The footprint could even be negative if the production process led to net carbon sequestration instead of release.

[5] In this paper we will abstract from emissions latent in the consumer-to-grave portion of a product's life cycle, as we will assume that such emissions are assigned to waste disposal services. Similarly, we will not assign to a product---e.g. a pair of jeans---the emissions arising from use of complementary products or services---e.g. emissions associated with laundering those jeans.

Suppose the D-type firm releases a portion of *U*'s latent emissions when utilizing the input; these actual releases would be subsumed in the parameter $e_{D,}$ while any latent emissions remaining in the downstream good would be L_D. The tax-inclusive price paid by final consumers of D would be

$$a_{UY} + a_{DY} + t[e_U + e_D + L_D], \qquad (1)$$

such that consumers would be charged for greenhouse gasses emitted during production of the good as well as final consumption.[6]

2.1 Applying a CFT to Traded Goods

Now suppose U and D are traded internationally. We denote values associated with ROW-produced goods with asterisks, and use uppercase letters to denote prices charged in ROW. For simplicity assume that producers in the Rest of the World (ROW) are homogenous and face the same unit-input requirements as do Home producers; we also assume there are neither transport costs nor tariffs and that ROW is policy-inactive, i.e. ROW does not impose any carbon policy of its own. ROW producers will charge ROW consumers

$$P_U^* = a_{UY}, \quad P_D^* = a_{UY} + a_{DY} \qquad (2)$$

A destination-based CFT would tax goods imported into Home from ROW at the same rate as domestically produced goods. Thus the retail prices in Home of ROW-produced units of good U and D would be

$$p_U^* = a_{UY}, \quad p_D^* = a_{UY} + a_{DY}$$

while the tax inclusive price of good U would be

$$a_{UY} + t[e_U + L_U]$$

and the tax inclusive price of good D would be

$$a_{UY} + a_{DY} + t[e_U + e_D + L_D]. \qquad (3)$$

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[6] We do not adopt a position as to whether the CFT levied on a product should be included in the tax base for other taxes such as value added taxes. Embedded and latent carbon can be viewed as inputs, and so an argument can be made that value added from carbon inputs should be subject to sales or value added taxes just the same as would value added arising from employing labour and other inputs. However, including CFT in the basis for other taxes may complicate reimbursements for CFT-paid on intermediate inputs since sales taxes levied on CFT would also have to be reimbursed.

Regarding exports, the principles of a credit-method[7] destination-based tax system suggest Home's exports would be *zero-rated*. Specifically, a Home D-producer would be eligible for reimbursement of the taxes she paid when purchasing her input of good U, but would not have to levy CFT on any sales of her output in the ROW market since the goods are not being consumed in the levying country.[8] As a result, the tax-inclusive prices in ROW of Home-produced units of U and D would be simply the retail prices

$$P_U = a_{UY}, \quad P_D = a_{UY} + a_{DY}. \tag{4}$$

2.2 Competitiveness

One of the key advantages of a destination based carbon tax is that domestically produced goods are not put at a disadvantage vis-à-vis competing goods produced in policy-inactive countries. Indeed, comparing equations (1) and (3) we see that the tax inclusive prices in Home for U and D goods are identical regardless of where they are produced in our example. Similarly, comparing (2) and (4) shows that Home's D producers remain competitive abroad.[9]

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[7] We suggest the CFT be implemented using the credit-method, but there are other options. VATs, for example, can also be implemented using either the *subtraction* or *addition* method. Under the *subtraction* method, tax is levied on the difference between a firm's sales (inclusive of VAT charged on their value added) and their purchases (inclusive of VAT paid on all inputs); under the *addition* method, tax is charged according to the firm's payments to production factors. For a detailed description of VAT computation methods see Zee 1995 or Bickley 2003.

A carbon tax implemented using the *subtraction* method would involve calculating the entire carbon footprint (+latent emissions) of a product (i.e. the carbon sold by the merchant), subtracting any upstream carbon (+latent emissions) contained in inputs (i.e. the carbon purchased by the merchant), and then levying the tax on this difference. As McLure (2012) points out, a downside of a subtraction-method approach is that downstream firms would have to calculate both the CF of their own product as well as that of their upstream inputs, as the CFs of goods far up the production chain would be unreported.

An *addition* method CFT could take the following form: a tax on emissions latent in any inputs purchased. A problem with this approach arises for inputs that release variable amounts of emissions when used (as with a fuel that may be either combusted or refined prior to resale) would need to be taxed at different rates depending on their use, which would raise administrative complexity.

McLure (2012) notes that both of these approaches---subtraction and addition method carbon added taxes---would also suffer from under-taxation if some upstream industries are exempt, which would incent lobbying for exemptions and provide no incentives for voluntary opt-in as would arise under a credit-method CFT.

[8] More accurately, exports from Home would be taxed at a rate of zero.

[9] Compare this to what would occur if Home instead pursued an origin-based emission tax $\tilde{t}$: the retail and tax inclusive price in Home and ROW of a Home-produced unit of good U would all be the same: $\tilde{p}_U = \tilde{P}_U = a_{UY} + \tilde{t}e_U$. In contrast, the retail and tax inclusive price in Home of a unit of U produced in ROW would be only $\tilde{p}_U{*} = \tilde{P}_U{*} = a_{UY}$, rendering Home's producers uncompetitive both at Home and abroad.

It should be noted, however, that even though destination-based carbon taxation can mitigate the effects of unilateral carbon policy on the competitiveness of carbon intensive industries, it should not be construed as a tool for increasing a *country's* competitiveness overall.

Similar concerns arose with respect to VATs in the 1950s and 1960s as members of the European Community tried to harmonize their tax systems and adopt credit-method destination-based VATs. In this context, a series of authors, including Grossman (1980), Whalley (1979), and Lockwood et al. (1994), confirmed *neutrality* between destination-based VATs, origin-based VATs, and zero-tax regimes: if exchange rates are flexible and taxes uniformly applied, then all three systems deliver identical relative prices to consumers and producers and trade volumes are unaffected. Moreover, if a country adopts a destination-based system but neglects to zero-rate exports, Feldstein and Krugman (1990) show that this is equivalent to a tax on imports. That is, *omitting* a BTA on exports is protectionist.

The neutrality result suggests that a country cannot give itself a competitive edge by adopting a destination-based VAT, because the exchange rate will adjust so as to prevent changes in nominal prices from having any real effects. Given this neutrality, Lockwood and Whalley (2008) contend that players in the climate policy debate are misguided when they talk about needing Border Carbon Adjustments (BCAs) in order to maintain a *country's* competitiveness: "If the BTA accompanying carbon emissions reductions are broadly based, ... the price-level effect will have no real effects" (p.812). They argue what matters are the effects of BCAs on relative prices.

In the carbon context, however, taxes are unlikely to be uniform: even though all embedded carbon will be taxed at the same rate per ton, because CFs vary across goods within and across product classes, CFT per dollar of value-added will vary widely. Thus we cannot expect neutrality to hold. However the essence of the Lockwood and Whalley (2008) critique remains valid: an economy-wide CFT would likely affect the exchange rate and so should not be viewed as a mechanism for promoting the competitiveness of the country as a whole. This is consistent with simulations conducted by Böhringer, Carbone and Rutherford (2013), who compare welfare when a 20% emission reduction in OECD countries is undertaken with and without full BTAs (i.e. tariffs on imports of embodied carbon plus rebates to exporters). In the simulations underlying their analysis, BTAs would appreciate the currencies of Canada, United States, France, and Germany by over 5% with respect to China and Russia.[10]

The CFT would encourage consumers to switch to low-carbon goods at the expense of higher-carbon substitutes both within and across product classes. However, not all of the competitiveness effects of a CFT would be environmentally favourable. Under an origin-based system, low-carbon exporters would have a cost-advantage relative to high-carbon competitors from the same home economy. Zero rating would erode this cost-advantage. Low carbon exporters might also be hurt by any exchange rate appreciation resulting from the CFT, as would domestic firms competing against low-carbon imports. In contrast, the exchange rate appreciation would help firms that import clean intermediate goods.

2.3 Leakage

[10] Personal communication with authors.

If unilateral regulation causes domestic supply for carbon-intensive goods to contract, this will raise the world price for those goods. Although domestic emissions will fall, the increase in the world price of the carbon-intensive goods will rise, increasing both quantity supplied by---and emissions from---unregulated countries.

The magnitude of this emission shifting is captured by the *leakage* rate, which reports the increase in releases in non-regulated economies divided by the reduction in releases in the regulated economy. Estimates of the leakage rate will vary depending upon a number of factors, including assumptions regarding fuel supply elasticities, degree of home bias in demand, range of sectors covered, effective carbon price, and how permits are allocated (if used). Assuming constant returns to scale production technologies, for policies such as taxes on industrial emissions or cap and trade programs with full auctioning, economy-wide leakage rates obtained from partial and general computable equilibrium analysis are typically in the 5% to 25% range; see, e.g. Ho Morgenstern and Shih (2008), Fischer and Fox (2009), Kuik and Hofkes (2010), Monjon and Quirion (2011), Winchester, Paltsev and Reilly (2011), and Böhringer, Carbone and Rutherford (2013). For energy intensive sectors, leakage rates are substantially higher.[11] Leakage rates may also be considerably higher if alternate production technologies and market structures are modeled; Babiker (2005) reports leakage rates of over 100% when energy intensive sectors are assumed to be imperfectly competitive, exhibit increasing returns to scale, and produce homogenous goods.

Another variable affecting the leakage rate is whether adjustments are used, such as border carbon adjustments, output-based permit allocations, and exemptions. We will focus on BCAs.[12]

[11] Ho, Morgenstern and Shih (2008) report a leakage rate of 52% for chemicals while Demailly and Quirion (2006) estimate a leakage rate for cement of 50%. For iron and steel, leakage estimates typically range from 35% (Kuik and Hofkes 2010) to 75% (Gielen and Moriguchi 2002).

[12] Under output-based allocation (OBA), firms in regulated sectors are granted some permits gratis based on their recent output. A number of computable partial and general equilibrium analyses have compared the relative effectiveness of border adjustments and OBA. Examining emission reductions scheduled for the third period of the EU ETS, Monjon and Quirion (2011) find that a BTA would reduce leakage by more than OBA because a BTA reduces European consumption of products from regulated sectors, thereby reducing demand for imports, and thus production, from the rest of the world. In contrast, an OBA effectively subsidizes domestic output, and so an OBA may be better at protecting production than is a BTA. This output protection can have perverse effects however: considering a carbon tax scenario, Fischer and Fox (2009) find that production rebates---the price equivalent to OBA---do little to the leakage rate because reductions in foreign emissions are matched by smaller reductions in domestic emissions; that is, production rebates can reduce the extent to which emissions actually fall in the regulated economy. While output protection may be politically attractive, Fischer (2001) shows that OBA can lead to an inefficient outcome whereby output contracts too little and emission intensity is driven too low relative to the social optimum. Other problems with OBA are as follows: OBA provides incentives to keep inefficient plants in operation (Grubb and Neuhoff 2006), insulates consumers from paying the marginal social cost of the goods they consume, and provides no incentive for foreign firms to reduce the emission intensity of the goods they sell in the regulated market. Böhringer, Fischer and Rosendahl (2011) point out that the efficiency of OBAs decline as the size of the coalition rises. Comparing full BTAs, import tariffs, and OBAs, they conclude that “[o]utput-based rebates achieve the smallest cost savings among the three anti-leakage instruments compared to a reference climate policy

If levied on all goods based on their actual embodied emission, BCAs convert an origin based tax system to a destination based one. Thus, even though there have not been any simulations conducted which specifically model the effects of a footprint tax on leakage rates, we can infer the impacts of a pure CFT from studies simulating the leakage rate when BCAs are paired with emission taxes.

In theory a BCA could raise or lower the leakage rate. Jakob, Marschinski and Hubler (2013) use a static 2 sector, 2 country model to address how BCAs impact overseas emissions. If, for example, the non-exporting sector in the policy-inactive country is more carbon intensive than the exporting sector, then BCAs lower the leakage rate. However, if the overseas export sector is relatively carbon un-intensive, then BCAs against that country's exports could actually raise the leakage rate.

The results from computable general and partial equilibrium analyses are less ambiguous. Böhringer, Carbone and Rutherford (2013) consider leakage rates when OECD countries levy BCAs on imported goods based on their embodied carbon content, while exported goods are rebated any emission taxes paid. They find that average leakage rate drops from over 15% under origin-based carbon taxes to 5% under destination-based policy. Winchester et al. similarly find that border adjustments reduce economy-wide leakage, lowering the rate from 10.1% to between 4% and 6%. BCAs have similar effects on leakage rates at the sectoral level. In the steel industry, Kuik and Hofkes (2010) find leakage drops from 35% to 2%, while Mathiesen and Maested (2004) report a reduction from 40% to -31%. Demailly and Quirion (2008) find leakage in cement drops from 25% to between -2% and 4%; for cement, iron and steel, aluminium and electricity collectively, Monjon and Quirion (2011) report that leakage drops from 5% to -3% when BCAs are applied.

The leakage rate can be negative because BCAs ensure that all goods consumed in the regulated economy are taxed. This reduces the regulated economy's demand for pollution intensive goods in general, including imports. Moreover, production techniques tend to be more carbon intensive in developing countries than in the OECD countries that are usually the subject of these studies. Thus, if BCAs are based on actual emission intensities---and not, for example, the average emission intensity in the regulated country---then BCAs shift market share away from imports in the regulated economy. As a consequence, imports will decline and foreign output (and foreign emissions) may fall as a result.

The aforementioned discussion focuses on leakage through changes in market share, which is one of two main channels through which leakage operates; various authors have called this the "competitiveness" or "trade" channel, or alternately "supply-side leakage". A separate channel operates through "demand-side leakage" (also called "energy-market" or "fossil fuel" leakage). The energy-market channel operates as follows: emission taxes reduce demand for inputs that have a lot of stored carbon---i.e. fossil fuels---, lowering fuel prices in global markets, prompting an increase in fuel consumption (and the carbon-intensity of activity) in unregulated markets.

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that places a uniform price on carbon without additional leakage measures. Furthermore, they induce excess costs as the coalition size increases toward full coverage because the distortions of output subsidies prevail, while the anti-leakage effect becomes zero." (p.3)

Kuik and Hofkes (2010) estimate that about half of leakage occurs through energy-markets, and point out that pairing emission taxes with BCAs will have little effect on this type of leakage.

Interestingly, a CFT may serve to reduce energy market leakage if fuel exports are not zero-rated. As Bushnell and Mansur (2011) point out, if a carbon tax is levied on the production of fuels according to their latent-carbon content---rather than levying taxes on actual emissions released when those fuels are consumed---then energy market leakage will be negative. The logic is straightforward: a tax on stored carbon reduces demand for carbon-rich fuels. If the regulating economy does not rebate carbon taxes to exports, then its carbon-content tax will be imbedded in the price of exported fuels, shifting inward the country's export supply curve which in turn raises the global price of carbon-rich fuels, reducing the quantity consumed abroad.[13,14]

2.4 Drawbacks to Destination Based Policy

As noted above, a clear advantage of destination based policy is that it reduces the extent to which unilateral policy impairs the competitiveness of domestic carbon intensive industries, and may mitigate some of the associated carbon leakage. However, even aside from implementation costs---a matter to which we will turn our attention shortly---, destination based policy has some drawbacks.

The first such drawback concerns *reshuffling*. Bushnell, Peterman and Wolfram (2008) point out that, when regulations apply to products rather than production, scenarios may arise in which producers simply change how they distribute their products across markets, shipping products with low levels of embodied carbon to the regulated economy, and high-carbon goods to economies without product regulations. If the pre-regulation supply of low-carbon goods was already large enough to satisfy demand in the regulated economy, then low-carbon mandates will have little to no effect on global production or emissions. Moreover, if transport costs are positive (but smaller than carbon taxes) then unilateral policy may induce goods to be wastefully cross-hauled. Reshuffling is less likely when transport costs are high relative to carbon taxes, and when low- and high-carbon goods are imperfect substitutes in the eyes of consumers because of either home bias or innate distaste for high carbon goods. In contrast, the scope for reshuffling may be considerable if the regulating economy is small and goods are homogenous in the eyes of consumers. Bushnell, Peterman and Wolfram (2008) point to energy markets: "Electricity provides a special case since electrons cannot be tracked to particular generators. As a result, reshuffling in the electricity sector is more of a financial arrangement than a physical activity." (P. 184)

Trade in petroleum may also be subject to reshuffling. Consider the case of the Canadian oilsands. More than half of Canadian oil production comes from bituminous sands located in the western province of Alberta, with extraction-related emissions that are approximately four times

[13] If the regulating economy is an energy importer, the production tax would instead shift out the country's import demand curve, also raising the equilibrium world price for fuels.

[14] If the regulating economy eschews zero-rating exports of any kind, there would still be supply-side leakage as domestic manufacturers would be at a disadvantage in export markets. If instead only non-fuel exports are zero rated, this would reduce supply-side leakage but introduce new inefficiencies because fuel use by exporters would be effectively subsidized.

as high as those for extraction from conventional petroleum deposits (Brandt 2011). At the time of writing, Canada's oilsand producers were negotiating with numerous stakeholders as to where additional pipelines should be built: through British Columbia (with the intention of exporting oilsand bitumen to Asian markets), through the American west (for refining in the United States), or eastward to Central and Eastern Canada (with the intention of displacing imports from OPEC and North Sea countries). If embodied carbon was priced at $30/tCO2, oilsand crude would bear extra taxes of approximately $1.50/barrel as compared to conventionally extracted oil[15]. Although this cost would be relatively small compared to extraction costs[16], it may have a significant bearing on the pipeline decision. It conceivable that a Canadian CFT would induce exports of Canadian oilsand crude to unregulated overseas markets, even if it were more efficient from the perspective of engineering costs and environmental risks for that crude to be consumed in Canada.

Another consequence of destination based policy that should not be overlooked concerns equity. As discussed earlier, a negative leakage rate can arise if production techniques are less carbon intensive in the regulating economy than abroad. In this setting, destination based carbon policy shifts market share away from imports, which reduces foreign export earnings and lowers foreign income. At the same time, carbon-efficient producers in the regulated economy gain market share (at least domestically). In theory, the gain in market share may be sufficient to raise welfare in the levying economy, even relative to the scenario in which there is no regulation at all. Böhringer, Carbone and Rutherford (2013)'s analysis suggests such an outcome is empirically plausible. They find that, compared to a scenario without any carbon taxes at all, an OECD program of emission taxes paired with full BCAs would lower welfare in non-OECD countries by 2.1%, but would *increase* welfare in OECD countries by 0.21%.[17] As noted by a number of authors, the negative welfare effects of unilateral destination based carbon policies could be mitigated if some of the revenues were returned to developing countries via lump-sum transfers or investments in carbon-reduction technologies.

3. A Hybrid CFT

As we will discuss in Section 4, the costs associated with calculating the carbon footprint of every product would be high. One way to economize on these transaction costs would be to pursue a hybrid system in which a *default* footprint dCF_i is established for each product class *i*. A firm producing a good in product class *i* could either calculate the unique footprint of her own product, or use the default for product class *i* as the basis on which her product would be taxed.

Firms---both foreign and domestic---would have the option to use the default CF; if utilized, the default would form the tax basis for that firm's good. A consumer who purchases the good would then be charged the retail price plus the tax rate times the default CF. Of course, if a

[15] Authors' own calculations based on figures reported in Brandt (2011).
[16] Oil sand extraction costs range from $40/barrel for low-cost producers to upwards of $80/barrel for some newer extractors. (Financial Post, 2012)
[17] In contrast, emission taxes without BTAs would lower welfare (without considering climate benefits) in OECD and non-OECD countries by 0.25% and 0.58% relative to the no-tax scenario. It's worth noting that OECD welfare rises with BTAs even though the overall leakage rate is positive.

firm's product has a CF smaller than the relevant default then that firm might choose to have its idiosyncratic footprint calculated and serve as the basis for taxation.

3.1 Under-Taxation

The clear advantage of a hybrid system---relative to a pure CFT---is that firms eschewing individual certification would be saved the costs of calculating their idiosyncratic CFs. This would be particularly important for small firms that have few units over which to amortize the fixed costs of certification.

This hybrid system with defaults would also have two significant disadvantages. Firstly, when choosing from amongst the set of goods utilizing the default, consumers would have no incentive to choose varieties with lower CFs.

Secondly, if the carbon tax that would ultimately be levied on a firm's output would be independent of the product's actual embodied emissions, the firm would have no incentive for *within-product* greening: the firm would have no incentive to reduce in-house emissions or use inputs with small carbon footprints.

3.2 Unraveling

This last failure---the absence of an incentive for downstream firms to buy low-CF inputs---may have consequences for the production decisions of upstream firms as well. Consider the extreme example in which all of an upstream firm's downstream users will utilize the default. Those downstream customers will be unwilling to pay a price premium (in terms of a higher retail price) in exchange for a low CF input, especially since any associated CF-taxes will just be rebated. If downstream firms aren't willing to pay a higher retail price for low CF inputs, then the upstream firm would have no incentive to undertake efforts to reduce its own CF, even if those efforts would lower the tax-inclusive price of its goods.[18]

This extreme example illustrates how allowing downstream firms to utilize defaults and receive rebates for carbon taxes paid may unravel some of the incentives for carbon-reduction upstream.

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[18] The following stylized example illustrates how defaults can unravel the incentives for upstream carbon-reductions. Suppose there are multiple competitive downstream and upstream producers and that neither good is traded. Assume upstream producers have access to two separate production methods: method "Small" (S) or method "Medium" (M), whereby $a_{UY}{}^{S} > a_{UY}{}^{M}$, $e_U{}^{S} < e_U{}^{M}$ and $a_{UY}{}^{S} + te_U{}^{S} < a_{UY}{}^{M} + te_U{}^{M}$. Assume the tax rate t is equal to marginal social damage from carbon emissions. As described, the Small method is socially preferable, since the value of non-carbon inputs summed with damages from emissions is less than with Medium. If a downstream user intends to utilize the default CF, then she has no incentive to purchase an upstream good produced using the Small method. This is because any CFT a downstream pays on her purchase of the upstream input will be rebated, while the CFT paid by her own consumers is independent of her own product's CF. Thus, she can reduce her net costs by purchasing upstream goods produced using the Medium method. If, in addition, there are fixed costs associated with employing a particular upstream production method, then if enough downstream firms utilize the default rather than calculating/certifying their idiosyncratic CFs, each upstream firm will employ the Medium production method and emissions will be higher than they would have been if downstream users were required to calculate their own CFs.

This problem would be most significant in industries with many small downstream producers---as most downstream firms would eschew individual certification---and when there is sufficient heterogeneity in upstream production methods. One defense against the unraveling problem would be to set a default that is very high, say, equal to the carbon footprint arising under the most carbon intensive methods possible. While such a punitive default may increase the likelihood that firms pursue individual certification, it will not ensure it---and so may not fix the unraveling problem---if the fixed costs of certification are very high relative to the tax differential associated with using carbon intensive versus un-intensive inputs.

3.3 Exemptions

A common method of reducing compliance costs is to *exempt* some sectors and firms from the tax system entirely. A firm being *exempt* from the CFT means that the firm would pay CFT on inputs purchased, but would not be eligible for rebates on CFT-paid, nor would it have to collect CFT when selling goods to consumers. Following the usual markup rules, we would expect these exempt firms to pass CF taxes-paid along to consumers, even though CFs would not be reported on either retail price tags or consumers' receipts.

If an industry's Scope 1 emissions arise only from combusting fossil fuels, then it may be a good candidate for exemption.[19] Suppose, for example, that D-type firms are exempt from charging CFT and have Scope 1 emissions $e_D = L_U > 0$ (i.e. D's only emissions arise from releasing carbon latent in the input purchased from the upstream industry). In this scenario, D-type firms would face input costs of a_{DY} and $a_{UY} + t[e_U + L_U]$ for generic and upstream inputs, respectively. The CFT portion of the firm's expenditure on good U would not be rebated by the government and so downstream firms would charge consumers a retail price of $a_{DY} + a_{UY} + t[e_U + L_U] = a_{DY} + a_{UY} + t[e_U + e_D]$. Consequently, even though good D is exempt from the CFT, consumers of good D would still face a net price for the good that fully internalizes the social costs of the carbon released when that good is produced.

Fossil fuel combustion generates the vast majority of territorial emissions in industrialized economies.[20] So even if a government were to exempt all products other than fossil fuels, its CFT system would still cover the majority of its territorial emissions. Moreover, because there are so

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[19] Because of the high fixed costs associated with tax calculation and reporting, exempting small firms may also be advisable. In the UK firms are not required to charge VAT on their goods if their annual turnover is below £77,000 (HM Revenue and Customs n.d.); the VAT registration threshold in Denmark is DKK 50,000 (KPMG 2012a p.4) and NOK 50,000 in Norway (KPMG 2012b p.3). Each country pursuing a CFT program may therefore wish to exempt firms for whom annual gross revenues fall short of some universal cutoff such as $100,000.

[20] Excluding emissions from Land Use, Land Use Change and Forestry, the International Energy Agency (IEA) reports that 83% of Annex I greenhouse gas emissions are generated by energy extraction and use (IEA 2010 p.18); approximately 80% of Canada's greenhouse gas emissions arise from production and consumption of fossil fuels (Government of Canada 2012); 94% of US CO2 emissions are from fuel combustion; US CO2 emissions account for 83.7% of US CO2e emissions (United States Environmental Protection Agency 2013).

few firms involved in extracting and processing fossil fuels, the transaction cost of such a tax[21] would be relatively low.

Metcalf and Weisbach (2009) argue that it would not be much more expensive administratively to also include in the tax base industries that are point sources of non-fuel Scope 1 emissions, for example cement. Indeed, they calculate that 80% of US territorial emissions could be covered by taxing the activities of just 3000 firms. Although the comparison is not direct---Metcalf and Weisbach (2009) evaluate an emission tax, not a product tax---their analysis suggests that a large fraction of territorial emissions in industrialized countries could be implicitly taxed even if many mid- and downstream industries were exempt from a CFT.

Exempting downstream firms would also mitigate the unraveling problem identified above. Recall from Section 3.2 the example in which an upstream firm has many small downstream customers who would utilize the default if they were not exempt from the CFT-system. If they were instead exempt, those downstream customers would opt for inputs that delivered the lowest tax-inclusive price, which would in turn provide the upstream supplier the appropriate incentive to seek out low-carbon production methods.[22]

3.3.1 Problems with Exempting Products -- Double Taxation

While exempting downstream industries would save transaction costs and mitigate the unraveling induced by defaults, it would also create several potential problems.

To begin with, exempting an industry's product may waste valuable information: consumers who care about the CF of a product (above and beyond the associated CFT burden) would not be able to distinguish between low- and high-carbon products. A non-regulated solution would be for producers selling exempt goods to undergo certification voluntarily and label their products accordingly, possibly using a table of Carbon Facts akin to the current Nutrition Facts labels mandatory on prepared foods.[23] A voluntary carbon labeling scheme based on ISO guidelines is unlikely to run afoul of the TBT; a mandatory scheme may well face opposition.

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[21] If all products other than fossil fuels were exempt from the CFT, the CFT would be almost equivalent to a fuel tax of the sort imposed in British Columbia (BC): the BC fuel tax is levied on fuels according to their latent GHG, while the CFT would also tax fuels according to their extraction emissions.

[22] If downstream firms are not exempt, it may nonetheless be advisable to *quasi*-exempt retailers: require retailers to track, display, and charge CFT on retail items using the CF *as reported by the manufacturer*. This would be aided if the economy employed a voluntary or mandatory labeling program. The advantage of this quasi-exemption would be that any CFs appearing on product labels would match those on the consumer's final receipt. Moreover, retailers would presumably build into their markups the CFT-paid on non-attributable inputs (such as heating and lighting) such that consumers would still face a net price that internalizes most of the social costs of producing and distributing final goods. However, if retailers were either exempt or quasi-exempt, then, while the cradle-to-gate emissions associated with imported final goods would be taxed, the emissions associated with transporting that final good from an overseas manufacturer to the importer's border would not be taxed either directly or indirectly.

[23] Given that these labels would be printed at the factory, and thus not include transport emissions associated with getting the product from the factory to the retailer, these labels would only be able to report emissions from cradle-to-gate, not cradle-to-consumer.

Exempting sectors/firms also introduces the problem of domestic double taxation. If an exempt good is used as an input to production in a non-exempt industry, the final good will effectively be taxed twice: once when its producer pays the CFT built into the retail price of the exempt input, and then again when the CFT is levied on the product's full CF; such a scenario is described in greater detail in the Appendix. As with most VAT systems, a solution is to allow exempt firms to *opt-in* to the CFT system. Firms with significant sales to non-exempt consumers will pursue this option if the transaction costs do not outweigh the benefits from facilitating their customers in recovering CFT-paid throughout the entire production chain.

3.3.2 Under-Taxation in Exempt Industries

If exemptions extend to industries with non-trivial non-fuel Scope 1 emissions, a significant portion of greenhouse gas emissions will go untaxed. As mentioned above, over two-thirds of the territorial greenhouse emissions in industrialized countries are the result of combusting fossil fuels. Nevertheless, restricting a CFT to fossil fuels would leave a substantial amount of territorial emissions uncovered in these countries. A number of observers argue that including a broad range of emissions---such as those arising from land use, land use change and forestry () as well as releases of greenhouse gases in addition to carbon---in the tax base should increase the policy's cost effectiveness by enabling greater flexibility in mitigation and abatement (Van der Werf and Peterson, 2009, p. 507). Several simulation-based studies confirm this result. Burniaux and Lee (2003) find that achieving a 30% reduction in emissions by including land use change emissions in a carbon tax base would reduce marginal abatement costs by 3% in the US and 30% in the EU (p. 2). Michetti and Rosa (2012) study the effect of including forestry-based mitigation in EU emissions abatement and find that doing so would reduce carbon leakage (p. 143) and lower the cost of achieving a 30% reduction in emissions over 1990 levels by 2020 by 29% (p. 142). Golub et al. (2009) model agricultural and forestry land use decisions under climate policy, and find that forestry and agriculture could provide emissions reductions of up to 3 billion metric tons of CO2e over a twenty year horizon in response to a tax of $100 per ton of CO2e (p. 310).

Of course there would also be drawbacks to including other emissions in the CFT's tax base. For instance, for many products it is likely that calculating LULUCF emissions would be very complex. Indeed, many early studies on the lifecycle emissions of biofuels ignored the effects of land use change due to the difficulties in quantifying those emissions (Delucchi, 2005, p. 40; Searchinger, 2008, p. 1238). Moreover, recent studies on biofuel lifecycle emissions that include land use change emissions tend to produce a wide range of results that depend on the modeling methods and data used (Djomo and Ceulemans, 2012, p. 405; Khanna and Crago, 2012, p. 180; Larson, 2006, p. 109). For example, Plevin et al. (2010) estimate that the indirect land use change emissions from corn ethanol production in the US could range from 10 to 340 g CO2 MJ^{-1} (p. 8105).

Including these hard-to-quantify emissions in the tax base would increase the costs faced by firms when calculating their carbon footprints. It is worth mentioning, however, that omitting these emissions from a CFT would distort market decisions and could produce sub-optimal substitution amongst goods. Consider two highly substitutable goods, A and B. Suppose the CF of A is larger than the CF of B, but A's CF is largely derived from LULUCF emissions and B's

CF has a small LULUCF component. Leaving LULUCF emissions untaxed could cause substitution to good A even though its CF exceeds that of good B. An important example of this is in the substitution between biofuels and fossil fuels. Many early biofuel studies that ignored land use change emissions found switching from gasoline to biofuels would reduce greenhouse gas emissions (Menichetti and Otto, 2000, p. 85). Recent studies that include land use change emissions have found the opposite: switching to biofuels could increase global emissions, or would take between 12 and 1000 years (depending on biofuel type, location of production, and study method) to produce a net decrease in greenhouse gas emissions (see, for example: Searchinger et al. (2008); Djomo and Ceulemans (2012); Kim, Kim, and Dale, 2009).

3.3.3 Leakage and Competitiveness Loss in Exempt Industries

Additional problems would arise in an open-economy context. As argued in Anonymous et al. (2013), exempting sectors from the explicit carbon tax system would remove a government's ability to levy border tax adjustments on goods produced by those industries. In theory, exempting downstream industries will impact competitiveness, leakage and efficiency.

An obvious efficiency problem is that the goods produced by exempted industries would not necessarily be produced a manner which minimizes social costs. When a product-class is exempted, all of the emissions associated with imports of goods in that class are tax free. This puts domestic firms at a disadvantage, as their costs will be $p_U + a_{DY} = a_{UY} + a_{DY} + te_U$ (if the Upstream sector is competitive) whereas their competitors will face costs of $p_U^* + a_{DY} = a_{UY} + a_{DY}$. Aside from hurting the competitiveness of domestic firms, this discrepancy may also incite inefficient substitution by consumers. Consider, for example, the case in which $e_U^* > e_U > e_D = e_D^* = 0$. If sector D is competitive and exempt, the price of domestically produced goods ($p_D = a_{UY} + a_{DY} + te_U$) will exceed that of imports ($p_D^* = a_{UY} + a_{DY}$), incenting consumers to substitute away from Home-produced downstream goods towards imports, even though the marginal social cost of ROW-produced goods is higher.

How large is this problem likely to be? Many authors suggest that there is a limited number of industries susceptible to significant cost increase arising from carbon taxation. For example, Wooders et al. (2009) conclude that "only some sectors and subsectors of European industry are susceptible to any significant loss of competitiveness and could thus be expected to 'leak' if [EU-ETS] carbon prices reach a certain level." Accordingly, many studies that contemplate the use of border adjustments restrict their attention to either the industries regulated by the EU-ETS directly or have energy-intensity above some cutoff.

The corollary would seem to be the exempting domestic industries that are not energy intensive would have little impact on competitiveness and leakage. However, in the few CGE analysis that have examined what happens when imports and exports of non-energy intensive products are not eligible for border adjustments suggest that the effect is non-trivial. Böhringer, Carbone and Rutherford (2013) find that the leakage rate associated with a 20% reduction in OECD emissions nearly doubles when non-EI sectors are excluded from a border adjustment program, rising from 4.86% under a full BTA program to 9.62% when only EITE sectors are eligible.[24]

[24] In comparison, the leakage rate when there are no border adjustments at all is 15.61%.

One of the reasons why restricting border adjustments to energy intensive (EI) sectors may have non-negligible impacts may be that the majority of international flows in international carbon are not delivered via trade in EI goods. Peters et al. (2011) estimate that in 2008 there were 7,847 Mt of CO2 embodied in goods traded globally, with Annex B countries importing 2,555 MtCO2 of embodied carbon from non-Annex B countries. 37% of these Annex B embodied carbon imports from non-Annex B countries were embedded in goods produced by non-EI manufacturing industries. In comparison, only 32% of Annex B embodied carbon imports were via goods produced by EI manufacturers.[25] Consequently, there is a lot of upstream carbon that could potentially enter a levying economy via downstream markets if those downstream industries are exempt.

Moreover, given that so much carbon is eventually embedded in production of downstream industries, exempting them from a carbon footprint tax (and thus excluding them from the use of border adjustments) may have non-negligible impacts on output as well. Mattoo et al. (2009) find that restricting BCAs to energy intensive sectors causes the output loss in European non-energy intensive manufacturing to rise five-fold (from a loss of -0.2% to -1.0%).[26],[27] Dissou and Eyland (2011) similarly suggest that limiting BTAs only to energy intensive industries may have considerable impacts on output of non-EI industries in Canada.[28]

At a less aggregated level, there may be particular downstream industries that would be impacted if their products were ineligible for border adjustment. These are likely to include industries for which scope 3 emissions make up a large fraction of carbon footprints. Consider for example the auto industry, a heavy user of steel and aluminium. Houser et al. (2008) note that in 2005 the US's imports of embodied steel (36.9 million tons) were larger than its direct steel imports (30 million tons). Accordingly, "using trade measures for imported steel but not for imported automobiles, for example, would increase the steel acquisition costs for the US auto industry vis-à-vis foreign competition, putting it at a competitive disadvantage" (Houser et al. 2008 p.76). Morgenstern et al. (2007) report that 74% of carbon costs in the automotive industry would come

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[25] It is also worth noting that non-Annex B countries are supplying an increasing percentage of Annex B carbon consumption: in 1990 Annex B countries imported 1,100Mt of embedded CO2 from non-Annex B countries (equal to 7.5% of total carbon consumption in Annex B countries); in 2008 those imports had risen to 2,555MtCO2 (or 16.5% of total consumption in Annex B countries) (Authors' own calculations using estimates provided in Peters et al. 2011, Supplementary Materials).

[26] The policy experiment in Mattoo et al. (2009) is a carbon tax commensurate with a 17% reduction in OECD emissions. In the scenarios we describe---labeled BTADU and BTADR by Mattoo et al.----border adjustments are levied only on imported goods---not exports---and are calculated using domestic emission intensities. Figures are reported in Mattoo et al. 2009 Appendix Table 5.

[27] For comparison, Mattoo et al. (2007) calculate that the output loss in the EI sectors in the BTADU scenario is only 0.5%.

[28] Modeling a $40/tCO2e tax applied throughout the Canadian economy, Dissou and Eyland (2011) compare how the carbon tax impacts output in non-energy intensive manufacturing sectors (labeled Other Manufactures) depending on whether EI-sectors receive a BTA. They find that, absent any BTAs, the carbon tax *raises* output of Other Manufactures by over eight percent, but when paired with BTAs for the EI sectors, Other Manufacturing output falls by between eleven and seventeen percent. It is unclear, however, how much of this output reduction can be attributed to import competition and higher costs of inputs purchased from upstream firms, as Dissou and Eyland assume BTA revenues are rebated to the most energy intensive industries, which also causes labour and capital to reallocate within the economy.

from Scope 3 emissions (Morgenstern et al. 2007, Table 2). Our own calculations suggest that carbon costs would account for approximately 4% of gross value added (GVA) in the US auto industry.[29] This number is small relative to estimates of carbon costs in the most affected industries.[30] Nevertheless, given the fragility of the US auto industry, a 4% rise in costs should not be dismissed out of hand.[31]

In summary, given the large fraction of embodied carbon trade that occurs via trade in goods produced by non-energy intensive industries, the potential for considerable leakage if downstream industries are not BCA-able, and given that scope 3 emissions may constitute the majority of emissions for many downstream emissions, we reject the presumption that non-EI downstream sectors should be exempted without further study.

4. Feasibility

The obvious disadvantage of a CFT would be the associated transaction costs, which would come in two forms. It would be costly to compute footprints; in the CFT's purest application every product would have its own footprint, right down to each product line produced by each firm/plant. It would also be costly for firms to collect and remit taxes. We look at each of these costs in turn.

4.1 Cost of Computing Footprints

One way to proceed would be to allow firms to calculate and self-report annually the (average) footprints of each of their product-lines, subject to random audit. For this firms would have to know their latent plus Scope 1, 2 and 3 emissions. Scope 2 and 3 emissions would be straightforward, as these would be reported on invoices for inputs purchased. Calculating Scope 1 emissions that arise from on-site fuel use would also be simple as it would be reported on fuel-purchase invoices (under the heading "latent" emissions). Calculating non-fuel related Scope 1 emissions and latent emissions would likely be more complicated, potentially requiring

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[29] Using US data, Burnham, Wang and Wu (2006) estimate that a 3300lb internal combustion engine vehicle typically embodies approximately 8t of CO2e. In 2007, US value added from automobile assembly was $22 billion, while the number of automobiles assembled was 3.9 million (Ohio 2011 Tables A3 and A11), suggesting gross value added in the US auto assembly was approximately $5600/vehicle. Assuming a tax rate of $30/tCO2e the carbon tax burden in auto assembly would be approximately 4% of gross value added.

[30] E.g. Hourcade et al. (2007) predict that a 20 euro carbon tax would impose costs equal to between 10% and 30% of gross value added in sectors such as cement, steel and iron, and petroleum refining.

[31] Using input-output analysis, Morgenstern et al. (2007) report that a $10/tCO2 charge would reduce Motor Vehicle Output by 1.01% in the short run; this is comparable to predictions of short run output losses of 0.96% for Chemical and Plastics and twice that for Petroleum (.42% output loss) and Paper & Printing (.48% loss). It should be noted, however, than in the long run (with general equilibrium responses including reallocation of capital), output losses in the automotive sector are projected to be much smaller. Conducting a CGE analysis using 21 sectors including 13 manufacturing industries in the US, Ho et al. (2008; Table 6) calculate that an economy-wide $10/tCO2 would reduce output from the Transportation Equipment sector by only 0.27% (as compared to a 1.14% loss in the short run); in contrast, the long run output loss in Petroleum Refining is predicted to be 5.36%

consultation with experts or input-output tables linking land-use practices, for example, to CO2e releases.

Electricity purchased from the grid poses an interesting complication. Electricity is typically dispatched through pools, so a firm's electricity use cannot be attached to a specific source. As a result, firms that use electricity from a grid with multiple sources would not be able to compute the exact footprint for their products. Absent a mechanism for tagging electricity, these firms would have to use the average emissions intensity of electricity from their source grid when calculating their CFs. This would be most problematic for grids with a mix of renewable and non-renewable energy.

A solution might be to track electricity using a system similar Renewable Energy Credits (RECs). Many jurisdictions that have renewable energy mandates issue RECs to local generators in exchange for units generated from renewable sources. Generators may sell these RECs to other utilities as well as to non-energy producers and retailers. By purchasing a REC, a firm/utility can claim that the corresponding amount of electricity it obtained from/supplied to the grid was from a renewable source (California Public Utilities Commission 2012). RECs could be used to reduce the pooling problem with electricity emissions in the case of footprinting; introducing tradable zero-carbon credits would allow firms wishing to reduce their footprint to buy credits from utilities and serve as evidence that their electricity is indeed zero-emission [32]

Once a firm calculates the sum of its latent plus Scope 1, 2 and 3 emissions, it would then apportion these to its various products using the same methods as employed to apportion attributable and non-attributable input costs when estimating average cost/unit. This would be an exercise in spreadsheet management that could be facilitated by mass market software. For example, Intuit, the producer of the QuickBooks accounting software, has developed an add-on module---"Green Snapshot"---which calculates firm-level carbon footprints based on the firm's expenditure data. Similar products could be developed to calculate average CFs on a product-by-product basis. Similarly, large companies may choose to adapt their proprietary inventory/accounting programs by introducing new datafields that track the CFs of inputs used and calculate the CFs of outputs generated.

One of the problems that might arise with a system in which individual firms calculate their own CFs is that it may be difficult for auditors in an importing country to evaluate the claims of foreign producers. It would be expensive for auditors to conduct on-site investigations of overseas operations. It is also unclear whether auditors would have the authority to levy penalties on foreign firms found to have understated their carbon footprints.

An alternative is to have firms hire third parties to calculate their CFs.[33] If each importing country were to require that CFs be certified by its own domestic agents, there would be wasteful

[32] If low-carbon generators are given tradable zero-emission credits, then the default CF of non-credited electricity would have to be adjusted upward accordingly.
[33] Even if third parties carry out certifications, CF calculations would still draw upon proprietary data, thereby opening the door to fraud. In order to avoid similar problems with organic certification, the

replication. Mutual recognition of national footprinting methods would solve the duplication problem, but wouldn't rule out the potential for bias in the methodologies themselves. For example, coal-burning countries might decide to ignore emissions embodied in electricity, while forest-converting countries might opt to ignore land-based emissions. Requiring that footprinting authorities use methodologies that are consistent with the International Standards Organisation (ISO)'s guidelines for carbon footprinting---ISO 14067---would be one solution.

Over the last fifteen years the International Standards Organization (ISO) has developed a number of international environmental standards. These standards are intended to help harmonize the many independent environmental standards, labels, and certifications being pursued at national and international levels. The WTO Technical Barriers to Trade (TBT) agreement requires that all standardizing bodies use any relevant international standard in existence as a basis for their own technical regulations and standards[34], provided the existing international standard is effective at meeting the objective pursued (see TBT Article 2.4 for technical regulations and paragraph F in Annex 3 for standards). The WTO recognizes ISO standards as being not overly trade restrictive, which means that harmonizing with these standards is likely to result in a more favorable judgment by the WTO (Dankers 2003, p. 18). Although there are currently no mandatory standards or labels based on ISO environmental standards, a number of voluntary labeling programs have been designed according to the ISO 14025 standard for environmental certification. In addition, the ISO 14064/14065 CO2e quantification and verification standards have been frequently used in the carbon offset market, either as a basis for carbon offset standards or in evaluating offset projects. The ISO 14067 and 14069 carbon footprint standards were designed to augment the ISO's Life Cycle Analysis methodology---as outlined in the ISO 14040 and 14044 standards---and offers standardized rules as to how a product's (ISO 14067) or organization's (ISO 14069) carbon footprint should be calculated.

There are examples of mandatory non-environmental regulations and labels based on ISO standards. Perhaps most notable is the European CE label[35], which is required for many products sold in the European Economic Area (EEA). This label indicates that the product satisfies all necessary EEA health, environmental and safety standards for that product, and is mandatory regardless of the product's origin (European Commission, n.d.; Commission of the European Communities, 1989, p. 6). The quality management requirements of the CE label were based on the ISO 9000 family[36], and compliance with the appropriate ISO 9000 standard is sufficient (although not necessary) to comply with the quality management components of the CE label (Julin, 1999, p.11).

International Federation of Organic Agriculture Movements (IFOAM) instituted three levels of monitoring: certification bodies perform farm inspections (sometimes unannounced) and review the farm/producer's written documentation while retail and trade quality managers perform quality tests (IFOAM, 2012). Certification bodies themselves are also subject to review by accreditation bodies, often by a national food inspection body, such as the Canadian Food Inspection Agency.

[34] A mandatory certification or label administered by a government body is referred to in the TBT as a technical regulation; a voluntary certification or label administered by a government or non-government body is referred to as a standard.

[35] CE is often taken as standing for *Conformité Européenne.*

[36] The ISO 9000 family of standards relate to quality management systems.

In addition, Health Canada (the Canadian federal department of health) requires that manufacturers of certain medical devices register to the ISO's medical device quality system standard (ISO 13485 or 13488[37], depending on the device) to receive a medical device license (QMI-SAI Global, n.d.). Moreover, a Health Canada medical device license is required for most[38] medical devices sold in Canada, regardless of origin (Health Canada, 2011, p.4). As a result, this regulation implies that all domestic and foreign medical devices sold in Canada must conform – and register – to the appropriate ISO standards.

The ISO footprinting standards solve the consistency problem of third party CF certification. The standards don't, however, assure that the footprinting process would be cheap.

We conducted an informal survey of consulting firms in an effort to identify the market price for third-party carbon footprinting. We contacted thirty LCA and CF consultants from around the world, three standards institutes from OECD nations, and two international non-governmental organizations. Fourteen of the thirty five experts responded; twelve were willing to share footprinting cost information. From the respondents, the lowest quoted price for a footprint was in the $50 to $100 range, and would use data from sectoral level input-output tables; the highest quoted price was $200,000 for a footprint which used firm level data and assumed a very high level of complexity. The typical estimates for a CF using methods that include Scope 1, 2 and 3 emissions and conform to one or more international LCA or carbon accounting standard/protocol were $18,000 for low complexity[39] products and $46,000 for high complexity products.[40]

The reported 18k-46k range from our survey likely overestimates the actual costs of third-party CF calculation. For starters, the firms' quotes assumed the CF in question was a first-time assessment for a particular product or firm; many of the consultants contacted indicated that costs could fall by half if the consultant had prior experience with a particular product or firm. Moreover, under our proposed CFT regime, firms will only have to calculate their own Scope 1 emissions, as Scope 2 and 3 emissions would have been reported by upstream suppliers. Moreover, costs will likely fall as the footprinting industry matures. As a point of comparison, the cost of conducting a nutritional analysis has fallen by between 67 and 90 percent since nutritional labels became mandatory in 1990 in the United States.[41]

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[37] These standards are the medical device sector specific versions of ISO 9001 and ISO 9002, respectively.

[38] Type I medical devices do not require Health Canada licenses.

[39] A Low Complexity product is loosely defined as one using few material inputs, simple manufacturing methods and a straightforward distribution system. High Complexity products require many material inputs, several manufacturing steps, a multi-mode transportation system and packaging.

[40] These figures represent prices charged for footprinting services. There would also be costs associated with accrediting firms providing these services, for which the costs of accrediting organic certifiers may be relevant. Stolze, Hartmann, and Moschitz (2012) assess the supervision costs--- per organic farmer or processor---to manage an organic certification scheme in each of six European countries and arrive at country-level supervision and accreditation costs of $624,978 CAD per year per country.

[41] In the Impact Analysis performed for the 1990 Nutrition Labeling and Education Act it was estimated that the costs of performing the required nutritional analyses was $1,785 USD for products that had yet to undergo any nutritional analyses (Food and Drug Administration, 1991, p. 9). This estimate assumed each product required a full lab assessment to acquire the necessary nutritional information. Currently, new products can undergo either a full lab assessment or a database nutrition analysis. Both of these methods

Nevertheless, even if the cost of a third-party certification falls considerably, certifying all products sold in an economy would be enormous. In Canada, for example, there are over 70,000 company Universal Product Code (UPC) prefix licenses[42]. If each license is used to generate just 10 distinct UPCs and the price of a third party CF certification is only $9,000, the transaction costs of having each product's CF certified would exceed six billion dollars.[43]

4.2 Calculating Default CFs

As mentioned, one way to economize on these transaction costs would be to pursue a hybrid system with default footprints.

The set of products described in the US Census' augmented NAICS tables serves as a likely candidate for the set of product-classes to which defaults would be assigned. There are 3,299 Mining and Manufacturing industries at the 10-digit NAICS-based level. Assume each 10-digit level industry requires a single default[44,45] and that the default for each product-class is calculated by measuring the actual CF of a representative product. Using current average costs for calculating low and high complexity footprints---$18,000 and $46,000---the cost of calculating a default CF for each of the 10-digit product classes would be between $59 million and $152 million. If we instead assume footprinting costs will fall by 2/3 (as did the costs of performing lab-based nutritional analyses), the cost of providing a complete set of 10-digit default footprints would range between twenty and fifty million dollars. Notably, the costs of

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satisfy the Food and Drug Administration's nutritional label requirements (Food and Drug Administration, 1998). To perform a database nutrition analysis, which uses data from similar or input food products to assess the nutritional information of a previously un-analyzed product, costs are between $75 USD (Sweetware, n.d.) and $125 USD (nutridata, n.d.). A lab-based analysis was quoted at $560 USD in 2003 (Food and Drug Administration, 2011, p. 26). The cost of a lab-based analysis fell by 67% after nutritional labels became mandatory in the US. In addition, because these labels were made mandatory, a database has been assembled that can be used to calculate – very inexpensively – the nutritional information of many products. In a case where a database analysis is sufficient, the cost, compared to the 1990 lab cost, has fallen over 90%.

[42] Personal communication with Kathleen McManus of GS1 Canada, October 25 2012.

[43] Alternately, the number of unique Global Product Classifications (GPCs) worldwide exceeds 11 million. (GS1 2013)

[44] The North American Industry Classification System (NAICS) classifies national industries to the 6-digit level. The US Census Bureau has developed additional NAICS-based codes for further classification; we base our count of 10-digit industries on the count of 10-digit codes in the US Census Bureau's 2007 "Numerical List of Manufactured and Mineral Products", available at http://www.census.gov/prod/ec07/07numlist/m31r-nl.xls.

[45] The 10-digit NAICS-based codes are *industry* codes, describing industries according to the goods produced. However, for many codes the industry code can be attributed to a fairly homogeneous product – e.g. "Candles, including tapers" (NAICS-based code 3399994100) – and so we take the liberty of referring to the 10-digit NAICS-based codes as *product codes* as well. However, for some industries the 10-digit code includes a variety of products which may need to be further disaggregated, eg. "Wood jewelry boxes, silverware chests, instrument cases, cigar and cigarette boxes, microscope cases, tool or utility cases, and similar boxes, cases, and chests" (NAICS-based code 3219207151) or classified based on weight and/or volume.

calculating defaults could be shared across multiple countries if all adopted a CFT and used the same product-class definitions.

The obvious downside to this bottom-up approach lies in the choice of which firms/products should be treated as representative. Governments and industry groups alike would have incentives to lobby regulators to choose the representative product for strategic purposes. Carbon intensive firms may prefer that a low-carbon product be chosen as the representative product so that the default CF is low.

Alternately, the default CFs could be calculated from multi-regional input-output (MRIO) data. MRIO is an accounting framework that connects national input-output (IO) tables with global trade flow matrices, capturing inter- and intra-industry flows of goods and services across countries. In this top-down approach to calculating defaults, MRIO data would be used to calculate average CFs for each product class and country. The default CF for each product class would then be a weighted average of these country-level CFs, where the weights are the country shares of international production.

We highlight three existing MRIO datasets that could be used to calculate default CFs. The Global Trade Analysis Project (GTAP) database[46] is the most commonly used data source for environmental MRIO analyses (Wiedmann et al. 2011 p. 1939). The current version of the GTAP database (GTAP8) includes IO data from 2007 for 129 countries. Data is disaggregated to 57 industries and sectors. The database can be converted to a full MRIO database following Andrew and Peters (2013). The EXIOBASE MRIO database[47] contains data on fewer countries than GTAP8 (27 EU countries and 16 non-EU countries), but to a higher degree of disaggregation (130 industries and products). The base year for EXIOBASE is 2000. Finally, the Eora MRIO database[48] provides the highest level of disaggregation, but does so differently across countries. There are 130 countries disaggregated to 100 industries and 40 countries disaggregated to between 200 and 500 industries. For example, the US is disaggregated to 429 industries, China to 123 industries, and Denmark to 131. The Eora database contains data from 1990 to 2011. All three datasets include data on CO2e emissions.

The advantage of an MRIO-based approach would be its cost effectiveness---analyzing a global set of input-output tables would be much less costly than calculating detailed CFs for representative firms. Moreover, the same structure could be used in determining defaults in later years; only the input-output tables would have to be updated. This would reduce the cost of calculating defaults in the future.

There are obvious disadvantages to this top-down approach. MRIO data is constrained by the level of disaggregation presented in national IO tables, which generally do not report to the product level. For example, the US Department of Commerce's national IO tables disaggregate some industries to the 7-digit NAICS code (soybean and other oilseed processing, for example, which has a 2002 NAICS code of 311222-3), but others are reported only to the 3-digit NAICS code (e.g. support activities for agriculture and forestry, NAICS code 115). IO tables for other

[46] See Narayanan and Walmsley (2008) or https://www.gtap.agecon.purdue.edu/.
[47] See Tukker et al. (2009) or http://www.exiobase.eu/.
[48] See Lenzen et al. (2010) http://www.worldmrio.com/.

countries often provide even less disaggregation. As a result, global MRIO data is highly aggregated and it cannot be used to calculate footprints at the product level. More detailed footprints can be calculated by relying on a subset of countries with more disaggregated IO tables (the OECD countries, for example). However, this will likely result in underestimation of true average global carbon footprints. It is possible to correct for this underestimation to a certain degree by imputing CFs of the omitted countries, but the resulting estimated global average CFs will still be biased downward. Precision could be improved by performing selective carbon footprinting, particularly of goods produced by sub-industries for which IO data is currently reported at high levels of aggregation. This, of course, will be subject to some of the same concerns as raised above: unless the rules determining whether an industry/products is footprinted are based on objective criteria which are uniform across sectors, industries may waste valuable resources lobbying regulators.

4.2 Collection and Remittance Costs

In addition to the footprinting costs, a carbon footprinting scheme would also impose significant filing costs; firms selling goods would have to collect CFT from purchasers and remit those taxes to the revenue authority. Moreover, firms buying intermediate goods would need to submit invoices to the tax authority in order to recover CFT paid on inputs. All of these transaction costs are mirrored in the costs of administering a credit-method VAT.

Estimated costs of complying with VAT regimes vary across countries. One useful metric is the amount of time that a standardized case study firm must spend annually in order to comply with a VAT. The World Bank and International Finance Corporation estimate that in 2010 the standardized case study firm[49] would have allocated 50, 30, 35, and 26 hours annually to VAT compliance in Canada, the United Kingdom, Japan[50] and France respectively. [51] For the full sample of 145 high, medium and low-income countries using a VAT or equivalent, the average annual VAT compliance time would have been 125 hours (Price Waterhouse Coopers 2011 p.6). Another metric takes the ratio of firms' compliance and governments' administration costs to GDP; for example, in the mid-2000's compliance costs in the UK, Denmark, the Netherlands, and Sweden were between 0.08 and 0.2 percent of GDP while administration costs ranged from 1/3 to 2/3 of a percent of GDP[52].

Countries with federal VATs could reduce some of the transaction costs of a CFT system by having CFT remitted to and recovered from the same tax authority using the same forms as for

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[49] Their standardized case study firm has 60 employees and "turnover of 1,050 times income per capita" (Price Waterhouse Coopers 2011 p.98).

[50] Japan uses a subtraction-method VAT and is the only country referenced in this section that doesn't use the credit-method.

[51] *Doing Business* database http://www.doingbusiness.org/data. Figures for Canada are for Ontario and the Harmonized Sales Tax.

[52] Authors' calculations based on data from KPMG (2006) for UK compliance costs, the SCM Network (2005) for Denmark, Holland, and Sweden's compliance costs, and the EU Project on Baseline Measurement and Reduction of Administrative Costs (2009) for administrative costs in all four countries.

VAT remittance/recovery.[53] Nevertheless, the CFT would impose an additional reporting burden in that Carbon Footprints are distinct from Value Added, and are arguably more complex. For example, there would inevitably be cases in which a firm produces a good that does not fall into a clearly defined product-class; if this firm didn't pursue individual certification, it would need to use discretion as to which default to employ. Similar problems arise with multiple-rate VATs. A 2005 study of VAT compliance in Norway, Denmark, Sweden and Netherlands found that compliance costs (per filing) rose by between 0 and 4 hours/filing when an establishment was required to levy two or three VAT rates instead of one (SCM Network 2005 pp. 7-9). The study found the "burden is primarily connected to sales...[and] consists of programming of cash register, informing staff and a concrete judgment of what VAT rate should be applied" (SCM Network 2005 p.15). Although the CFT is simpler than a multi-rate system in that a single tax rate applies to all embodied/latent CO2e, there would still be one-time costs associated with reprogramming inventory systems and cash registers to report and tax goods based on their CFs, as well as ongoing costs of updating databases when products' CFs change over time.

4.3 Revenues

Depending on the carbon tax rate, a CFT may be a net revenue generating program. In 2008, CO_2 consumption in Canada, US, UK, Germany, France and Japan was 600, 6153, 704, 994, 536 and 1516MtCO_2 respectively (Peters et al. 2011, Supplementary Table 8). Suppose a 30$ tax per tonne of CO_2e would reduce overall CO2e consumption by 14%;[54] then in 2008 a pure CFT would have raised 15, 159, 18, 26, 14, and 39 billion dollars in revenues in these countries, respectively[55]; under a hybrid CFT, some products would be taxed on smaller basis than their true footprint and so actual revenues would have been smaller than suggested by these figures.

Revenues could be used for a variety of purposes. They could be used to reduce government deficits. Alternately, many economists have suggested that a carbon footprint tax be made *revenue neutral:* other taxes could be reduced or eliminated so as to keep the tax burden unchanged, both for the country as a whole and for different income groups. Revenue neutrality may raise the political acceptability of any carbon-pricing scheme, since it would help dispel perceptions that carbon policies are disguised tax hikes[56]. A revenue neutral CFT might also

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[53] Countries like the United States which do not have a federal sales or value added tax would not have this advantage.

[54] Jorgenson and Wilcoxen (1993) find that a tax equivalent to $30 in current Canadian (CAD) dollars would achieve a 14.4% reduction in US CO2 emissions over a 25 year time horizon; Böhringer and Rutherford (1997) find that a carbon tax equivalent to $24.8 in current CAD would achieve a 10% reduction in German emissions, while Metcalf (2009) finds that a tax equivalent to $20.35 in current CAD would achieve a 14% reduction in US CO2E emissions.

[55] To put these revenues into perspective, note that in the 2008-2009 fiscal year Canada's federal value added tax (called the GST) raised $9.5B, while federal personal income taxes raised $116B (Government of Canada 2009).

[56] Political viability would also be improved by appropriate framing. Economists recognize Pigouvian taxes as price instruments designed to force consumers/producers to internalize the environmental costs of their actions. However, to the general population, *tax* indicates a revenue generating mechanism designed to transfer wealth from citizens to government. Describing a carbon footprint price as a *fee* or *charge* may convey the correct signal that the policy is designed to charge consumers for use of a public good.

generate a *double dividend.* On the one hand, *revenue recycling* would allow governments to reduce other distortionary taxes such as those on personal income taxes and capital.[57] However, carbon policies also carry with them additional *tax-interaction* effects: efforts to reduce carbon will raise the prices consumers pay for goods, thereby eroding the real return to their labor supply and savings, exacerbating distortions already present in labor and capital markets.[58] In empirical analysis, which dominates---the revenue recycling or the tax-interaction effects---depends on the characteristics of the taxes being offset; see, for example, Bovenberg and Goulder (2002) and Parry (2003).

Countries that are net importers of embodied carbon would generate more revenue by taxing embodied carbon consumption than they would by taxing carbon releases. While this might increase the attractiveness of a CFT for some countries, as noted earlier many developing countries could be made markedly worse off. This is because BCAs will hurt the terms of trade of carbon-exporting countries, acting "as a sort of 'back-door' trade policy …, substituting for optimal tariffs that would be illegal under free trade agreements." (Böhringer, Carbone and Rutherford 2013 p. 21) Atkinson Hamilton Ruta (2011, Table 2) calculate the effective tariffs which developing country exports would face if industrialized countries were to tax virtual carbon at $50/t. They calculate that imports from China, Russia and South Africa--- the most intensive exporters of virtual carbon--- would face trade-weighted average tariffs of 9.7%, 11% and 11.5% respectively. As mentioned, the welfare effects of such BCAs could be considerable. Considering a program whereby OECD emission reductions of 20% are paired with embodied carbon tariffs, Böhringer, Carbone and Rutherford (2011) find that GDP in China---the world's largest net carbon exporter of embodied carbon---would fall by almost 5%, while welfare in the OECD countries would *rise* relative to business as usual (BAU). Winchester, Paltsev and Reilly (2011) similarly find that developing countries would suffer a greater welfare loss (percentagewise) than would Annex I nations if the latter were to pair domestic emission reductions with BCAs.

One solution that has been proposed is for taxing nations to return some of the revenues to developing countries, for example via lump-sum transfers or technological assistance. However, it should be noted that direct transfers might themselves increase carbon emissions if marginal propensity to consume carbon-intensive goods is relatively high in recipient nations. Alternately, some of the revenues generated by destination based carbon taxes could be earmarked for mitigation and adaptation in developing countries. As Hillman (2013) argues, returning to developing nations some of the carbon tax revenues collected from imports might mitigate concerns that destination based carbon taxes are intended to protect domestic industries rather than combat climate change.

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[57] Some voters will be wary of government introducing a new tax with the promise that rates of some other taxes will be reduced. Such voters may suspect that future administrations will erode cuts in personal income taxes through incremental increases in future years. One solution to this commitment problem might be to have CFT revenues managed by a third-party which then issues lump-sum rebates to residents. This approach would also convert the CFT program from being regressive to progressive.

[58] In the case of carbon taxes, an additional interaction is possible: to the extent that introducing a carbon pricing policy induces innovation that reduces the CF of goods in the future, consumers may delay the purchase of some durables so as to reduce the lifetime tax bill.

5. WTO-Consistency of a Carbon Footprint Tax

Destination based carbon policy mitigates some of the arguments governments give for not pursuing unilateral action: leakage and competitiveness loss. We believe that a major reason for using a CFT as the means to implement destination based policy is that it is less likely to be deemed WTO-inconsistent than would pairing border tax adjustments with either domestic emission taxes or tradable emission allowances. It is beyond the scope of this paper to give a full assessment of the legal considerations surrounding the use of BCAs; readers interested in the legal precedents for a carbon footprint tax are referred to Anonymous et al. (2013). We instead provide a brief overview of some of the key issues.

Legal scholars advocating in favour of pairing BCAs with domestic emission taxes and/or tradable permit schemes usually offer the following justification.[59] Article II:2(a) of GATT allows governments to tax imported goods according to their constituent ingredients if domestic use of those ingredients is similarly taxed (Pauwelyn 2013). A Dispute Settlement Panel confirmed this interpretation in its report on the US-Superfund case (GATT Case No. 34), in which the US taxed imported chemicals and "certain imported substances produced or manufactured from taxable feedstock chemicals" (GATT Panel 1987 p.2) on the grounds that domestic use of those chemicals was taxed. Moreover, even though the European Community contended that the tax on imported goods constituted double taxation (in the case where use of such inputs was already taxed in the exporting country) and violated the polluter-pays-principle, the Panel disregarded these concerns on that grounds that while the "General Agreement's rules on tax adjustment ... give the contracting party ... the possibility to follow the Polluter-Pays Principle, ...they do not oblige it to do so" (GATT Panel 1987 p. 17). Moreover, whether a tax is adjustable depends on how it is applied, not why: "[w]hether a sales tax is levied on a product for general revenue purposes or to encourage the rational use of environmental resources, is ... not relevant for the determination of the eligibility of a tax for border tax adjustment" (GATT Panel 1987 p.17).

The problem with extending the US-Superfund precedent to the case of emission taxes and/or tradable permit programs is that greenhouse gas emissions are not physically incorporated in the traded goods. The Panel was silent in the US-Superfund case on whether inputs need to be physically present in the traded good in order to be eligible for taxation. Demaret and Stewardson (1994) point out the GATT is ambiguous on this point. While the English language version makes no mention of inputs being incorporated, the French language version uses the term "incorporée" (translated as "incorporated"), making it unclear "whether Article II:2(a) is intended to limit Article III, so that only taxes on physically incorporated articles are eligible for adjustment on the import of the like final product, or merely to itemize one of the meanings of a tax applied "indirectly" to a product" (Demaret and Stewardson 1994 p.19). Moreover, in its 1970 Report, the Working Party on Border Adjustments did not include energy taxes---the kind of tax most directly comparable to a carbon tax---in the list of indirect taxes eligible for border adjustment; energy taxes were instead given as examples of *taxes occultes*, for which the

[59] Excellent treatments of the use of BCAs in tandem with emission taxes and cap and trade can be found in de Cendra (2006), Howse and Eliason (2009), Hufbauer, Charnovitz and Kim (2009), Low, Marceau and Reinaud (2011) and Pauwelyn (2013).

Working Party gave no guidance as to the permissibility of border adjustments. Accordingly, there is no clear precedent for imposing border adjustments for taxes on non-incorporated inputs.

An alternate defense would seem to take the following form: even if the taxed input is not physically incorporated in the traded good, a BTA is warranted on the grounds that foreign firms would have had to pay those charges if the product had been produced locally. However, we believe such a justification would invariably violate the National Treatment principle because the BTA would constitute a tax on imported *products* while the tax for non-imports is levied on *firms*. Specifically, domestically produced goods would be exempt from the product tax on the grounds that their producers already paid via emission taxes or allowance requirements. However, unless such an exemption was also available to foreign producers for mitigation costs that they incurred themselves, such a defense would fall short. Extending the exemption to foreign producers would incur high administrative costs: the parties involved would need to calculate not only the carbon embodied in the imported goods, but also any mitigation costs already incurred. This latter calculation would be particularly difficult when foreign governments use non-market mechanisms for controlling emissions, as the implicit foreign carbon price would not be readily observable.

A consumption tax would get around many of these problems because it would target products, not firms. As a product tax the CFT would be an indirect tax. GATT III:2 and the Report of the 1970 Working Party on Border Tax Adjustments have long-since established the eligibility of indirect taxes for border adjustment (Hufbauer, Charnovitz and Kim 2009). Moreover, Footnote 1 to the Agreement on Subsidies and Countervailing Measures stipulates that exempting exported products from certain internal taxes does not constitute an export subsidy:

> "the exemption of an exported product from duties or taxes borne by the like product when destined for domestic consumption, or the remission of such duties or taxes in amounts not in excess of those which have accrued, shall not be deemed to be a subsidy."

One of the conditions under which a product tax is allowed is that the tax treats imports and domestically produced goods equally (Pauwelyn 2013). A CFT would be origin neutral, in that it would be levied on products consumed in the taxing country regardless of where they are produced. Nevertheless, a CFT may face legal challenge because cases will invariably arise in which two products that are physically identical bear different per-unit tax burdens because of differences in their non-product related Process and Production Methods (npr-PPMs). In particular, if two products---which are physically identical but for the carbon released during their production---are deemed "like," then the Appellate Body (AB) could find a CFT in violation of GATT Article III:2, 2nd sentence, which addresses National Treatment.

Hillman (2013) suggests this is unlikely, as past cases in which tax systems were overturned for GATT III:2 violations involved differential tax *rates* for products based on arbitrary distinctions[60]. Because a CFT would be uniform---in that each tonne of latent/embodied CO2e

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[60] E.g. the 1996 Japan-Alcoholic Beverages case (WTO Dispute Numbers 8, 10 and 11) centered on Japan's practice of taxing Shochu at a lower rate than Vodka. The dispute in the 1999 Chile-Alcoholic Beverages case (WTO Dispute Numbers 87 and 110) concerned Chile's practice of levying an *ad valorem* tax of 27%

would be taxed at the same rate regardless of the good's product class, country of origin, or overall carbon intensity---it would not be susceptible to the complaint that it arbitrarily discriminates between products.

Nevertheless, as noted there will invariably be cases in which the total CFT-burden will vary across products that are physically alike. Difference in per-unit tax burdens could be construed as violating GATT III:2, which allows for no distinction in the tax treatment of "like" goods. It is unclear whether the AB would interpret goods that are identical---but for differences in their embodied carbon---as "like". While there have been a number of cases in which the AB has disallowed origin-neutral distinctions between products based on their npr-PPMs[61], recent precedence indicates a willingness to treat products as dissimilar if their production externalities differ. For example, in the recent Canada-FIT case (WTO Dispute Numbers 412 and 426.) the AB deemed the markets for electricity from renewable and conventional sources to be distinct, in part because of the health and environmental concerns underlying policies to promote renewable energy sources. If we allow the corollary that goods with distinct markets are not "like," the AB's ruling in the 2013 Canada-FIT case would seem to open the door for treating goods with different embodied carbon as unlike. We should, however, note that the context for the AB's ruling regarding distinct markets was the Agreement on Subsidies and Countervailing Measures, not GATT Article III:2. As many legal scholars have noted, the meaning of "like"-ness varies considerably across agreements and even across paragraphs within the same agreement; see e.g. Hufbauer, Charnovitz and Kim (2009) and Low, Marceau and Reinaud (2011). As a result, whether or not goods with high- and low-embodied carbon would be deemed "like" in the context of GATT III:2 remains an open legal question. This concern not without standing, and as we argue in Anonymous et al. (2013), we believe that a hybrid CFT stands a better chance of withstanding a challenge via the WTO than any other proposed method of implementing destination based carbon policy.

7. Conclusion

In a 2001 speech, US President Bush justified the US' refusal to ratify Kyoto on the grounds that "complying with those mandates would have a negative economic impact, with layoffs of workers and price increases for consumers" while "the world's second largest emitter of greenhouse gases is China. Yet China was entirely exempted from the requirements of the Kyoto protocol" (Sanger 2001). In the intervening years the global scientific community has provided increased precision regarding the likely consequences of climate change. But governing bodies have not been able to arrive at a binding global agreement to limit releases from many of the world's largest emitters, and so much policy research has instead focused on unilateral approaches. As illustrated in President Bush's remarks, for many countries a unilateral approach that does not protect competitiveness is untenable.

One mechanism for mitigating supply-side leakage and protecting competitiveness is to adopt destination based policy. In this paper we have fleshed out the mechanics of a consumption tax

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on beverages with alcoholic content of 35% or lower, but taxing beverages with alcoholic content over 39% at a 47 per cent *ad valorem* rate.

[61] For example, in the 1992 US-Malt Beverages case (GATT Case No. 23), the Panel found Minnesota's practice of offering tax breaks to small breweries (including foreign breweries) violated GATT III:2.

on embodied carbon. As we argue elsewhere---see Anonymous et al. (2013)---amongst the set of policies that tax imported goods according to their associated emissions, the CFT would be the most likely to withstand challenges under GATT. Product taxes may also be desirable as they focus attention on nations' embodied carbon footprints, which have been rising in many countries even as their territorial emissions have declined or stabilized.

Although the administrative costs of implementing a CFT would be higher than alternate schemes such as upstream fuel taxes, our analysis suggests a hybrid CFT would still be logistically and economically feasible. For example, using a bottom-up approach (in which 10-digit NAICS industry codes define product classes and baselines are based on the actual footprints of representative firms), the administrative costs of calculating the set of default CFs would likely be between 0.1% and 1% of CFT revenues in a country such as Canada. Pursuing a top-down approach---utilizing existing MRIO tables for example---may cost considerably less but offer less precision. Moreover, in many countries---but not, notably, the United States---the envisioned CFT could minimize compliance costs by building on existing tax collection infrastructures. Like emission taxes the CFT could also finance reductions in distortionary income, payroll and capital taxes. Alternately, a country might consider using a top-down approach in which baselines are calculated using data from country-level input-output tables from a sample of nations.

Despite its merits, a CFT would also have several drawbacks. Employing a system of default CFs might be necessary for keeping compliance costs low and avoiding allegations of GATT-violations. However, the default system would remove incentives for the most carbon-intensive producers to lower their own carbon emissions. Defaults could also unravel incentives for upstream abatement when producers are credited for CFT paid on inputs. Exempting downstream firms may mitigate the unraveling problem, however it opens the door for double-taxation as well as competitiveness loss and carbon leakage in downstream industries.

Additionally, zero-rating exports would dis-incent exporters from reducing their carbon intensity; zero-rating might also lead exports of high-CF goods to crowd out exports of low-CF goods from the same country. Further, zero-rating would exacerbate demand-side leakage. Accordingly, countries might want to forego some of the competitiveness benefits of a CFT by phasing out the practice of zero-rating unless trade partners have adopted their own destination-based carbon pricing schemes. After an adjustment period has passed, it might make more sense for large CFT-levying countries to utilize their full policy-reach and require that exported products be taxed similarly to those consumed domestically.

Finally, when judged relative to origin-based carbon pricing (or no carbon policy at all), some of the revenues raised by a CFT should be interpreted as a transfer from net exporters of embodied carbon to net importers. As Böhringer, Carbone and Rutherford note, "[carbon] tariffs exacerbate pre-existing income inequalities as (richer) OECD countries shift the burden of emission abatement to (poorer) non-OECD countries." (2013, p. 29). While such transfers might be an effective "stick" in multilateral negotiations and/or induce trade partners to adopt destination-based climate pricing themselves, the distributional implications of climate policies that transfer rents from (predominately) industrializing countries to (predominately) rich industrialized countries should not be dismissed.

With these caveats in mind, whether a CFT is preferable to a production-based policy such as Cap and Trade or a fuel tax ultimately depends on the extent to which equal treatment of traded goods is important. For countries with high trade intensities, putting forward policy that places domestic and foreign-produced goods on an equal footing may be the critical factor determining whether effective climate policy is enacted at all.

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Appendix

A1. Carbon Footprint Tax Accounting

In Section 2 we describe a highly stylized example of a two-industry economy producing generic upstream (U) and downstream (D) goods.

In this Appendix we provide a more concrete example to illustrate how a CFT would be implemented in an economy in which multiple inputs are employed and some inputs are exempt. We build our example on the agricultural industry. Specifically, we consider a stylized example of the production of an apple. As in Section 2, we use t to denote the CFT rate per tonne of CO2e. For simplicity, we limit the set of potential intermediate inputs to electricity (E), metal (M), seeds (S), fertilizer (F), tractors (T), dirt (D), and fossil fuels (P). We consider the production of tractors and apples individually. Tractors are produced from electricity, metal, and fossil fuels; apples are produced from seeds, fertilizer, tractors, dirt, and fossil fuels. Denote the unit requirements of input j used in the production of output i as a_{ij}; these input requirements are given in row 2 of Table 1. The total emissions released during the production of one unit of input j are denoted by e_j. For example, the amount of electricity used in the production of a tractor is given by a_{TE}, and so the corresponding emissions attributed to electricity used in tractor production is $e_E a_{TE}$. Let L_j denote CO2e latent in a unit of input j. We assume latent emissions are zero for all inputs other than fossil fuels, such that $L_P > 0 = L_E = L_S$ etc. Letting e_P denote the emissions released during extraction and refining process, the carbon footprint of a unit of fossil fuels is thus $e_P + L_P$. We assume that tractor and apple production releases all of the carbon latent in fossil fuels employed. Finally, let e_i^j denote the emissions released directly during the production of good i arising from the use of input j. To clarify, e_j represents the emissions released from the production of a unit of input j and e_i^j represents the emissions released when a unit of input j is used in the production of good i. For example, we assume the use of fossil fuels in apple production releases all of the carbon latent in those fuels, such that $e_A^P = L_P$.

We decompose a good's emissions into two categories: direct emissions released during production and emissions embodied in inputs. Following the LCA convention, direct emissions correspond to Scope 1 emissions and embodied emissions capture both Scope 2 and 3 emissions. In our example, direct emissions include those from burning fossil fuels and from land use change (the dirt input for apple production) only.

Table 1 presents a breakdown of the CFT process for an apple. CFT paid by the farmer when purchasing inputs is given in row 4. Row 6 lists the credit the farmer receives for CFT-paid. The consumer of the apple pays CFT on the apple's entire footprint (row 5) to the farmer. The farmer remits to the tax authority the difference between the total product CFT and the CFT paid on inputs, which corresponds to the CFT added by the farmer (row 7).

Table 1: Apple CFT without Exemptions

	Direct Emissions		Embodied Emissions			
	Scope 1		Scope 3			
	Fossil Fuel	Dirt	Fertilizer	Seeds	Tractors	Fossil Fuels
Units Used	a_{AP}	a_{AD}	a_{AF}	a_{AS}	a_{AT}	a_{AP}
Emissions (tCO2e)/ Unit	$e_A^P = L_P$	e_A^D	e_F	e_S	e_T	$e_P + L_P$
CFT Paid	NA	NA	$te_F\, a_{AF}$	$te_S\, a_{AS}$	$te_T\, a_{AT}$	$t[e_P + L_P]\, a_{AP}$
Total CFT on Apple	$t\,[e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P] a_{AP} + e_A^D\, a_{AD}]$					
Total Credit Available	$t\,[\, e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P]\, a_{AP}\,]$					
CFT Added	$t\, e_A^D\, a_{AD}$					

The CFT process for the production of an apple that uses inputs of seeds, fertilizer, tractors, dirt, and fossil fuels. The production process releases emissions from fossil fuel use and land use change (called dirt here). We assume that the use of fossil fuels in production releases all latent emissions in the fuel, so that direct emissions arising from use of fossil fuels is L_P. The tax rate is t and no sectors are exempt from the CFT.

A2. CFT Accounting when an Input is Exempt

We now examine how CFT accounting would work if an intermediate input---tractors---were exempt. We continue to assume fossil fuels, electricity, metal, seeds, and apple production are all non-exempt. One of the purposes of this example is to show how exempting an intermediate input may lead to double taxation if the exempted sector does not “opt-in” to the CFT system. For this, we first provide a breakdown of tractor production, which uses non-exempt inputs of electricity, metal, fossil fuels. As before, we assume that tractor production releases all carbon latent in its fossil fuel inputs.

Table 2 provides the breakdown for tractors. We follow the notational conventions outlined in appendix A1. The tractor producer must pay CFT on all inputs (row 4), but no CFT is levied on tractor purchases.

Table 2: Tractor CFT when Tractors are Exempt

	Direct Emissions	Embodied Emissions		
	Scope 1	Scope 2	Scope 3	
	Fossil Fuel	Electricity	Metal	Fossil Fuels
Units Used	a_{TP}	a_{TE}	a_{TM}	a_{TP}
Emissions (tCO2e)/Unit	$e_A^P = L_P$	e_E	e_M	$e_P + L_P$
CFT Paid	NA	$t\, e_E\, a_{TE}$	$t\, e_M\, a_{TM}$	$t[e_P + L_P]\, a_{TP}$
Total CFT Paid on Inputs	$t[e_E\, a_{TE} + e_M\, a_{TM} + [e_P + L_P]\, a_{TP}] = t\, e_T$			
Tractor Carbon Footprint	$e_T = e_E\, a_{TE} + e_M\, a_{TM} + [e_P + L_P]\, a_{TP}$			

The CFT process for the production of a tractor that is exempt from the CFT. Tractor production uses inputs of electricity, metal, and fossil fuels. We assume that the use of fossil fuels in production releases all latent emissions in the fuel (L_P). The tax rate is t.

Our next table (Table 3) shows the amount of CFT (embodied and direct) that would be attached to apples if tractors were exempt but apples were not. A common result in the literature on VATs is that exempting an intermediate industry leads to double taxation if that industry's output is used as an input by a non-exempt industry. Table 3 confirms that a similar outcome occurs in the case of a CFT. CFT is levied on the total carbon footprint of an apple at the point of sale (row 7). The apple farmer can claim CFT credits on purchases of all non-exempted inputs (row 8). CFT is not levied directly on tractors, so no CFT credit is available to the farmer for the tax embodied in tractors. The result is that the emissions embodied in tractor production are double taxed (row 9).

Table 3: Apple CFT when Tractors are Exempt

	Scope 3 Emissions			
	Fertilizer	Seeds	Tractors	Fossil fuels
Units Used	a_{AF}	a_{AS}	a_{AT}	a_{AP}
CFT Paid on Input	$t\, e_F\, a_{AF}$	$t\, e_S\, a_{AS}$	*NA*	$t[e_P + L_P]a_{AP}$
CFT Included in Gross Input Price	$t\, e_F\, a_{AF}$	$t\, e_S\, a_{AS}$	$t\, e_T\, a_{AT}$	$t[e_P + L_P]a_{AP}$
Direct Emissions from Apple Production	$e_A^P\, a_{AP} + e_A^D\, a_{AD} = L_P\, a_{AP} + e_A^D\, a_{AD}$			
CFT on Purchase of Apple	$t\, e_A = t[e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P]\, a_{AP} + e_A^D\, a_{AD}]$			
Total Credit Available to Apple Farmer	$t[e_F\, a_{AF} + e_S\, a_{AS} + [e_P + L_P]\, a_{AP}]$			
CFT Included in Gross Apple Price	$t\, e_A + t e_T\, a_{AT} = t[e_E\, a_{AE} + e_S\, a_{AS} + 2e_T\, a_{AT} + [e_P + L_P]\, a_{AP} + e_A^D\, a_{AD}]$			

The CFT process for the production of an apple if tractors are exempted from the CFT. The top panel shows the CFT process for all apple inputs. The bottom panel shows the CFT process for an apple. Tractors are not directly taxed and no CFT credit is available to the apple farmer for the CFT embodied in tractors. Exempting tractors from the CFT leads to over taxation of the apple's carbon footprint.

A3. CFT Accounting when a Downstream Industry is Exempt

The final variant we consider has both the apple and tractor industries exempt from the CFT. The CFT accounting associated with tractors is as given in Table 2 above, while that for apples is given by Table 4 below. Table 4 shows that exemption of the intermediate input (tractors) and final product (apples) results in land use change emissions from apple production being untaxed (row 9).

Moreover, as noted in Section 2, when a downstream firm is exempt from the CFT, the CFT levied on its inputs is not reimbursable. The result is that domestic producers of an exempt good would face higher production costs than producers of a substitute good in a policy-inactive country. In this example, assuming the same before-tax production costs and a competitive apple industry, an apple produced in a policy-inactive country would cost $t[e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P]\, a_{AP}]$ less than a domestically produced apple, regardless of whether it was purchased domestically or abroad.

Table 4: Apple CFT when Tractors and Apples are Exempt

	Scope 3 Emissions			
	Fertilizer	Seeds	Tractors	Fossil fuels
Units of Input Used	a_{AF}	a_{AS}	a_{AT}	a_{AP}
CFT Paid on Input	$t\, e_F\, a_{AF}$	$t\, e_S\, a_{AS}$	*NA*	$t[e_P + L_P]a_{AP}$
CFT Included in Gross Input Price	$t\, e_F\, a_{AF}$	$t\, e_S\, a_{AS}$	$t\, e_T\, a_{AT}$	$t[e_P + L_P]a_{AP}$
Direct Emissions from Apple Production	$e_A^P\, a_{AP} + e_A^D\, a_{AD} = L_P\, a_{AP} + e_A^D\, a_{AD}$			
Apple Carbon Footprint	$e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P]\, a_{AP} + e_A^D\, a_{AD}$			
CFT Included in Gross Apple Price	$t[e_F\, a_{AF} + e_S\, a_{AS} + e_T\, a_{AT} + [e_P + L_P]\, a_{AP}]$			
Untaxed Emissions of an Apple	$e_A^D\, a_{AD}$			

The CFT process for the production of an apple if tractors and apples are exempt from the CFT. The top panel shows the CFT process for all apple inputs. The bottom panel shows the CFT process for an apple. Apples and tractors are not directly taxed and no CFT credit is available to the apple or tractor producers for CFT paid on inputs. Exempting tractors and apples from the CFT leads to under taxation of the apple's carbon footprint.