NBER WORKING PAPER SERIES

CARBON TARIFFS 101

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Working Paper 33024
http://www.nber.org/papers/w33024

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
October 2024

Thanks to Matt Ashenfarb, Joyce Bond, Jevan Cherniwchan, Brian Copeland, Josh Ederington, Kyle Meng, Gib Metcalf, and Jinhua Zhao for helpful insights and careful reads. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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JEL No. Q5, Q56

ABSTRACT

We evaluate the economic and environmental consequences of taxes on imported goods based on their carbon content. The analysis uses the simplest possible partial equilibrium framework, with one small open economy and a global pollution externality. It relies on graphs of supply and demand, rather than equations or formulas, hoping to reach readers familiar with basic economics. Despite its simplicity, the framework imparts numerous lessons. (1) Absent a domestic price on carbon, a carbon tariff imposes the same costs on domestic consumers as a domestic carbon price, but a carbon tariff also subsidizes domestic pollution. (2) If one small country imposes a carbon tariff, with or without a domestic carbon tax, the economic incidence of the tariff falls on its consumers. (3) If a holdout country joins the rest of the world by enacting its own carbon regulation and consequently imports more from other countries, those increased imports are not “leakage.” They are the cessation of leakage from when the holdout country’s policy was lax. And (4) if other countries do not appropriately regulate emissions, no single small country can use a combination of carbon taxes and carbon tariffs to fully correct the problem caused by its consumers or producers.

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Introduction

Carbon tariff proposals are trending. The European Union's Carbon Border Adjustment Mechanism (CBAM) started collecting data in October 2023 and will begin collecting payments in 2026. The United Kingdom plans to implement a CBAM starting in 2027. Canada, Japan, and the United States have considered similar measures.

All the proposals involve fees charged to imports based on estimates of the carbon or other greenhouse gases (GHGs) that result from their production. Beyond that common thread, proposals differ. Some closely link tariff rates to domestic carbon prices of the importing country, such as pollution tax rates or cap-and-trade permit prices. Other proposals link carbon tariffs to domestic nonprice regulations of the importing country, such as technology standards, pollution limits, or subsidies for carbon abatement. A third set would levy tariffs on the carbon content of imports without reference to domestic carbon policies of any kind.

To evaluate the economic and environmental consequences of carbon tariffs in general, we describe the fundamentals of international trade and tariffs when there is a global pollution externality. We rely on graphs rather than equations or formulas, hoping to reach any reader familiar with the basic economics of supply and demand. Our models are partial equilibrium in that we consider only one market at a time, ignoring interactions. We assume tax and tariff revenues are refunded without affecting prices. And we assume the country imposing the carbon tariff is small relative to world markets, to avoid the complications that would arise if one country's tariff rates affected world prices for its imports. We limit the analysis to importing countries because they are the ones enacting the carbon tariffs, recognizing that a whole different set of issues faces countries confronting carbon taxes on their exported products.

We start with a textbook demonstration of the deadweight loss of tariffs: the loss to consumers exceeds any gains to domestic producers and tax revenues. In the standard setup, a tariff on imports is economically equivalent to a domestic consumption tax *plus* a domestic production subsidy. We then add an unregulated global externality, like carbon pollution. Analogously to the standard setup, a tariff assessed on the carbon content of imported goods is economically equivalent to a domestic carbon tax *plus* a subsidy for domestic carbon pollution.

If one small country enacts its own domestic carbon tax, its domestic producers lose more than any tax revenues the country gains, and the environmental benefit is mostly offset by increased pollution elsewhere. The climate policy jargon is "leakage." A domestic carbon tariff can offset leakage, benefiting the global environment by shifting the cost from mobile domestic producers to immobile domestic consumers.

If all countries except one impose the appropriate taxes, the one holdout enjoys a comparative advantage based on mispriced externalities. It gains market share and employment opportunities thanks to being the recipient of the rest of the world's leakage. If the holdout begins regulating pollution, that must be good for the climate. Any resulting movement of production from the newly regulating holdout to countries already appropriately regulating pollution will reduce global emissions. So we don't call that leakage; it's the reversal of previous leakage due to the holdout's previously insufficient policy.

The welfare and environmental effects of a carbon tax depend on whether pollution intensities vary across countries and whether other countries' domestic carbon taxes cover part or all of their own emissions' marginal global damages. If the carbon price set by other countries is insufficient to account for the full externality, a single country using a combination of taxes and tariffs discounted by foreign carbon prices can only partially address the problem, not fully correct it.

Our paper joins a long list describing how Pigou's simple idea of taxing pollution is complicated when the pollutant is global and goods trade freely across borders. Markusen (1975) provides an early example with trade between two countries, where one uses taxes and tariffs to regulate a cross-border externality. In his model, unlike ours, the taxing country's taxes and tariffs affect world prices, complicating the analysis. The tax setter has two goals: manipulating the terms of trade and internalizing the externality. With trade, the economic incidence of taxing demand is not identical to the incidence of taxing supply. As a result, the second-best system for one country that can only tax its own residents would be to levy pollution taxes on both sides of the market. That insight also holds for our simpler case with one small country that takes world prices as given.

Like Markusen, Weisbach et al. (2023) model bilateral trade between two countries, where the behavior of each affects world prices. As with our approach, they illustrate their analysis with a set of simple demand and supply curves, providing helpful intuition for Markusen's conclusions that taxing both production and consumption is preferred to taxing either alone. Our setting is much simpler, which we believe has its own merits, both as an illustrative tool to consider carbon tariffs alone and as a baseline against which to consider the more complex settings.

Kortum and Weisbach (2017), Morris (2018), Böhringer et al. (2022), Jakob et al. (2022), and Clausing and Wolfram (2023) provide current overviews of some of the legal and practical obstacles absent from our simple model. And Campolmi et al. (2024) suggest a clever alternative they call a leakage border adjustment mechanism (LBAM), designed to overcome some of those obstacles.

Empirical evidence indicates that fears of leakage are overblown. Dechezleprêtre and Sato (2017) survey decades of studies showing that tightening environmental regulations have not shifted pollution-intensive production to countries with less strict policies. Nevertheless, alarms about potential leakage form the basis for much of the rhetoric opposing domestic climate regulations and many of the arguments in favor of proposed carbon tariffs. It's worth thinking carefully about how these two important policies interact.

Carbon Tariffs in Theory

Before adding global pollution externalities, we start with basic trade theory found in undergraduate economics texts (see, e.g., Krugman et al. 2022). This is one version of the classical argument for free trade and against tariffs.

Basic trade theory and tariffs

Without international trade, each country's own supply and demand determine its price for each good. Figure 1a depicts that case. Country i's supply S_i represents the marginal cost of producing q_i. Demand D_i represents the marginal benefit. They intersect at quantity q_i^* and domestic price P_i^*.

With open and free international trade, the global price will be determined by world demand and supply, the sums of countries' individual demands and supplies: $D_W = \sum D_i$ and $S_W = \sum S_i$. Figure 1b shows the resulting world price P_W at which the good is available everywhere, including as depicted in country *i*.

As drawn in Figure 1a, country i's domestic price without trade, P_i^*, would be higher than the world price with trade, P_W, which means the good can be produced less expensively abroad and will therefore be imported. Because of low-cost imports, consumers in country *i* will demand more of the good (quantity q_i^D rather than q_i^*). But also because of low-cost imports, domestic suppliers will lose sales and domestic production will be lower (quantity q_i^S rather than q_i^*). At the world price P_W, imports will make up the difference between domestic supply q_i^S and domestic demand q_i^D.[1]

Now consider what happens if country *i* imposes a tariff τ, raising the cost of imports from P_W to $P_W + \tau$ in Figure 1a. The higher price shrinks imports for two reasons. Domestic demand falls to $q_{i,\tau}^D$ because of the higher prices. And domestic supply increases to $q_{i,\tau}^S$ because the tax on foreign goods means domestic producers can charge higher prices.

As a result of the tariff, domestic producer surplus increases by ΔPS_τ—the area between the old price P_W and the new price $P_W + \tau$ up to the supply curve. And the government earns tariff revenue, R_t, which we assume gets spent on goods and services consumers value. But domestic consumer surplus shrinks by the whole polygon $\Delta CS = \Delta PS_\tau + a + R_\tau + b$—the area between old price and new price up to the demand curve.

On balance, the tariff results in lost consumer surplus that exceeds the tariff revenue and gains in producer surplus by the amount of the two deadweight loss triangles, *a* and *b*. The first, *a*, represents the fact that some of the output, $q_{i,\tau}^S - q_i^S$, is produced in a way that is inefficiently

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[1] If the world price P_W were above the level where country i's *S* and *D* curves crossed, q_i^S would exceed q_i^D, and country *i* would export *q*.

costly, by domestic producers rather than foreign producers. The second, *b*, represents the fact that domestic consumers pay higher prices for less of the product.

Importantly for our later discussion, the tariff τ in Figure 1a is economically equivalent to a domestic consumption tax of τ, combined with an equal domestic output subsidy of τ. The consumption tax would raise the price paid by residents of i by τ, causing a reduction in demand to $q_{i,\tau}^{D}$ and a deadweight loss of *b*, just as with the tariff. The domestic output subsidy would cost the government outlays equal to the rectangle $\Delta PS_\tau + a$ and benefit producers by the amount ΔPS_τ, leaving a deadweight loss of *a*, just as with the tariff.

In this textbook case, the costs of a tariff exceed the benefits. But the standard textbook case ignores pollution, the central rationale for carbon tariffs.

Trade theory with pollution

To add pollution, consider that producing q causes a damaging global pollutant, greenhouse gases (GHGs). Countries' supply curves, S_i, represent the *private* marginal cost to producers. That ignores pollution, an externality with costs borne by people everywhere affected by GHGs and the resulting climate change. Those external global costs are depicted in Figure 2 by the vertical difference between private marginal cost S_i and the curves labeled *MSC* representing the marginal *social* cost of production, the social cost of carbon. The *MSC* curves include both the private and external costs.

With no carbon pricing in country i or the rest of the world, producers and consumers disregard the pollution externality. Globally, in Figure 2b, production will be at Q_W, which is higher than the socially optimal quantity Q_W^* where marginal social costs equal marginal benefits. Without some sort of regulation, tax, or international agreement, the world would overproduce the good and suffer too much pollution. That overproduction is depicted by the standard deadweight loss triangle, vertically striped in Figure 2b. For all the extra global production between Q_W^* andQ_W, social marginal costs exceed the marginal benefits depicted by the demand curve.

The global overproduction also translates to overproduction in country i, which faces world price P_W. Domestic firms produce q_i^S based on their private marginal costs when the socially optimal quantity to produce would have been lower at q_i^{S**}. This overproduction results in a deadweight depicted by shaded triangle *c*, because for every unit of extra production, the social cost of producing (reflected in MSC_i) exceeds the revenue received from selling (P_W).

One subtlety in Figure 2 requires clarification. To add pollution to the framework described in Figure 1, we need to redefine the good, *q*. The simplest way to do that, and the approach we follow here, is to consider *q* to be a good for which pollution is an unavoidable one-for-one consequence of production. Then it is irrelevant whether we measure *q* in units of the good itself (tons of steel or gallons of gasoline) or in units of pollution (GHGs). One is a multiple of the other. And it doesn't matter whether we think of the pollution problem as stemming from overproduction or overconsumption. The only way to abate pollution in this framework is to produce and consume less of the good. Changes in the quantity *q* on the bottom axes of the figures represent changes in consumption of the good and, equivalently, changes in the amount of pollution. Each ton produced is a ton consumed and results in the same climate damage. By illustrating the externality as a marginal social cost above the supply curve, Figure 2 depicts the problem on the production side.

A more detailed model would allow producers to adjust the pollution intensity of their processes—the pollution per unit of output. Then efforts to reduce GHGs would not necessarily reduce consumption of the product q one-for-one. In response to a tax on pollution, producers could reduce emissions per unit of output, shrinking the gap between MSC_i and S_i in Figure 2. That could be accommodated by interpreting q as the carbon embodied in goods and services and D and S as the derived demand and supply curves for GHGs. That interpretation complicates some of the applications we describe below, without changing fundamental insights. Appendix Figure A1 describes that situation.

Another simplification we adopt, for now, is to assume that the vertical difference between S and MSC is the same for country i in Figure 2a as for the world in Figure 2b. Producing a ton of steel anywhere causes the same marginal damage. In extensions below, we consider cases where producing q in country i involves different pollution damage than producing q in the rest of the world.

However we think of pollution, as a fixed or flexible input and as equally or differently pollution-intensive in various countries, the natural and simple solution prescribed by economists since Pigou (1920) would be a tax: require producers of q to pay a pollution tax—a carbon tax—equal to the difference between S_i and MSC_i. In this context, with q traded internationally, that solution is not so straightforward.

A unilateral domestic carbon tax

Suppose that country i enacts a domestic carbon tax t as depicted in Figure 3. It charges its own producers a tax equal to the global marginal external cost of producing q_i. Producers would receive P_W in revenue for each unit of q_i produced and sold, but then would pay t in taxes, to net $P_W - t$.

Facing such a tax, producers in country i would reduce supply and pollution. Because the tax is set to equal the damages of pollution, the resulting production equals the optimal level from Figure 2a, q_i^{S**}. With the world price unaffected from country i's perspective, consumers in i would continue to demand q_i^D, so imports would increase by an amount sufficient to offset the loss of domestic production. That's leakage.

Here's where the small-country simplification needs a slight tweak. It's convenient to think about P_W staying unchanged from the perspective of country i. If the rest of the world has constant marginal production costs, that's realistic, but if not the reduction in i's supply shifts the world supply curve in Figure 2b to the left slightly. That increases the world price, also slightly, reducing other countries' demands and increasing other countries' supplies, relative to what would happen if P_W were truly unchanged.[2] Put differently, the combination of reduced demand and increased supply in other countries accounts for the increased imports to country i depicted in Figure 3. The portion of those increases that comes from increased supply rather than decreased demand is carbon leakage.

From the perspective of country i, carbon leakage means that country i's carbon tax has imposed costs on its producers but accomplished little. Its consumers are no better or worse off, still consuming q_i^D and paying P_W. The only difference is that a larger share of their consumption is imported. The government gains revenue R_t, but producers in i have lost producer surplus equal to $R_t + d$. Country i thus suffers a net loss of d, while its abatement efforts are undermined by

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[2] See Bradford (1978) for this insight in a standard trade model without the global externality.

increased emissions elsewhere.[3] This type of costly and ineffectual climate effort—carbon leakage—is what carbon tariffs are meant to prevent.[4]

A unilateral carbon tariff to complement a carbon tax

To combat leakage from its carbon tax, country *i* might impose a carbon tariff as depicted in Figure 4 (Fontagné and Schubert 2023, McKib). It charges a tariff τ on imports equal to the domestic carbon tax, *t*. As drawn, both fees also equal the marginal global social cost of pollution, though that's not necessary. The cost of imported goods becomes equal to the world price plus the tariff, $P_W + \tau$, and domestic producers can charge that as well. Faced with the higher price of $P_W + \tau$, domestic consumers reduce demand to $q_{i,\tau}^D$. If the tariff were the only change, domestic producers would increase output, as in Figure 1. But in this case, domestic producers also face the domestic carbon tax. If the tariff and tax are set equal, $P_W + \tau - t = P_W$, and producers earn the same net revenue per unit as without the tax and tariff.

In this example, the carbon tariff τ and the equal domestic carbon tax *t* exactly offset one another. Leakage is halted, but country *i*'s producers do not do anything different than they would have with neither the tax nor the tariff. The pollution benefits of the carbon tax and tariff are apparent only on the consumption side of the ledger. Country *i*'s consumers reduce demand for the polluting product.

Two key features differentiate this case from the protectionist tariff in Figure 1. First, the carbon tariff is matched to a domestic carbon tax of equal magnitude. So domestic producers and importers face the same costs, and there's no deadweight loss like *a* in Figure 1 from producing *q*

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[3] In fact, depending on the pollution intensity of the production of imports, emissions globally could rise, a scenario we turn to later.

[4] For completeness, Appendix Figure A1 describes carbon leakage in the more complicated case where pollution is a flexible input to producing *q*.

in an inefficiently costly way. And second, although domestic consumers purchase less q at higher prices, losing the same consumer surplus as in Figure 1, that consumer cost in this case has offsetting global benefits from the reduction in GHG damages. The reduction in consumption from q_i^D to $q_{i,\tau}^D$ leads to a loss in consumer surplus of *b*, but the avoided external pollution costs amount to a gain of $b + f$, so the net gain is represented by *f*.

Recall that in the previous case, without the tariff, the carbon tax burden fell on producers, causing leakage as consumers were able to costlessly switch to imports. Here the carbon tariff offsets leakage, benefiting the global environment by shifting the cost of addressing climate problems from domestic producers to domestic consumers. To prevent leakage, the carbon tariff removes the incentive for firms to relocate production by switching the burden of the carbon tax onto the consumers who cannot easily move their consumption abroad.[5] In fact, in our simple case where production and consumption are inextricably proportional to pollution, the combination of a domestic carbon tax plus a carbon tariff is equivalent to a consumption-based carbon tax (McAusland and Najjar 2015).

Some carbon tariff proposals, however, involve tariffs by themselves, without an associated domestic carbon price. We turn to that situation next.

A carbon tariff alone

Figure 5 depicts the case in which country *i* imposes a carbon tariff τ but no domestic carbon tax *t*. As in Figure 1, the tariff raises revenue R_τ and reduces domestic consumption. Unlike in Figure

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[5] If pollution is a flexible input to q, rather than occurring one-for-one, then domestic producers may be able to reduce their tax bills in ways in which importers cannot reduce their carbon tariffs. Domestic producers may deploy abatement technologies or use cleaner inputs to reduce their demand for q_i. Importers may not, either because tariffs τ are calculated in such a way that would fail to reflect those efforts or because country *i* is too small in world markets to make those investments worthwhile. That breaks the equivalence between *t* and *τ*.

1, however, in Figure 5 the deadweight loss from reduced consumption (*b*) is more than offset by the gain from reduced pollution ($b + f$), leading to a net gain of *f*. In both cases, the tariff works by reducing consumption of q, whether or not the tariff is linked to a domestic carbon price.

On the producer side, the carbon tariff increases domestic production, leading to an inefficiency loss of a, just as in the textbook tariff case in Figure 1. However, the tariff-only carbon policy also involves a sort of "reverse leakage." The carbon tariff increases pollution from country i by replacing some imports with domestic production. If pollution per unit of production is the same everywhere, there would be no change in emissions from the shift. However, country i is producing the good at marginal cost $P_W + \tau$, rather than just P_W, forgoing the comparative advantage associated with imports. The deadweight loss from producing domestically rather than importing is triangle *a* in Figure 5. Considering both the consumption and production sides, the net effect of the tariff is $f - a$.

Importantly, the carbon tariff τ in Figure 5 is economically equivalent to a domestic carbon consumption tax of τ combined with an equal domestic carbon pollution *subsidy*. A carbon consumption tax would reduce consumption in country i, with lost net consumer surplus of *b*, because the decrease in consumer surplus ($\Delta PS_\tau + a + R_\tau + b$) exceeds the gain in government revenues ($\Delta PS_\tau + a + R_\tau$). Accounting for the reduced global damages of $b + f$, this leaves a net gain of *f*, just as with the tariff. The domestic carbon subsidy would increase domestic production to $q_{i,\tau}^S$, cost the government outlays equal to $\Delta PS_\tau + a$, and increase producer surplus by ΔPS_τ, leaving a deadweight loss of a, just as with the tariff. The net benefit of the consumption tax and production subsidy is also $f - a$.

That last point is worth reiterating. A unilateral carbon tariff, without an accompanying domestic carbon tax, is equivalent to a domestic carbon tax *plus a domestic pollution subsidy*. We expect that economists and environmentalists would have similar antipathy to subsidizing pollution.

In Figure 5 demand and supply curves have approximately the same slopes, so the size of the loss a is approximately the same as the gain f. A tariff-only carbon policy does achieve the same gain from reducing domestic consumption. But it also relocates to domestic production the pollution that would have otherwise been emitted elsewhere. This is reverse leakage, or onshoring pollution. The onshoring does not provide any global environmental gain or cost because we assume domestic and foreign production have the same pollution intensity. Later, we address the case where domestic production of q is less carbon-intensive than world production, so that onshoring q has a global benefit.

Remember, the convenience that P_W is unchanged from the perspective of i cannot hold globally. The tariff has decreased global demand and increased global supply. The world price must fall, perhaps imperceptibly in Figure 4, but enough to increase global demand to absorb the extra supply from i, above and beyond i's reduced demand.

One more point before we turn to the case in which other countries have their own domestic carbon taxes. If one small country i imposes a carbon tariff τ, with a complementary domestic carbon tax t as in Figure 4 or without a domestic carbon tax as in Figure 5, all the incidence of the tariff will be borne by consumers. The price of good q in country i rises by the amount of the tariff. That contrasts with what happens when other countries have their own carbon taxes, which we turn to next.

A world carbon tax

Suppose the rest of the world does impose a carbon price so that the world price P_W^* depicted in Figure 6 corresponds to the intersection of world demand and marginal social cost, as depicted in Figure 2b. If country *i* does not have its own carbon tax, it will produce q_i^S, at which point the *MSC* of producing output exceeds the revenue from selling it, P_W^*. This excess production represents leakage from the rest of the world to country *i* because it is the only one failing to regulate the carbon externality. The deadweight loss from this overproduction is the shaded area a.

If country *i* joined the rest of the world and imposed a carbon tax *t*, shrinking its supply from q_i^S to $q_{i,t}^S$, imports would increase to $q_i^D - q_{i,t}^S$. Those increased imports would not be leakage. They would reverse the leakage from the rest of the world to *i* and eliminate the deadweight loss a.

At that point, every country has internalized the externality. Globally, the marginal cost of producing the last unit, including external GHG damages, equals the marginal benefit received by the last consumer. Production is cost-effective and the allocation of resources is economically efficient. There's no leakage because every country has imposed the same carbon tax. A carbon tariff is unnecessary.

If country *i* were to impose a carbon tariff anyway, despite other countries' having their own carbon taxes, domestic prices would rise from P_W^* to $P_W^* + \tau$. The consequences would parallel those in Figure 1, leaving a deadweight loss of the tariff equal to the two shaded triangles *a* and *b*. Unlike the case in Figure 1 where pollution played no role, in this case there is an offsetting gain. The reduction in consumer demand q_i^D reduces the global externality by *b* and *f*. In this case in Figure 6, where country *i* imposes a carbon tariff despite a world carbon tax, *b* + *f* depicts gains from GHG reduction above and beyond the efficient amount at which global marginal benefits equal social costs. Even though abatement exceeds the global optimum, it nevertheless represents a gain.

As drawn, the gain from excessive abatement, b and *f*, approximates the losses represented by triangles a and b. Whether the gains exceed the losses depends on whether area *f* exceeds area a, which in turn depends on whether the elasticity of demand exceeds the elasticity of supply. If the demand is more elastic than supply, *f* can exceed a, and the carbon tariff has net global benefits. If demand is less elastic than supply, the reverse is true, and the tariff would impose net global costs. Either way, the losses accrue to country i, while the gains from pollution reduction benefit the world.[6]

Many proposals for carbon tariffs would discount the tariffs charged to imports based on the carbon taxes levied by the exporting countries. In the case depicted in Figure 6, that would reverse the carbon tariff entirely. Country *i* would charge a tariff τ on imports, less refunded taxes *t*, and since by construction $t = \tau$, that would return the price received by imports to the world price P_W^*.

In this example, carbon tariffs accomplish little, with or without a refund for carbon taxes already paid. Without the refund, domestic losses from production and consumption inefficiencies approximately offset the global gains from reduced GHGs and almost certainly outweigh any domestic gains. With the refund, the tariff and refund exactly offset one another.

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[6] Because a world carbon tax would be efficient, adding one country's tariff must reduce global welfare. The welfare loss would result from small decreases in consumer and producer surpluses in all the other countries that in sum exceed the pollution gains depicted in Figure 6. From the perspective of one small country, that loss would not be evident.

But what if the world's carbon taxes are insufficient, and country *i* wants to do its part and impose a meaningful carbon tax? We explore that case next.

A world carbon tax that is too small

Now suppose the rest of the world imposes a carbon tax that is smaller than the global social cost of carbon, depicted in Figure 7 as $t' < t$. The world price faced by country *i* is therefore lower than would be optimal, at P_W' rather than P_W^*. Keen and Kotsogiannis (2014) explore this situation mathematically, finding that optimal carbon tariffs account for differences in carbon prices. Here we offer graphical intuition for their result.

If country *i* imposes a domestic carbon tax of the appropriate magnitude, *t*, but no tariff, the situation is similar to Figure 3 but starting at the lower price P_W' rather than P_W. Consumers are no better or worse off, still consuming q_i^D and paying P_W'. The government gains carbon tax revenue R_t, but producers in *i* have lost producer surplus equal to $R_t + d$. Domestic emissions shrink but are replaced by an offsetting increase in emissions from imports, or leakage. Country *i* thus suffers a net loss of *d* while achieving no global reduction in emissions.

If country *i* imposes a tariff *τ* equal to its domestic carbon tax *t*, the domestic price in *i* will rise to $P_W' + \tau$, as shown in Figure 8. On the consumption side, just as in Figure 5 the tariff τ reduces the quantity demanded. Consumer surplus declines by more than the increase in producer surplus and tariff revenue, but pollution damages more than make up for that loss, leading to a net benefit, the large diagonally striped triangle in Figure 8. On the supply side, the tax and tariff would offset each other, and producers would net P_W' and supply $q_i^{S'}$, as they would if faced with neither the tax *t* nor the tariff *τ*.

The difference between this scenario and the one in Figure 5 is that here the rest of the world imposes a partial carbon tax t', so the initial world price, P_W', already accounts for some of the externality. Adding the full cost of the externality in the form of a tariff τ on top of a world price that already accounts for some of the externality (t') would mean that imports face taxes $\tau + t'$, which exceed their marginal climate damages and exceed the taxes paid by domestic producers $t = \tau$. By not accounting for the partial world carbon tax—setting the tariff at τ rather than $\tau - t'$— the tariff reduces domestic consumption by too much, down to $q_{i,\tau}^D$ and increases domestic supply by too much, up to $q_i^{S'}$.

The resulting costs of hiking the tariff above $\tau - t'$ mirror the even larger costs from the even more excessive tariffs in Figure 6. Consumer surplus declines by more than the increased producer surplus and tariff revenue ($\Delta\mathrm{PS} + \Delta\mathrm{R}_t$). But reduced climate damages more than compensate, resulting in a net gain represented by the small dark-shaded triangle *f* in Figure 8, a subset of the larger diagonally striped triangle.

On the supply side, larger carbon tariff τ rather than $\tau - t'$ would increase domestic output to $q_i^{S'}$, exactly what they would have produced with no tariff and no carbon tax. But without a tariff or carbon tax, that increased domestic production would represent inward leakage to country *i* from countries that do impose a carbon tax. That leakage results in producer surplus for country *i* but a loss because *q* is produced at higher cost in *i* rather than being imported from the appropriately regulated foreign producers, a deadweight loss shown as the dotted triangle *a* in Figure 8.

As in Figure 5, the excess tariff means producers of imported goods pay higher carbon taxes than producers of domestic goods, yielding net carbon benefits *f* offset by a loss of comparative advantage a. And as in Figure 5, if supply and demand curves have the same slopes, the loss and gain are of similar size. In practice, which is larger would depend on the elasticities of supply and demand.

In sum, Figure 8 depicts the case in which the rest of the world has imposed an insufficient carbon tax, while country *i* has imposed an efficient carbon tax *t* equal to the external costs of producing q. Ignoring that difference would result in leakage from *i*. Producers in *i* would supply too little, and consumers in *i* would demand too much. A tariff $\tau = t$ would overshoot that mark, resulting in leakage to *i*. Consumers would demand too little and suppliers would produce too much. A tariff $\tau - t'$ that accounts for foreign carbon taxes paid would help, But that subtraction cannot correct the global mispricing. [7]

Imports that are more carbon-intensive

Finally, suppose that country *i* can produce *q* using less carbon than the rest of the world. The setup is depicted in Figure 9, where the gap between the supply curve and the marginal social cost is smaller in *i* than in the world. With no global carbon tax, the world price P_W would be artificially low because of a mispriced externality, leading to the usual global deadweight loss triangle, shaded in Figure 9b.

If producers in *i* faced a domestic carbon tax *t* based on the damages caused by their carbon emissions, they would produce less, $q_{i,t}^S$ rather than q_i^S. That would reduce their producer surplus

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[7] Deducting foreign carbon taxes has the additional benefit of incentivizing other countries to impose or raise their own carbon taxes. Note that unless foreign carbon taxes were all equal, deducting foreign carbon taxes paid from carbon tariffs charged would not bring producers' net revenues down to the efficient price P_W^*. The difference between the ideal world price P_W^* and the actual world price is not the same as the gap between the world carbon tax *t'* and the externality *t*. The difference between *t*' and *t* is mechanical, but the difference between P_W' and P_W^* depends on the relative elasticities of the world supply and demand curves.

and generate tax revenue R_t with a net loss of *d*. Imports would increase to offset the loss of domestic production, and any gain from reduced pollution by producers in *i* would be offset by leakage, increased pollution from importers. If the domestic and foreign pollution intensities were equal, as in Figure 3, that offset would be a wash, and the net loss from the carbon tax would be triangle *d*.

But if foreign production were more carbon-intensive, the exchange of country i's output from q_i^S to $q_{i,t}^S$ for an equal quantity of imported goods would yield a small reduction in domestic pollution but a large increase in foreign pollution. The environmental benefit of reducing domestic emissions is depicted as the solid shaded box in Figure 9a. The environmental cost of increased foreign emissions to produce imports to *i* is depicted as the larger outlined rectangle. Then the net *cost* of country i's carbon tax would be the deadweight loss of the tariff *d* plus the increased damages from foreign pollution (the outlined rectangle), less the gain from reduced domestic pollution (the shaded box). Because area *d* equals half of the shaded box (to a linear approximation), the net cost of the carbon tax is the diagonally striped polygon. In this example, leakage means the carbon tax is worse than useless. It is environmentally counterproductive.

A tariff τ equal to the domestic carbon tax *t* would eliminate the counterproductive leakage from country i's carbon tax. It would move the net price received by country i's producers from $P_W - t$ back up to P_W and return quantity from $q_{i,t}^S$ back up to q_i^S. Production would relocate to the country able to produce in a less emissions-intensive way, benefiting the global environment. The net gain from the tariff would be the diagonally striped polygon: the gain from eliminating deadweight loss d (or equivalently half of the shaded box) plus the difference between domestic and foreign emissions.

On the demand side of Figure 9, a tariff τ equal to country i's carbon tax *t* would raise the price faced by domestic consumers to $P_W + \tau$ and reduce their demand to $q_{i,\tau}^D$. The net benefit from the consumption reduction resulting from this tariff $\tau = t$ is therefore the dotted polygon in Figure 9(a). That's the rectangle representing reduction in pollution by importers, less the usual net loss of consumer surplus in excess of tariff revenues, area *b*.

Overall, this tariff τ equal to the domestic carbon tax *t* would have benefits equal to the two polygons. The diagonally striped one on the left results from producing more of world output in country i, where production is less carbon-intensive. The dotted one on the right results from demanding less of this good with a high global external cost. In this case, both the production and the consumption sides generate environmental gains.

But Figure 10 shows that country *i* could do better. A tariff τ_w equal to the *global* external damage from producing q, rather than country *i's* own damages or carbon tax *t*, would expand country i's production of q all the way to $q_{i,\tau W}^S$, and because it would raise the price faced by consumers in i, it would reduce their consumption all the way down to $q_{i,\tau W}^D$.

Without accounting for pollution, the tariff τ_w results in the usual deadweight loss triangles, shaded and labeled *b* on the consumer side and *a* on the producer side, just as in Figure 1. But the reduction in consumption yields global environmental benefits *b* + *f*, for a net gain of *f* on the consumer side, just as in Figures 4 and 5.

On the producer side, though, things look different. The increase in domestic production to $q_{i,\tau W}^S$ results in increased damages from domestic emissions equal to the bottom solid outlined rectangle and an offsetting decrease in foreign emissions from imports equal to the entire square, dashed and solid, with height τ_W and width $q^S_{i,\tau W} - q^S_{i,t}$. The net environmental gain from the tariff is thus the top diagonally striped rectangle.

In this case, with foreign pollution intensities larger than domestic, the typical welfare losses of a tariff (a and b) are both compensated by large environmental gains. The total net gains are represented by the triangle *f* plus the diagonally striped rectangle minus the deadweight loss triangle a. As in the simpler case in Figure 4, country i's carbon tariff offsets leakage, benefiting the global environment by shifting the cost of addressing climate problems from domestic producers to domestic consumers, effectively subsidizing domestic pollution. But here, because production in country *i* is cleaner than elsewhere, the tariff yields climate benefits not only by reducing consumption but also by onshoring production to the tariff-setting country, where it is cleaner.

While the theory described by Figures 1–10 illustrates a number of key principles, it leaves many topics related to carbon tariffs undiscussed. Some can be analyzed with extensions to the model, and some are too complex for that but deserve mention as caveats to the principles outlined so far.

Discussion: Complications and Extensions

Complications and extensions include the possibility that carbon intensities may vary across producers within exporting countries, leaving open a problem described as "export shuffling." Another is that many countries, including the United States, have domestic regulations that are not price-based. Yet another is that many countries regulate emissions not by taxing carbon emissions, but rather by subsidizing carbon abatement. And finally, for large countries like the United States, carbon tariffs or abatement subsidies may affect world prices.

Export shuffling

For most of the cases we described so far, we have assumed that carbon intensities—the link between output q and pollution—are the same everywhere. In Figures 9 and 10, we considered the possibility that they vary across countries. In practice, though, carbon intensities also vary across firms within countries. Countries levying carbon tariffs must choose to calculate tariffs either at the firm level, based on the exporting firm's carbon intensity, or at a more aggregate level based on the average carbon intensity for that firm's industry in that country.

A firm-specific carbon tariff could be evaded by what is called export shuffling, in which low-carbon firms export to the countries with carbon tariffs, and high-carbon firms produce for domestic consumption or for export to countries without carbon tariffs. The alternative to a firm-specific tariff would be a tariff based on the importing industry's average emissions intensity. A tariff on average emissions reduces the incentive for individual foreign firms to reduce emissions. That trade-off between preventing export shuffling and incentivizing foreign firms to decarbonize is unavoidable, in our simple model or any other.

Nonprice policies

Instead of taxing carbon emissions, the United States and many other countries have enacted domestic climate policies that impose technology or emissions standards on producers. Technology standards require firms to install and maintain particular equipment. Emissions standards require them to cap total carbon emissions or emissions per unit of output.

Technology and emissions standards impose costs on domestic producers and raise the same risk of leakage as price-based policies. But unlike price-based policies, regulatory standards do not result in a price per unit of abatement—a tax rate or a price for tradable permits—that can easily be interpreted as the industry's marginal cost of abating carbon. So it's not obvious what would be the appropriate leakage-prevention tariff rate.

One option would be to charge imports a tariff equal to the domestic industry's average cost of compliance, per unit of product: estimate the costs incurred by the domestic industry to comply with a nonprice regulation, per dollar of production, and impose those costs on competing imports in the form of a tariff. That has several problems. It does not account for domestic emissions reductions due to the regulation. Even an ineffective domestic policy that imposes high costs without reducing emissions at all would be protected by a high tariff rate, essentially protecting domestic polluting industries. Ideally, carbon tariffs would prevent domestic low-carbon firms from relocating production overseas where abatement costs are lower and carbon emissions higher. Moreover, a tariff based on average domestic costs would also be unrelated to foreign carbon intensities, so there would be no way to adjust for foreign nonprice regulatory strictness and no encouragement for foreign decarbonization.

An alternative would be to charge foreign polluters the marginal regulatory cost of polluting faced by domestic industries. But with technology or emissions standards, that would often be either zero or infinite. Consider a domestic rule requiring control equipment that is expensive to install but costless to operate. The marginal abatement cost, once the equipment is installed, would be effectively zero. Or consider a domestic rule capping emissions, with stiff penalties for exceeding the cap. The marginal abatement cost would be high at the cap and zero everywhere else.

A third option would be to try to calculate the true marginal abatement cost for domestic manufacturers, using some econometric study to estimate the implicit price of polluting, often called a "shadow price" (see Van Soest et al. 2005 for an example.) Aside from being difficult, conceptually and practically, that shadow price is not what domestic firms pay. Charging that to foreign firms would be unrelated to the amount of leakage.

While it's true that leakage from nonprice domestic climate regulations could pose as much of a problem as leakage from price-based climate policies, identifying appropriate carbon tariffs to prevent that leakage is a challenge (Pizer and Campbell 2023). We have not heard of, nor can we think of, a practical way to do so.

Domestic subsidies for carbon abatement

A similarly knotty problem arises when, instead of taxing carbon emissions, countries subsidize technologies that reduce carbon emissions. Think of the US tax credits for producing solar panels or generating carbon-free electricity. In those cases, concerns about leakage as a rationale for carbon tariffs disappear. Domestic industries have no incentive to relocate production overseas to avoid subsidies, and they do not need carbon tariffs to protect them from subsidies. If anything, subsidies may attract clean investment, in what Kotchen and Maggi (2024) call "reverse leakage."

From the perspective of country *i*, subsidies don't change the world price but do increase global supply of the clean good, reducing its price slightly. That reduces other countries' supplies of the good and increases other countries' demands. The net of those changes accounts for the reduced imports to *i*. Appendix Figure A2 depicts that case.

Whether the subsidy benefits the global climate depends critically on whether it affects foreign supply or foreign demand. If foreign supply is inelastic, the shrinking imports to *i* must be caused by growing foreign demand due to the price drop caused by *i*'s subsidy. If foreign demand is inelastic, the shrinking imports to *i* must be caused by shrinking foreign supply. In that case, the subsidy has merely replaced foreign supply of the clean good with domestic, with no consequence for the global climate.

In the case of the carbon tax on a polluting good, with mobile producers and immobile consumers, the only way for a small country to affect global pollution is to reduce consumption. A small country cannot affect global pollution without imposing a cost on its own consumers. In the case of the subsidy for a clean good, the only way for a small country to affect the climate is to reduce prices for the rest of the world's consumers.[8]

Large-country tariffs

If the tariff-setting country imports enough of the polluting good to affect world prices, it has a self-interested reason to impose a tariff, above and beyond climate concerns. A tariff τ reduces global demand and the world price, lowering the cost of country i's imports. As a result, the price paid by country i's consumers will rise by less than τ, and their demand falls by less than in Figure 1. The price that can be charged by country i's producers rises by less than τ, and their supply rises by less than in Figure 1. The resulting deadweight loss triangles a and b are smaller. But the tariff revenue $R\tau$ will be larger than in Figure 1 because its height will still be τ and imports will have grown (see Appendix Figure A3). If the extra revenue exceeds the deadweight loss triangles a and b, it can be in country i's best interest to impose a tariff. The gains are those of a monopsony, restricting its own demand to reduce the price it pays for purchases.

When there's a global externality like carbon pollution, and a country has enough monopsony power that a tariff would improve its situation, two market failures work in opposite directions. The pollution externality means that country i's own incentives are to produce and consume too

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[8] Kotchen and Maggi (2024) describe a more complex setting in which the fossil sector lobbies against carbon taxes, the green energy sector lobbies for subsidies, and countries sign international agreements addressing both.

much of the polluting good because much of the damages will be borne by others. Its monopsony power means that country *i*'s own incentives are to consume too little of the good. Which is larger depends on the amount of monopsony power and the size of the pollution externality, and it's not clear whether country *i* acting in its own interest will consume too much or too little of the polluting good, from the perspective of global welfare.[9]

This discussion strengthens the case for focusing on the small-country scenario, as we have done. By doing so, we limit the discussion of tariffs to their use as a tool to prevent leakage, not as a tool for market exploitation.

Conclusions

The model we outline oversimplifies complex issues surrounding carbon tariffs. But its simplicity yields multiple benefits. The obvious one is clarity. By extrapolating from effects on world prices and considering only carbon pollution tied one-for-one with production, we can focus on the most important environmental and economic effects of carbon tariffs. And we can do so using only the most basic economics of supply and demand curves.

A few of the lessons taught by this exercise stand out to us as being important and not necessarily obvious without the exposition. With free trade and mobile industries, a small open economy acting alone can most effectively reduce global pollution if the incidence of its climate policy falls on its consumers. Some changes in trade flows that follow regulatory changes represent not leakage, but rather the elimination of leakage from previously mispriced comparative advantage. And a carbon tariff that is not paired with a domestic carbon price is

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[9] This point was made by Buchanan (1969) in the context of polluting monopolists.

economically equivalent to a domestic carbon consumption tax combined with a domestic carbon production subsidy.

Around the world, carbon tariffs being proposed and implemented run the gamut. Some, like the European Union’s CBAM, are based on existing domestic carbon prices. Other carbon tariff proposals, like the Foreign Pollution Fee Act introduced in the US Senate, would tax imported goods without reference to domestic carbon prices. Some carbon tariffs account for foreign carbon taxes paid. Some are assessed at the firm level; others use national aggregates. Some are emissions based; others assess tariffs based on emissions per unit of product, or intensity.

In the end, however, the problem is global. A ton of carbon emitted by any industry anywhere causes the same global damage. International trade, through leakage, has the potential to undermine individual countries’ attempts to abate their own emissions. Sensible carbon tariffs can help mitigate that leakage. At the same time, international trade has the potential to help address climate change by helping countries with a comparative advantage in clean technologies export their cost savings. Sensible carbon tariffs will not obstruct those gains. Today the variety of carbon tariffs under discussion suggests that lessons from the simple model we have described have yet to be widely recognized.

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Figure 1. A unilateral tariff τ

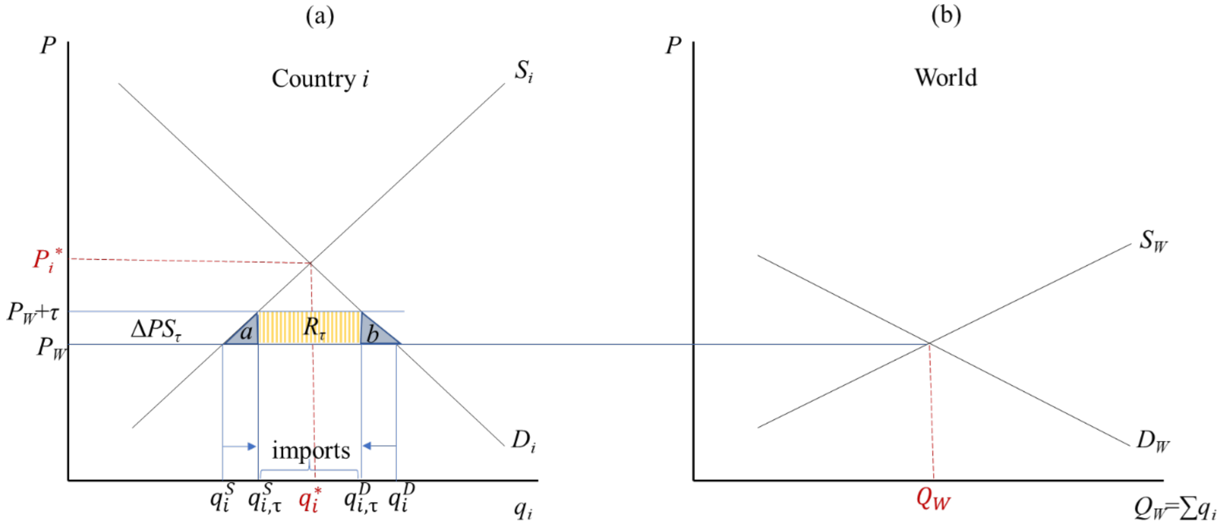


Figure 2. Trade and a global pollutant

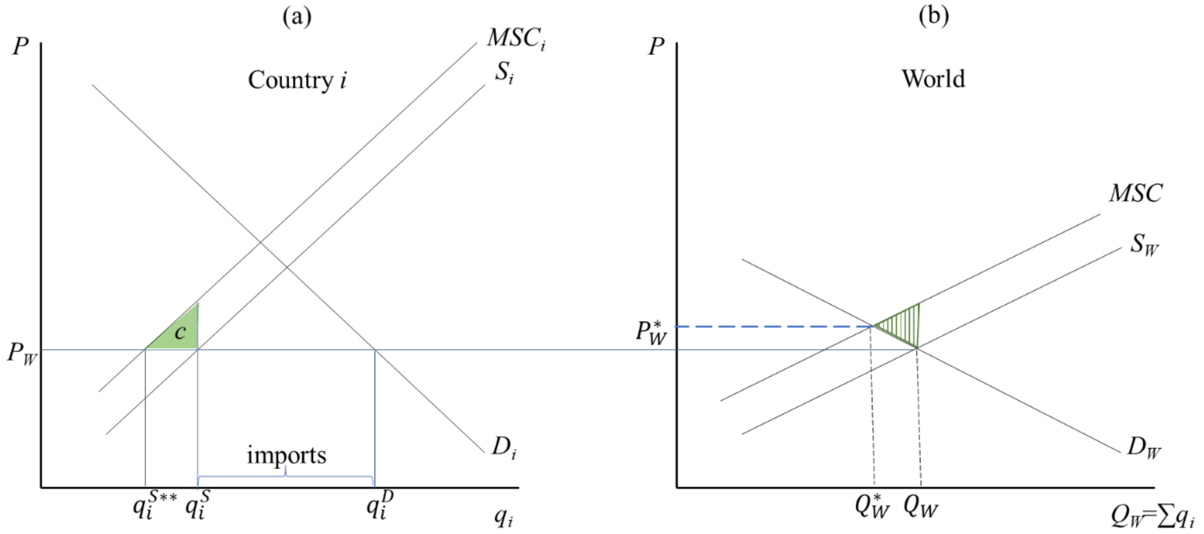


Figure 3. A unilateral domestic carbon tax t

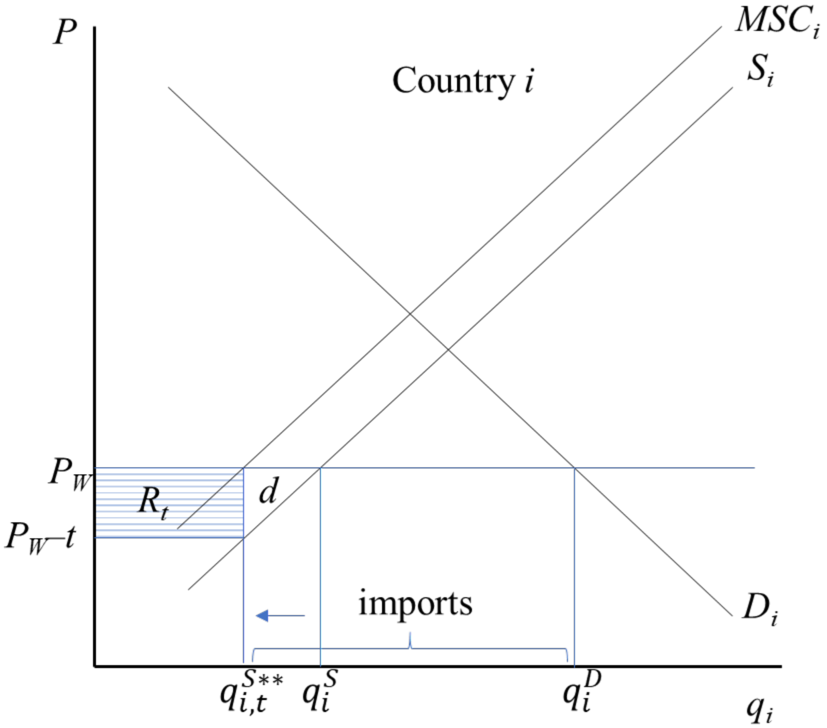


Figure 4. A unilateral domestic carbon tax and carbon tariff

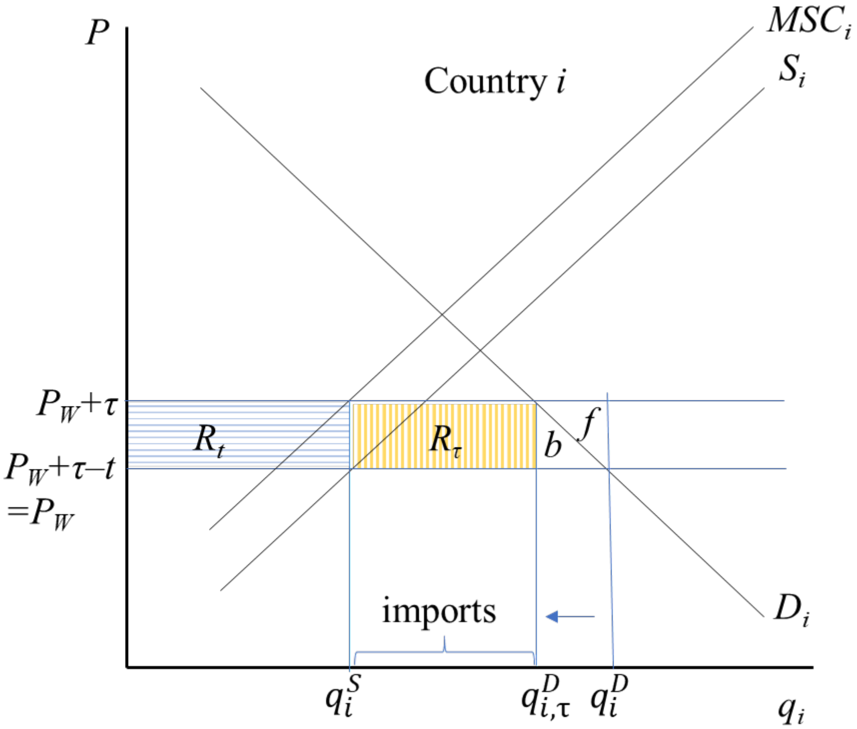


Figure 5. A carbon tariff alone

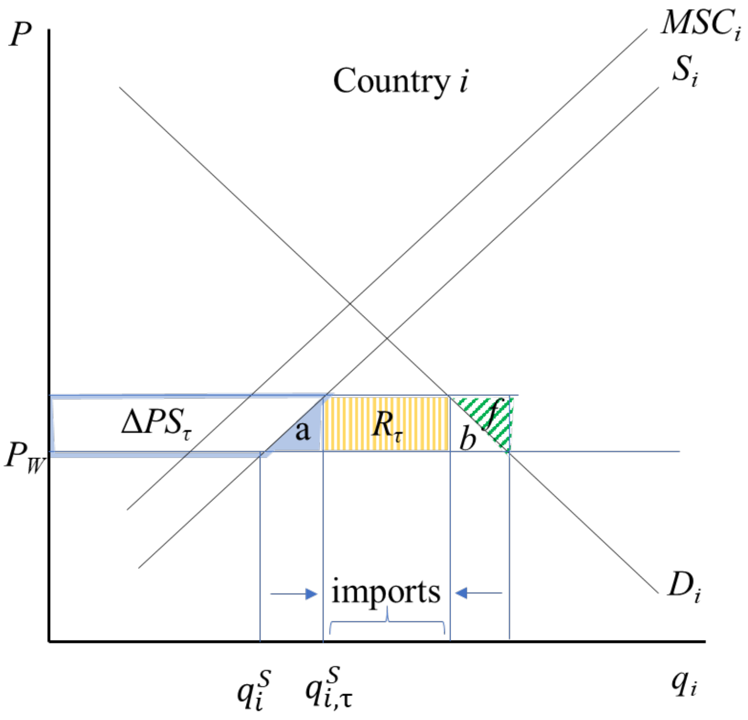


Figure 6. A world carbon price

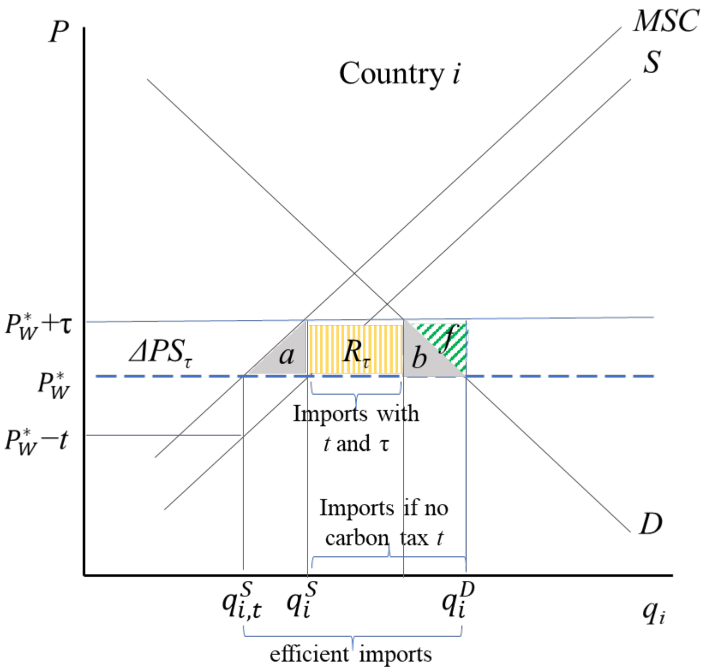


Figure 7. A too-small world carbon price

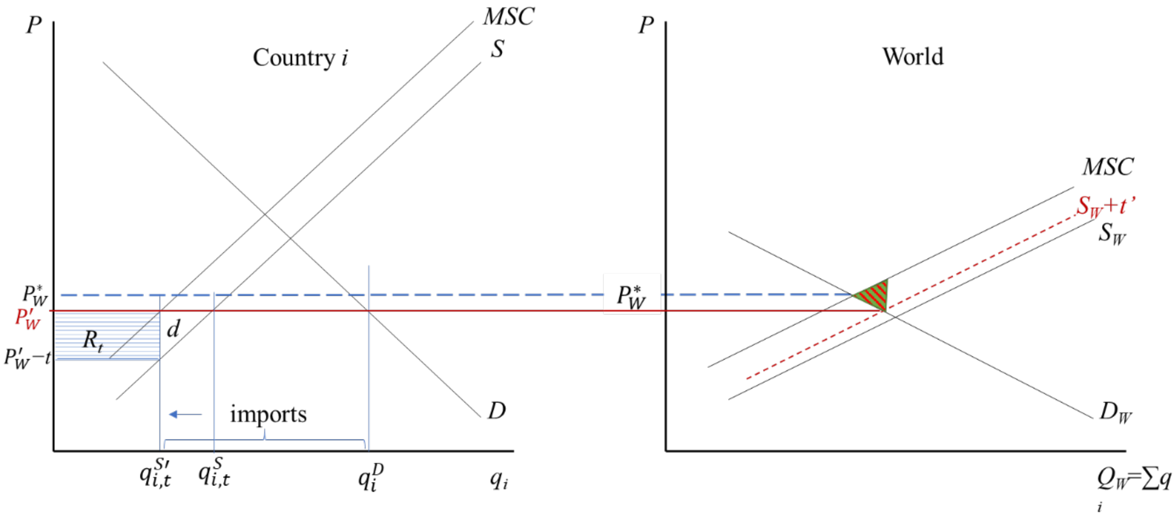


Figure 8. A too-small world carbon price with a carbon tariff

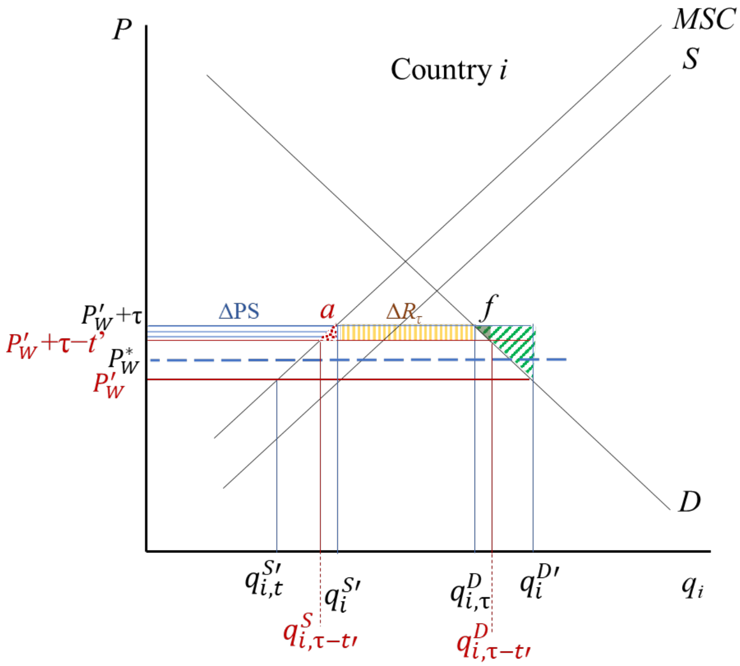


Figure 9. Different local and global carbon intensities with carbon tariff equal to domestic carbon tax

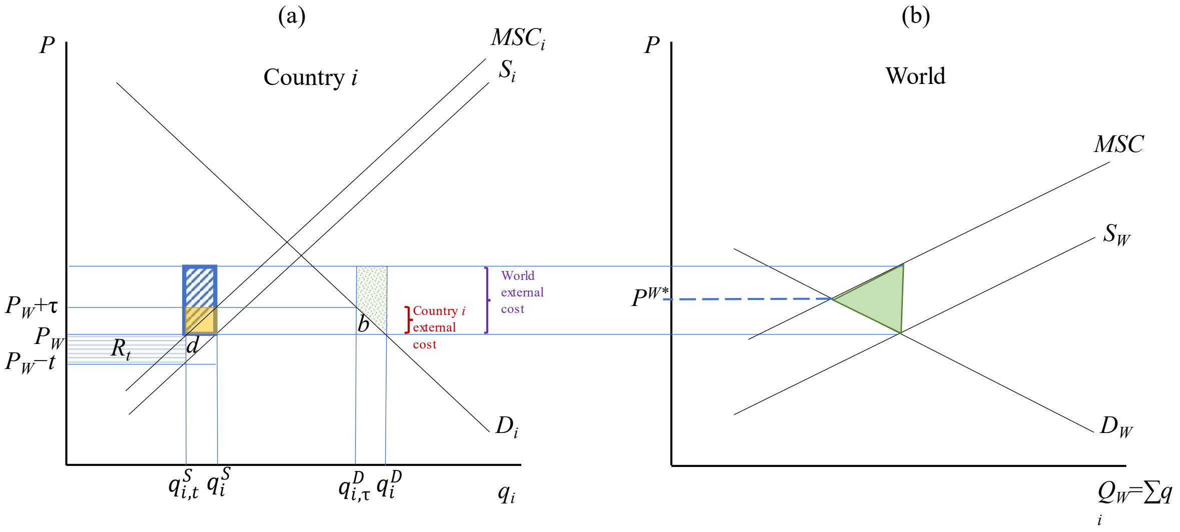
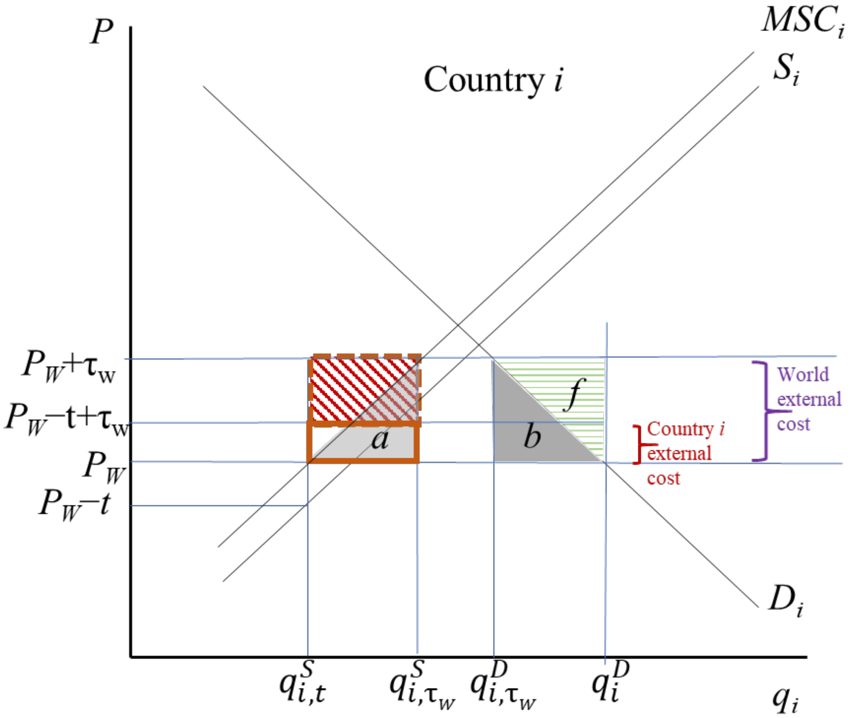


Figure 10. Different local and global carbon intensities with carbon tariff equal to foreign external cost



Appendix

Figure A1 is a version of Figure 3 for the more complicated case where pollution is a flexible input to producing q. In response to a carbon tax, producers take abatement measures that raise the private marginal cost of producing q from S_i to S_i' (the finely dashed line). Those measures reduce the external costs—the pollution damages—from MSC_i to MSC_i' (the thickly dashed line). The carbon tax paid is the difference between the two dashed lines. Consumers in *i* still consume q_i^D because world prices are unchanged. Domestic production falls, but not by as much as if reducing q were the only possible abatement technology. Tax revenues are the striped box R_t, and the deadweight loss is the shaded polygon *d*.

Producers in *i* respond to the carbon tax by reducing pollution in two ways: by deploying the technology that reduces the gap between S_i and MSC_i and by reducing output from q_i^S to $q_{i,t}^S$. With world prices fixed, the portion of pollution that is abated by shrinking output is replaced by imports and pollution elsewhere, or leakage. Just as with the simple one-for-one case, that carbon leakage is what carbon tariffs are meant to prevent. Figures A2 and A3 are described in the main text.

Figure A1. A unilateral domestic carbon tax *t* where pollution is a flexible input to *q*

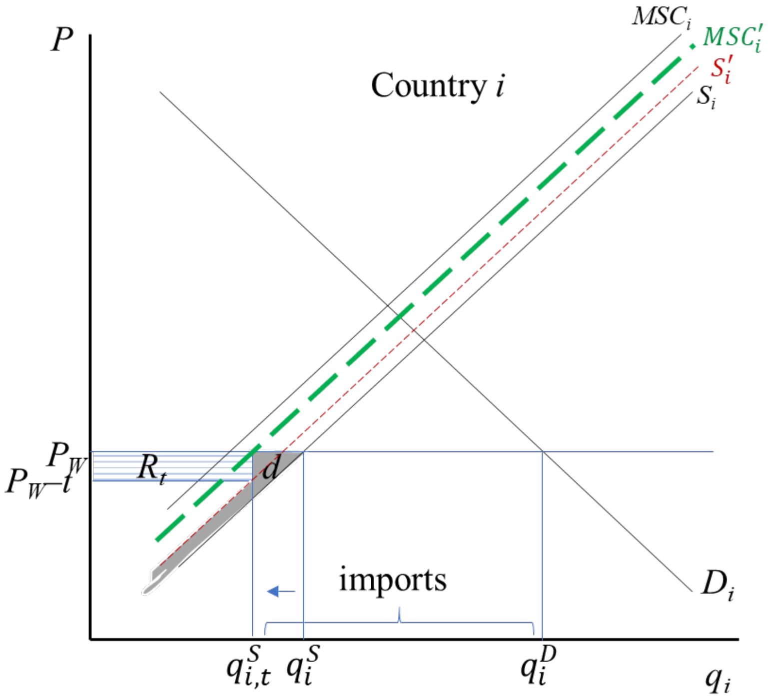


Figure A2. An abatement subsidy

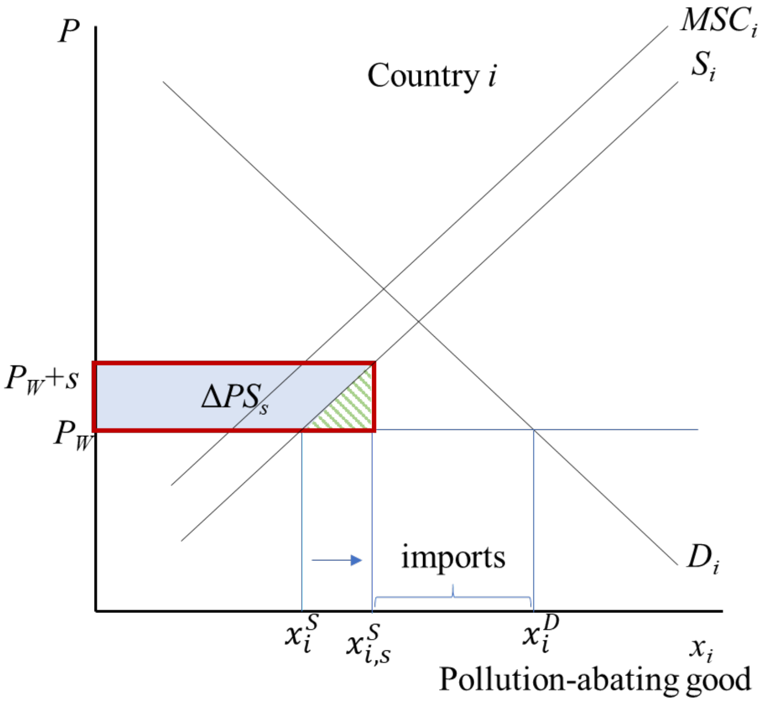


Figure A3. Large-country effects of a unilateral tariff τ

(a)