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"The European Union's Carbon Border Adjustment Mechanism: Challenges and Perspectives"

Stefan Ambec

Toulouse School of Economics

The European Union's Carbon Border Adjustment Mechanism: Challenges and Perspectives

Stefan Ambec[1]
Toulouse School of Economics
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Summary

This report uses an economic lens to analyze the Carbon Border Adjustment Mechanism (CBAM) which is currently under discussion at the European Union (EU). The CBAM, which is set to replace free allowances for specific ETS sectors after a transition period, aims to address carbon leakage and preserve the competitiveness of industries participating in the EU ETS. Although the two policy instruments share the same goals, their economic impacts differ. On the one hand, free allowances level the playing field both within the EU and on international markets by reducing the cost of the EU ETS for firms. European firms have an incentive to reduce their carbon emissions even if they obtain a certain part of their allowances for free. On the other hand, the CBAM levels the playing field only within the EU unless it is complemented with export rebates (such as benchmark-free allowances on exported production). However, the CBAM incentivizes not only European firms but also foreign firms to reduce their carbon emissions when exporting to the EU. Furthermore, unlike free allowances, the CBAM is more consistent with the polluter-pays principle.

The CBAM calls for product-based pricing of embedded carbon emissions equivalent to the manufacturing plant-based pricing of the EU ETS. The shift of the pricing base requires choices to be made on the economic sectors to target, the scope of emissions, the adjustments to be made for firm-specific carbon intensity and to country-specific carbon pricing. The pros and cons of those choices are discussed. The CBAM will generate substantial revenues which can be used to foster and smooth out decarbonization.

The CBAM differs substantially from the Climate Club that has been proposed by the Nobel Prize winner, William Nordhaus, for extending carbon pricing worldwide. Yet, by allowing importers to pay only the carbon price difference between the CBAM jurisdiction and the manufacturing country, the CBAM also incentivizes countries to implement their own carbon price.

Introduction

In the Green Deal and the 'Fit for 55' package, the European Union has committed to cut greenhouse gas emissions by at least 55% by 2030, and to achieve carbon neutrality by 2050. To achieve these goals in the power and manufacturing sectors, the EU relies mostly on the Emission Trading Scheme (ETS). Since 2005, the EU ETS caps the greenhouse gas emissions of the most polluting industries within the EU. Over time, the cap has been reduced to meet EU's more ambitious climate mitigation targets. The EU ETS cap is programmed to decline gradually over time to incentivize abatement efforts and reduce overall emissions. Each allowance allows the EU ETS participant to emit 1 ton of CO_2 equivalent (CO_2e). The participating firms can buy allowances through an auction system, receive them for free, and freely trade allowances on the EU ETS market.

The conventional wisdom in economics is that an emission trading scheme is a powerful and cost-effective policy instrument to lower greenhouse gas emissions. However, it is also well known that it might lead to carbon leakage in an economy open to trade. Notably, if emissions are capped within some territory, the burden of carbon pricing for manufacturers fosters the delocalization of carbon-intensive activities outside the borders. In a nutshell, greenhouse gas emissions leaks outside EU while EU industrial activity shrinks. The emission cap imposed by the ETS becomes ineffective. Worse, the ETS can turn out to be counter-productive if European manufactured products are replaced with more carbon-intensive products.

Carbon leakage is addressed in the EU ETS by assigning a certain number of allowances for free to manufacturing plants in industries that are emission intensive and exposed to international competition. Plants receive their emission quotas based on an evaluation of their historical emissions[2]. Last year, the European Commission launched a proposal to deal with carbon leakage which aims at replacing the free allowance policy for selected sectors: The Carbon Border Adjustment Mechanism (CBAM). This report provides an economic analysis of the CBAM project currently discussed by the EU parliament and Council of States.

The paper proceeds as follows. In Section 1, we first briefly introduce the problem of carbon leakage and explain how it is addressed with climate policies before summarizing the main features of the EU's CBAM project. In Section 2, relying on graphical illustration of microeconomics reasoning, we discuss how free allowances, CBAM and export rebates impact the economy, namely through effects on production, prices, trade, and emissions. We first examine how firms respond to the ETS and how their costs and profits are impacted. We then widen the picture by looking at the economic outcomes in a closed- and in an open- economy. We find out to what extent free allowances, CBAM and export rebates address carbon leakage and level the playing field both in the domestic market and in international markets. Section 3 focuses on several key features on the design of a CBAM such as: Which sectors to target? How to adjust the carbon price at the border to the carbon footprint of the product or to the carbon price in the country of origin? What to do with the revenues raised with the CBAM? To what extent does the EU's CBAM comply with the World Trade Organization (WTO) rules? What is the link between a CBAM and a Climate Club? Section 4 concludes.

[2] Historical emissions are evaluated based on a sectorial benchmark emission intensity applied to plant level production.

1. How to address carbon leakage and international competitiveness with carbon pricing

1.1. The leakage problem

Carbon leakage occurs due to relocation of production from countries with stricter regulations to those with laxer regulations, or due to increased imports of equivalent products from the latter countries. The literature has identified several economic mechanisms leading to carbon leakage: the competition channel, the energy channel (EP, 2020), and the income channel (Cosbey et al, 2019).

The ***competition channel*** operates when carbon pricing in a particular jurisdiction increases production costs, which induces firms to move to laxer jurisdictions so as not to lose their competitive edge. The ***energy channel*** works when falling demand for fossil fuels in countries with strict carbon pricing policies leads to a price drop on the international market, which then increases demand and hence emissions in unregulated jurisdictions. The ***income channel*** is one where carbon pricing policies change relative prices, terms of trade and hence global income distribution in a way that induces carbon leakage.

On the other hand, ***technological spillovers*** between the jurisdiction with the ETS and the rest of the world might lead to ***negative leakage***. The technological spillovers channel arises because the ETS induces innovations in decarbonated or low-emission technologies that are exported outside the ETS jurisdiction. Evidence of technological spillovers abounds. Nevertheless, estimating the magnitude of this phenomenon is difficult as it raises challenging econometric identification issues.

Many studies estimate the magnitude of the leakage problem. In a multi-region general equilibrium model, Fischer & Fox (2012) estimate the impact of a carbon price implemented unilaterally by the US on several energy intensive industries (electricity, oil, chemicals, iron & steel, among others). According to their estimates, a carbon price of \$50 per ton of CO2 leads to substantial carbon emission leakage rates[3], ranging from 2% in the pulp and paper industry to 58% in the iron and steel sector. In the same vein, in a structural partial equilibrium framework, Fowlie & Reguant (2022) analyze the leakage risk across 312 manufacturing sectors in the US. They find a leakage rate of 46% on average with a carbon price of \$25 per ton of CO2. Studies on carbon leakage are summarized in Appendix.

1.2. How carbon leakage is addressed with climate policy

From a policy perspective, carbon leakage is addressed through various mechanisms that can be combined:

- Border charge on imports
- Border rebates on exports
- Domestic rebating based on output or emission abatement efforts

[3] The leakage rate is the increase of foreign carbon emissions divided by the decrease of domestic carbon emissions.

The border charge on imports is central to the CBAM. It can be combined with rebates on exports, output, or abatement. The rebate can be a direct subsidy such as with a refund of the carbon tax, or an indirect subsidy such as with free allocation of allowances which is based on exports, production, or abatement investment (decarbonation efforts). As discussed in Section 1.3, the current EU CBAM project combines a border charge with (indirect) domestic rebating - through free allowances based on total production- during a transition period replaced by border rebates on exports – through free allowances based on exported production. Note that William Nordhaus's proposal of a Climate Club is another option to reduce carbon leakage. It is described later in Section 3.6.

Fischer and Fox (2012) compare the properties of the above-mentioned mechanisms. They show that, while all can support competitiveness, they cannot be ranked easily on their effectiveness in reducing emissions. Using a computable general equilibrium model calibrated on several energy-intensive sectors in Canada, Europe and the United States, they found that a CBAM is usually more effective followed by output-based rebating for key manufacturing sectors. In the same vein, Quirion (2021) highlights that output-based rebates are distortionary, which is detrimental to welfare.

1.3. The EU's CBAM project

On June 2021 the European Commission (EC) published a proposal to the European parliament and to the European Council of States establishing a CBAM (European Commission, 2021). The main specificities of EC's proposal are:

- Only a subset of sectors, namely aluminum, cement, electricity, fertilizers, and iron & steel, are involved.
- Importers must buy allowances at the same price prevailing in the ETS. Those allowances are not taken from the EU ETS market, so not subject to the EU ETS overall cap.[4]
- The pricing base for the allowances is the total emissions embedded in the product, also called the emission factor (in CO2e per ton or Kwh), the emission intensity, or the carbon footprint.
- Importers should submit an annual declaration of the embedded emissions in the goods, hereafter called the emission factor. It should be verified by an accredited third-party. A default emission factor is otherwise applied.
- Direct emissions (Scope 1) will be applied to compute the emission factor.
- For the CBAM sectors, the free allowances system will be phased out progressively over ten years, while the CBAM is phased in.

On March 15th 2022, the European Council of States reached a high level agreement on the CBAM while leaving the details on its implementation for later. On June 22nd 2022, the European parliament adopted the CBAM proposal with the following main amendments:[5]

[4] Strictly speaking, the CBAM's allowances are not part of a market since they cannot be exchanged among them. Allowances in excess can only be re-sold to the authorities. To some extent, importers pay a border charge based the emission factor of their products and the price of allowances in the EU ETS.

[5] https://www.contexte.com/article/energie/paquet-climat-ce-quil-faut-retenir-des-votes-en-pleniere-au-parlement-europeen_151637.html
https://www.europarl.europa.eu/doceo/document/TA-9-2022-0248_EN.pdf

- A calendar for progressive phase out of free allowances from 2027 to 2032 with exemption on production exported to countries without carbon pricing similar to the EU ETS.
- An extension to three other sectors: hydrogen, plastics, and organic chemicals.
- The allocation of the revenue of the CBAM to the general budget and to decarbonization in less developed countries.
- To expand the emission scope to indirect emissions (Scope 2) mirroring the scope of the EU ETS.

To document the economic effect of their proposal, the EC has performed an integrated impact assessment on several options. They conclude that the option proposed has a net positive impact relative to the status quo of the free allowance system. It has a limited impact on employment, and has low monitoring and enforcement costs. Among the six options analyzed, the EC assessment considers it the most effective one in tackling carbon leakage.

2. Climate policies to address emission leakage: Free allowances, CBAM and export rebates

This section relies on basic microeconomics to investigate how the ETS (with and without free allowances) and the CBAM affect firms' strategies. It does not consider specifically the EU's CBAM but rather the different options to address carbon leakage mentioned above. It then analyzes the impact of the ETS and the CBAM on the economy, including effects on production, consumption, trade and greenhouse gas emissions. The modeling assumptions, results and proofs can be found in Ambec, Esposito and Pacelli (2022).

2.1. Firm's incentives

How do firms react to carbon pricing in an ETS? We answer this question with a simple framework which nevertheless requires some notation. Consider a manufacturing plant emitting *e* tons of CO2 when carbon emissions are not priced. Let *p* denote the price of allowances in the ETS. Consider a manufacturing plant part of the ETS emitting *e* tons of CO2. The cost of the ETS for this plant is *p* x *e* if it buys all the allowances it needs. Yet emissions can be reduced at some cost by investment into pollution abatement. This cost is called ***abatement cost***. It is likely to be increasing with abatement effort at an increasing rate, reflecting a decreasing marginal return in abatement investment. The plant will first use the cheaper abatement technology (e.g. increased isolation, optimized combustion) before turning to the more expensive ones (e.g. fuel switch to hydrogen, or carbon sequestration and storage) as it further cuts emissions.

By investing into pollution abatement, the firm can avoid part of the ETS burden *p* x *e*. When deciding how much to invest, the firm compares the benefit of reducing emissions, which is p per ton of CO2, to the abatement cost. From the firm's point of view, it is optimal to invest if the price of allowances *p* is higher than the marginal abatement cost (MAC). Hence the ETS incentivizes firms to lower their carbon emissions to the point of equalizing their MAC to the price of allowances *p* at the optimal emission level that we denote *e**. This economic mechanism is illustrated in Figure 1 below.

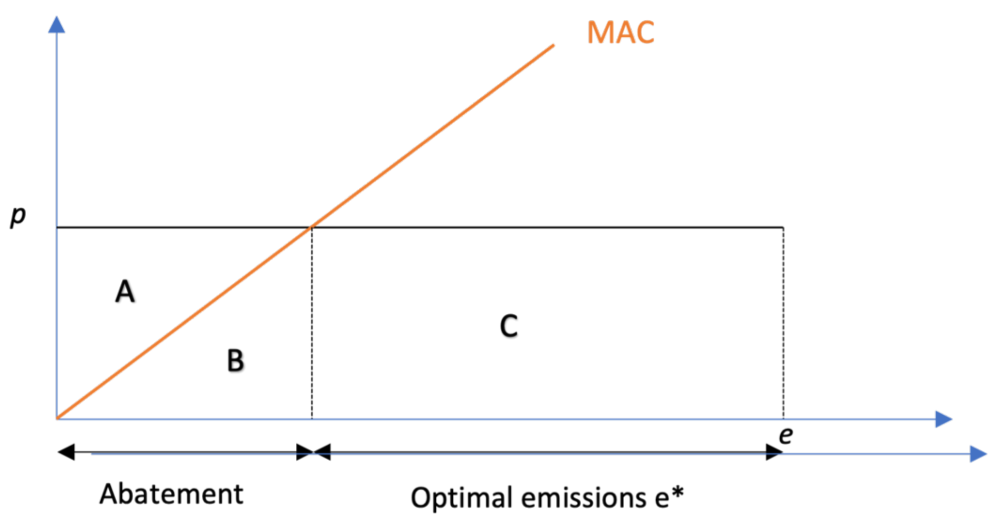

Figure 1: Emission and abatement at the plant level

When all allowances are auctioned, the cost of the EU ETS if the firm does not control its emissions *p* x *e*, is the area A+B+C. Now, the firm can save money by investing in pollution abatement to cut those emissions units for which the MAC is below p. It is optimal for the firm to reduce emissions from *e* to *e**, implying costs of the area B but savings of the area A. The total cost of the ETS when abating emissions optimally is B+C: the total abatement cost plus the regulation cost on the remaining emissions *p* x *e*.*

What if allowances are provided for free? The firm does not have to pay *p* x *e* anymore. Yet the incentive to reduce emissions from e to e* remains. By investing into abatement at the cost of area B, the firm can sell *e*-e* emission allowances (the optimal level of abatement) at price *p* which yields a revenue (*e*-e*) x *p*, that is A+B. Hence the firm can obtain revenue from selling allowances net of abatement costs, which is represented by A.

To empirically investigate to what extent firms manage to reduce their emissions, we compare the allowances freely assigned to the manufacturing plants with their verified emissions (i.e., how much allowances they need to cover their emissions). They reduce emissions if they receive more allowances than they need. In this case, they are net sellers of allowances. Otherwise, they are net buyers. The ratio of free allowances to verified emissions[6] in graphed in Figure 2 below.

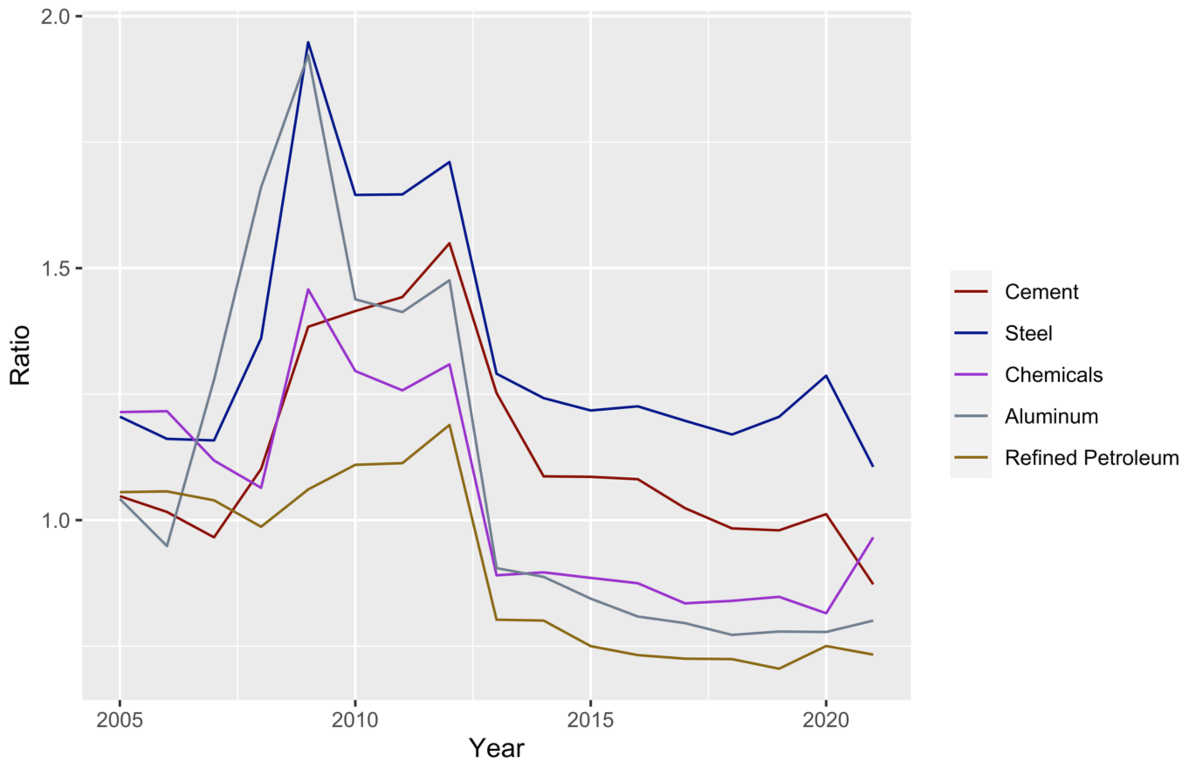

Figure 2: Ratio of free allowances to verified emissions

The ratio of free allowances to verified emissions started slightly higher than 1 and increased steadily to almost 2 during Phase II of the EU ETS. This means that for every unit of verified emission in that

[6] Computed from data available on https://euets.info.

period, there were twice as many free allowances. This surplus of free allowances was mostly due to production decline following the 2007 financial crisis. The ratio started declining after but remained higher than 1 throughout Phase 2. The ratio has decreased further during Phase III of the EU ETS, mostly because the number of free allowances received has been updated. Most industries turn out to be short of allowances with the notable exception of steel.

To sum up, **the ETS incentivizes firms to reduce emissions at the same level regardless of how many allowances are allocated for free**. **The free allocation of allowances impacts the firms' profits but not their incentive to reduce emissions. Firms obtain higher profits with a higher share of free allowances, which favors entry and the supply of goods in that industry. The emission level per manufacturing plant is unaffected but more plants become profitable.** We now examine the impact of carbon pricing with or without free allowances on emissions and the corresponding economic outcome through supply and demand analysis.

2.2. Economic outcomes

2.2.1. ETS with free allowances under autarky

We now move to a larger scale from the firm level to the industry level in an economy (say the EU) with trade. Let us consider the supply curve of an industry subject to the ETS in the EU. The supply curve plots firms' unit costs of supplying the good produced by this industry from the lowest to the highest. The unit cost sums up the cost of producing the good and the cost of complying with the regulation (the ETS). When firms buy all their allowances (no free allowances), the regulation cost is the price of allowances multiplied by the emission factor per unit of output (e.g. how much ton of CO2 equivalents are emitted per ton of steel produced). Denoting γ as the emission factor of the product, the regulation cost is γp. If firms purchase only a share α of their allowances with $\alpha < 1$ (they get share $1-\alpha$ for free), the regulation cost per output boils down to $\alpha\gamma p < \gamma p$. Hence, compared to full carbon pricing, firms obtain a subsidy of $(1-\alpha)\gamma p$ per unit of output.

Demand is determined by consumers' willingness to pay for the good ranked from the highest to the lowest. The demand (in red) and supply (in blue) with and without free allowances are graphed in Figure 3.

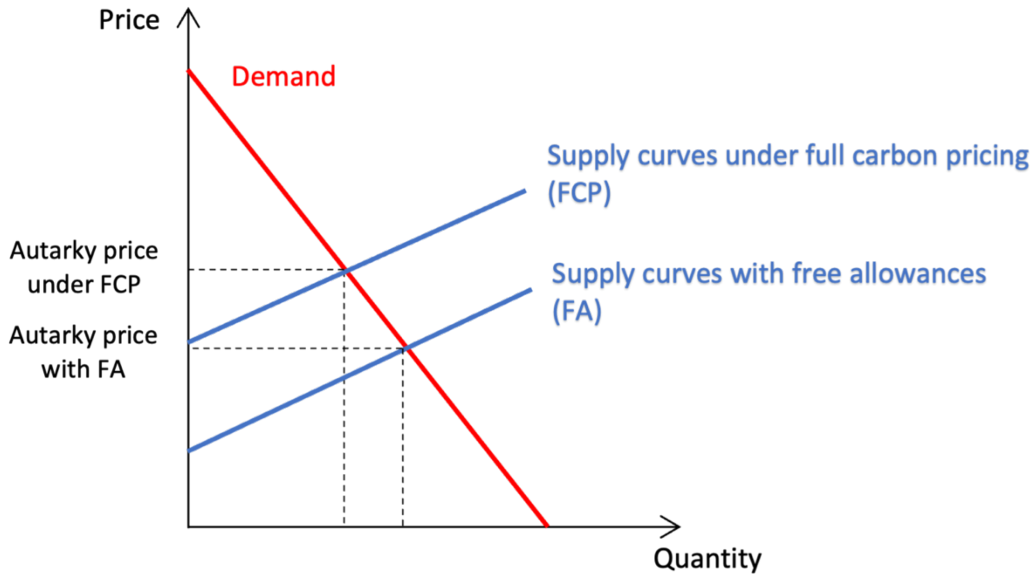

Figure 3: Economic outcomes in a closed economy with and without free allowances

In a closed economy (without trade), the equilibrium price results from the intersection of the two curves, i.e., for a quantity of good such that supply is equal to demand. We call this price the autarky price. Providing free allowances shifts the supply curve downward which results in more quantity supplied at a lower equilibrium price. Even if a higher quantity produced would otherwise imply more emissions, this is not an issue with an ETS because total emissions are capped. The price of allowances goes up which makes firm abate more while, at the same time, increasing production costs and thus reducing supply.

2.2.2. ETS with free allowances under trade

In an open economy, local products are competing with imported ones sold at price c, which reflects the production cost abroad plus tariff and shipping costs. If c is lower than the autarky price, the product is imported, and the market price is *c*. Yet some local producers might remain competitive at this price, namely those with the lowest production costs. Figure 4 below plots the economic outcomes with trade under full carbon pricing and with free allowances.

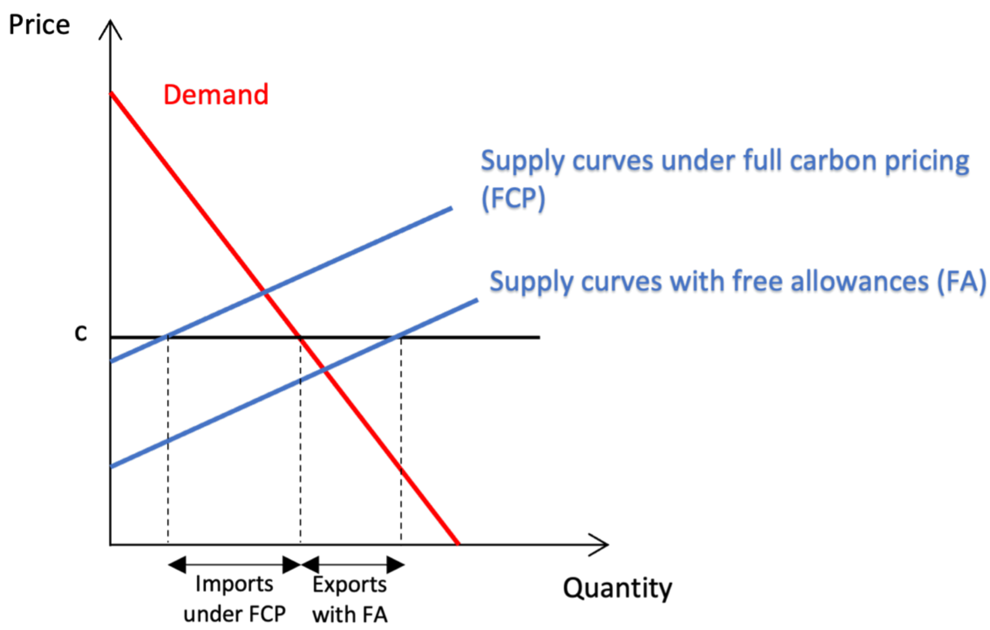

Figure 4: Economic outcomes in an open economy with and without free allowances

The supply curve in the open economy is the minimum between the two supply curves: the blue one for domestic production and the black horizontal line at c for imports. In the example illustrated in Figure 4, some domestic firms are able to supply the good at a cost lower than c. Their supply cost is plotted in the part of the blue line which is below the black line at c. The equilibrium price is determined by the cost of foreign products c which is lower than the autarky price.

Opening to trade induces carbon leakage as many domestic producers are replaced by foreign producers whose emissions are not capped by the ETS. It is problematic for the climate goals within the EU not only because the EU production which is replaced by imports leaves extra emission allowances for the other sectors but also because the emission factor of foreign products is likely to be higher. Hence, overall, emissions increase with trade.

By shifting the supply curve downward, free allocation of allowances reduces imports and, therefore, emission leakage. As the share of free allowances 1-α increases, the regulation cost per unit of output $\alpha\gamma p$ decreases, such that more domestic plants become competitive compared to foreign ones. Imports are replaced by domestic products as the share of free allowances increases. At some point, foreign producers are excluded from the domestic market. With all allowances assigned for free (α=0), the regulation cost is nil: $\alpha\gamma p$ =0. Domestic firms might export their product if they are competitive compared to foreign producers. This is indeed the case illustrated in Figure 4.

By reducing regulation costs, providing some allowances for free levels the playing field in the EU and outside the EU. Yet, as we have seen in Section 2.2.1, as long as allowances are priced, firms from the EU retain the incentive to reduce their CO2 emissions and save on costs if they do.

2.2.3. ETS with a CBAM

A Carbon Border Adjustment Mechanism (CBAM) is intended to make foreign firms pay the same price as EU firms for every ton of CO_2 embedded in their products that are imported into the EU. Doing so, the CBAM levels the playing field in the EU domestic market. It introduces a tariff corresponding to the emission factor times the price of allowances γ x p per unit of output imported. Foreign products are thus sold at price c + γp instead of c in the domestic market.

The CBAM shifts the supply curve of foreign firms upward (horizontal line in black in Figure 4) by γp. As a result, the CBAM reduces imports as long as $\gamma p > 0$. It also increases the domestic price by γp, from c to c + γp. A high carbon tariff γp lead to an autarky equilibrium as illustrated in Figure 5 below.

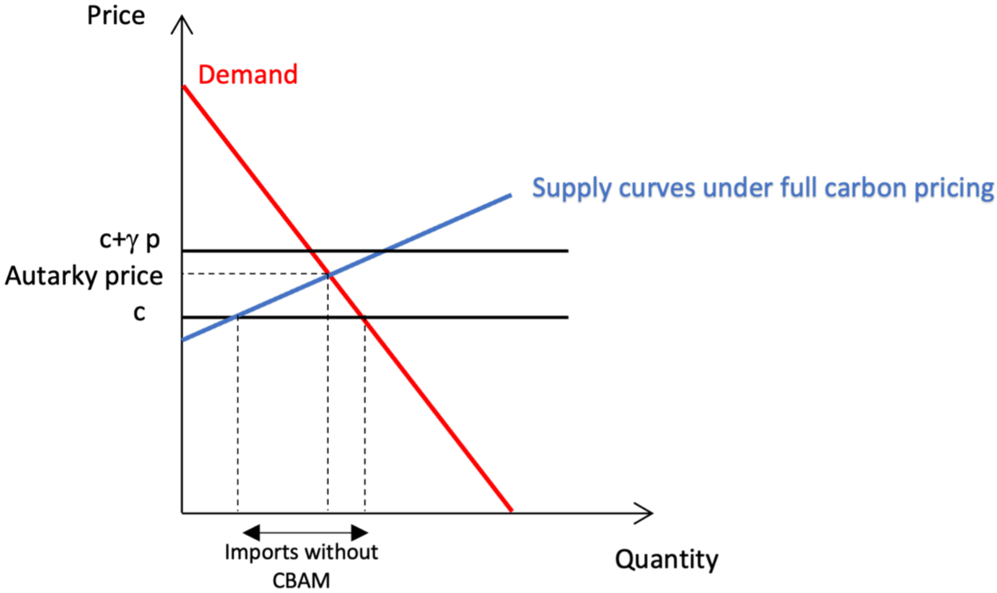

Figure 5: Economic outcomes with and without a CBAM

The overall supply curve in the domestic market being the lower envelope between the domestic supply curve (in blue) and the foreign supply curve (upper line in black), the good is exclusively supplied by domestic firms. The equilibrium price is the autarky price. It is lower than the price of the foreign products c+γp, that is the foreign supply curve (upper line in black). Foreign firms are thus not competitive in the domestic market at the autarky price. To become competitive, foreign firms must reduce their costs c and/or the carbon intensity of their product γ.

The emission factor applied to foreign products γ is obviously a key ingredient of the CBAM. Applying the EU's emission factor to foreign products would equalize the regulation cost γp on both sides of the border. However, unlikely as it sounds, it would not treat EU and foreign firms the same way because EU firms can reduce their regulation cost by abating – their manufacturing plant emits less so they need less permits- while foreign firms cannot – their emission factor is not related to their abatement investments. Furthermore, it would have an adverse impact on efficiency since foreign firms do not have any incentive to reduce their emissions since doing so will not change the cost of the CBAM for them. Adapting the emission factor to the actual emission intensity as proposed by the EU's CBAM restores the incentive to abate pollution, even though it could be difficult to implement in practice due to measurement issues. Furthermore, it might give rise to the resource shuffling problem that we describe later.

On the efficiency ground, the CBAM dominates free allowances because it makes domestic firms pay for the full cost of their CO2 emissions. It thus follows the Pigouvian principle of charging to polluters the external costs of their behavior. Firms fully internalize the social cost of their pollution if they buy all their allowances at a price reflecting the social cost of carbon. If firms obtain part of their allowances for free, or if the allowance price is lower than the social cost of carbon, firms pay only part of the external costs they induce to the climate.

To sum up, by leveling the playing field in the domestic market, a CBAM reduces imports and might lead to autarky. Hence the CBAM manages to reduce and even eradicate EU domestic emission leakage. However, since the CBAM does not level the playing field outside the EU border, it does not address the carbon leakage risk in international markets, unlike free allowances. On the other hand, unlike free allowances, it is consistent with the polluter-pays principle for EU firms (Ambec and Ehlers, 2016) and Pigouvian taxation (Pigou, 1920).

2.4. Export rebates

Although the EU CBAM project proposes the phasing out of free allowances for CBAM sectors, the amendment adopted by the parliament stated that they will be kept, but only on exports. Firms will be assigned free allowances at the benchmark level, but only for the share of production that is exported to countries without carbon pricing similar to the EU ETS. This policy can be referred to as an export rebate in the sense that firms obtain a rebate equal to the ETS regulation cost γp per unit of output exported. To investigate the impact of an export rebate under a CBAM, we plot the supply and demand curves in the domestic and international markets in Figure 6 below.[7]

[7] Note that the below analysis encompasses partial export rebates: a share $\alpha < 1$ of free allowances on exports. The export rebate is then $\alpha\gamma p$ instead of γp. The supply curve on exports with a partial export rebate is above the one with full export rebate $\alpha=1$ (blue lower line in Figure 6), the gap increasing when α is decreasing.

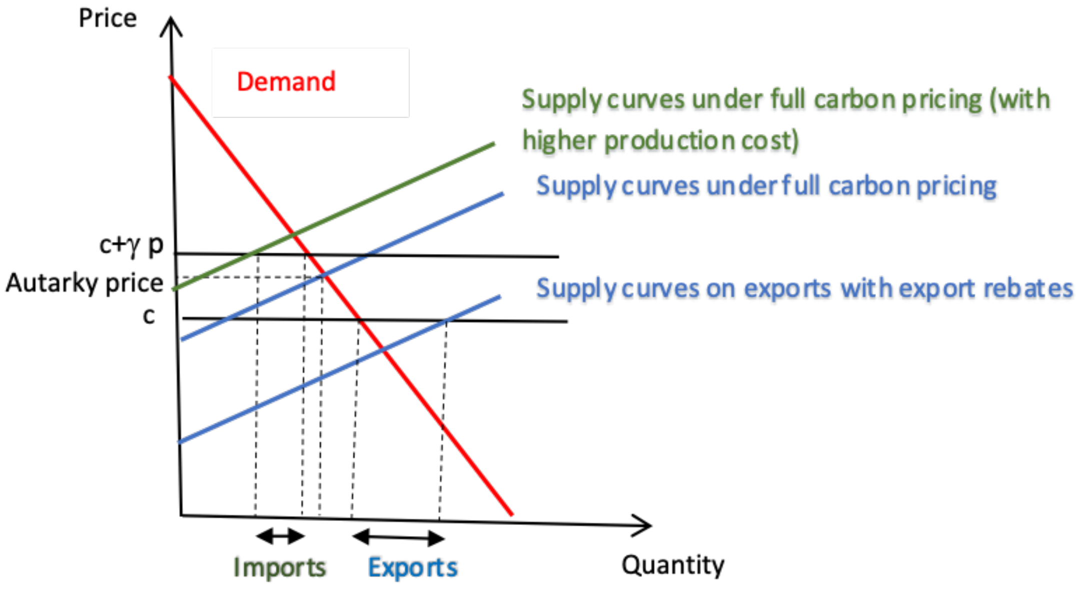

Figure 6: Supply and demand under the CBAM with export rebate.

Under a CBAM with export rebates, supply curves differ on both sides of the EU border. Within the EU, the supply curve is the one under full carbon pricing (without free allowances as in Section 2.2.2). In Figure 6 we plot two potential supply curves under full carbon pricing, the green being with higher production costs than the blue one. As already mentioned, the CBAM reduces imports. If production and regulation costs lead to the green supply curve, the CBAM allows some EU firms to survive facing the competition of foreign firms. The share of imports on total consumption are highlighted by the double arrow above "Imports" in green letters. The equilibrium price is the cost of imported products $c + \gamma p$. With lower production and regulation costs leading to the blue supply curve, the CBAM builds a barrier at the borders that precludes high intensity imports. Imported high intensity products are too costly. The domestic market is under autarky. In both cases, with imports or under autarky, the CBAM levels the playing field within the EU market.

In international markets, since domestic firms do not have to pay for the regulation cost $c + \gamma p$ associated with the exported outputs, the supply curve moves downward. Many domestic firms are competitive at the international price c. They can export because they are competitive on production costs and partly exempted to pay the EU carbon price on international markets that do not have a carbon pricing policy similar to the EU ETS. The share of exports on total domestic production is shown by the double arrow above "export" in blue letters. The export rebate helps to level the playing field in international markets.

Export rebates reduce emissions despite fostering exports if they replace foreign products with higher emission factors. It is likely to be the case since carbon is not priced as in the EU ETS in markets for which EU firms will obtain free allowances. For instance, Mini and Saïsset (2021) report an emission factor for cement of 619 kgCO2e per ton in Europe as opposed to 654 kgCO2e per ton on average in the world. Similarly, their estimate of the emission factor for steel is 1.28 tons CO2e in Europe while it is 1.83 on average in the world.

To sum up, by combining a CBAM with some kind of export rebate (such as benchmark-based free allowances on exported production), we get a better outcome than with a CBAM or free allowances alone. The playing field is leveled and carbon leakage risk is mitigated, both within the EU (with the help of the CBAM) and outside the EU (with the help of the export rebate). We have a policy consistent with the Pigouvian taxation and the polluter-pays principle with a CBAM which charges firms the full cost of their greenhouse gas emissions. With benchmark-based free allowances on exports, the export rebate reduces emissions outside the EU by replacing foreign products with less carbon intensive EU products, without compromising the incentive for EU producers to reduce their emissions for exported products.

3. Issues raised by the CBAM

Even though the CBAM sounds like a clever concept to address climate change at least on paper, its design and implementation can prove challenging. One of the challenges is the simultaneous use of two different pricing bases: the manufacturing plant and the imported product. This requires defining a method to measure the emission embedded in imported products which should be at the same time feasible and accurate. This raises many questions: which sector to target? How far to go in measuring emissions along the supply chain and during a product's lifetime? To what extent should the carbon intensity of imported product be differentiated based on the production process and the carbon pricing of the manufacturing country?

3.1. Targeting only a subset of sectors

Only few sectors (aluminum, cement, electricity, fertilizers, and iron and steel) are targeted in the EU CBAM proposal. While targeting a subset of sectors rather than the whole economy seems better for administrative feasibility, it can also bring about some undesirable effects. First, products from those targeted sectors can be replaced by ***close substitutes*** that are not part of the CBAM. For instance, by substituting cement and steel by wood or glass in the building industry. The emission leakage mitigated for the targeted sectors can then be more than offset by an increased import of raw materials or products not targeted by the CBAM. Second, since the targeted products constitute an input for several manufacturing products manufactured in the EU, by increasing the cost of production for these sectors within the EU, the CBAM might lead to carbon leakage in ***other sectors downstream the supply chain*** of manufactured products. For instance, car and plane manufacturers might move their production abroad because they have access to cheaper steel, electricity, or aluminum, and can import the cars and planes into the EU without being subject to a CBAM.

This supply chain leakage effect could be avoided by covering more products downstream the supply chain. For instance, by including the weight of basic raw materials that are covered in the CBAM, which are embodied in the imported products (Garicano, 2020). However, it would introduce another layer of complexity as the carbon intensity of steel, aluminum or power embedded in say planes and cars are difficult to track and measure. Kortum and Weisbach (2017) argue that the complexity costs more than offset the economic costs. In the same vein, according to Droege and Fischer (2020), focusing on core energy intensive and trade exposed sectors seems to be more effective. It is also consistent with the empirical evidence reported by Shapiro (2021) that dirty upstream industries have substantially lower import tariffs and non-tariff barriers.[8]

The EU parliament proposes to extend the sectoral coverage of the CBAM to hydrogen, plastic, and organic chemical products[9], which significantly adds complexity to its implementation. Hydrogen is an emerging and innovative sector with emission factors that are likely to vary a lot across production

[8] Shapiro (2021) relates the dirtiness of industries, defined as CO2 emissions per dollar of output, with imports tariffs and non-tariff barriers. He provides evidence that (i) imports tariffs and non-tariffs barriers are lowers in the dirtiest industries, (ii) the dirtiest industries are upstream the global value chain (iron and steel, fertilizers, bricks, tiles, coke oven products).

[9] https://www.contexte.com/article/energie/paquet-climat-ce-quil-faut-retenir-des-votes-en-pleniere-au-parlement-europeen_151637.html

processes and time. Plastic and chemical products are also more differentiated products with potentially very heterogeneous emission factors, and which serve long and complex value chains. They might come from multi-product manufacturing plants and the allocation of manufacturing plants' emissions among the various products might not be straightforward.

3.2. The scope of emissions to be covered by the CBAM

Measuring the ETS-relevant carbon footprint of a product is not an easy task. To have a full picture, one needs to consider the full supply chain of the product. Also, the scope of emissions in both the production process and use matters. It is usual to distinguish between three scopes. ***Scope 1*** covers direct emissions from the production process at the manufacturing plant such as, from the use of fossil energy when manufacturing the product. ***Scope 2*** includes indirect emission from manufacturing, for instance emission embedded in the power supplying the plant. ***Scope 3*** extends to indirect emissions along the supply chain, including emission from extracting mineral, producing raw material, transporting the good to the final consumers and end-of-life treatment.[10]

The Commission proposal recommends including ***only the direct emissions (Scope 1)*** in a first stage, in the calculation of a product's carbon footprint. The Parliament adopted an amendment stating that ***indirect emission (Scope 2)*** should be included in the calculation to mirror the scope of the EU ETS. Although it has the merit of simplicity and easing administrative processes, ***excluding indirect emissions does not only underestimate the carbon footprint but it also generates perverse incentives***. For instance, a manufacturing plant can dramatically reduce the Scope 1 carbon footprint of its product by switching from in-house energy generation to grid power. This switch does not necessarily reflect a reduction of emissions. It might well increase emissions if grid power is more carbon intensive than in-house energy, for instance if it comes from a coal thermal power plant. In this case, Scope 1 emissions would fall but Scope 2 emissions would rise, so, not accounting for the latter can slow down decarbonization efforts. It leads to emission leakage from the manufacturing to the electricity generation sector for which emissions are generally not capped outside the EU.[11]

3.3. Adjusting for carbon intensity and carbon pricing

Estimating the carbon footprint of any given product can be tricky, especially when the good is produced outside the EU jurisdiction. Data on emissions at the manufacturing plant level are not always available, or reliable, or cannot be easily verified. One needs to track the product at several stages along the supply chain, potentially in different countries. The EU CBAM project mitigates those problems through a certification process with an accredited third-party. Importers submit an emission factor that is verified by the third party. If they do not do so, a default emission factor is applied.

[10] The EU ETS overlooks some of the Scope 3 emissions as they do not capture all the emissions across the life cycle of products, notably consumption by households and out of industrial sectors.

[11] Fowlie and Reguant (2022) makes the point that measuring of scope 1 emissions would capture leakage mostly through the competition channel. It would miss most of the energy channel.

Using a default emission factor has a major drawback: foreign producers have no incentive to reduce the carbon footprint of their own products by investing into pollution abatement. However, it avoids ***resource shuffling***, a source of inefficiency faced in the Californian ETS. It refers to the strategy of reducing the emission factor applied on the products by exporting the one produced by the cleanest manufacturing plant without investing in emission abatement. Doing so, the firm receives credit for emissions reductions that have not actually taken place.[12]

The EC proposes ***to adapt the carbon price paid on imports to the carbon pricing mechanism implemented in the country of origin*** (if any). More precisely, importers will be charged only the carbon price difference between the EU and the country of origin.[13] Adjusting for the foreign carbon price adds two appealing features to the CBAM project. First, it makes the EU CBAM more compatible with the WTO rules. Domestic and foreign products would overall receive the same treatment by paying the same price for their carbon footprint. Otherwise, foreign producers would be charged twice on their emissions and pay more for the same carbon footprint as EU producers due to the EU CBAM. Second, carbon pricing adjustment makes climate change mitigation more cost-effective. Economics states that pollution is reduced at a minimal cost by charging the same price for emissions to all polluters. Charging only the carbon price difference to imports helps the convergence to a unique carbon price for all products traded outside the EU borders.

However, adjusting for carbon pricing turns out to be more complex to implement than it sounds due to the heterogeneity in carbon pricing mechanisms worldwide. Assessing how much firms pay per ton of CO2 emitted is not always straightforward, let alone translating that installation charge to the individual product level. For instance, China has launched an ***ETS based on emission intensity rather than the nominal emissions***. The government determines emission intensity per unit of output. Firms that emit less that the standard obtain allowances that they can sell. Those which emit more must buy allowances to cover excess emissions (Zhang et al. 2017). Implicitly, firms are assigned some allowances for free allowances at a rate that depends on the emission intensity set by the government. Hence, they do not pay full the price of their emission allowances but only part of it[14].

The question of ***closing the carbon price gap between countries*** in a CBAM has been investigated in Pizer & Campbell (2021). They consider two countries, domestic D and foreign F, which carbon pricing differs in two dimensions: the carbon price and the emission standard above which allowances must be purchased (and below which allowances can be sold). We reproduce their

[12] Cullenward and Weiskopf (2013) provide an example of resource shuffling for electricity trade: A California utility swaps its contract for 100 MWh of coal-fired electricity for a Nevada utility's contract for 100 MWh of natural gas-fired electricity, the California utility will be able to report a reduction in emissions, even though no reduction in physical emissions has taken place.

[13] "An authorised declarant should be allowed to claim a reduction in the number of CBAM certificates to be surrendered corresponding to the carbon price already paid for those emissions in other jurisdictions." Page 21 in European Commission (2021).

[14] Note that the measurement problem is even more severe if the carbon price is adjusted to other climate policies that are not market-based, such as technological standards. It would indeed be difficult to assess the implicit cost of a coal ban, or of (non-tradable) emission standards, in terms of carbon price equivalent. This problem echoes the one assessing the cost of non-tariff barriers in international trade.

analysis but adapt it in the case of nominal emissions (rather emission intensity) and free allowances in Figure 6 below.

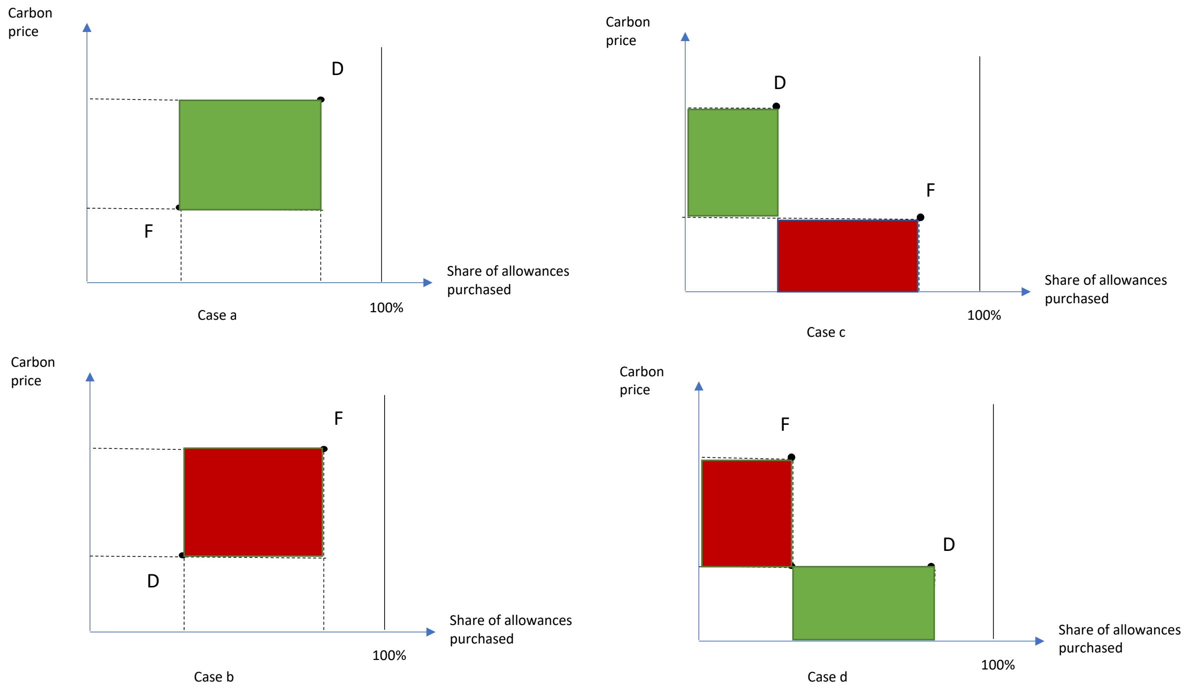

Figure 6: Carbon pricing adjustment with different carbon prices and share of free allowances

In case a in the upper left, firms in country D experience both higher prices and less free allowances. Firms in country F must pay for the price difference on all supplementary allowances they get for free as compared to domestic firms, that is the green area. Case b is the mirror image of case a. An export rebate equals to the price difference for all allowances that firms in country F purchase but not firms in country D. In case c, foreign firms pay a lower carbon price but they purchase a higher share of their allowances than domestic firms. Their net payment should be the green area net of the red one. They should pay the price difference on all allowances firms located in both countries purchase. Moreover, they should be refunded for the supplementary share of allowances they purchase compared to the domestic firms. Case d is a mirror image of case c, with domestic firms being refunded the extra free allowances but paying the price differential for the share of allowances purchased in the foreign country.

The certification of the emission factor of a product to pay a lower carbon tariff than with the default emission factor can have substantial impacts on emissions and economic outcomes. As certification is voluntary, one can expect that the products with lowest emission factor will be certified, thereby creating a self-selection bias. The average emission factor in the pool of uncertified products is likely to be higher than without certification. The emission factor estimated for the uncertified products should therefore be updated as more goods get certified. This phenomenon has been analyzed by Cicala et al. (2021). They show that voluntary certification produces a negative externality from the certified producers to the uncertified ones. They identify the efficiency gain from voluntary certification. Assuming a carbon tariff on steel at the OECD level, they estimate the impact of allowing for voluntary certification on Brazilian steel. They find that voluntary certification reduces emissions by half and increases welfare by one-fifth.

3.4. What to do with the revenues

The EU CBAM proposal does not earmark the revenue collected by pricing carbon at the border on specific spending ends or goals. Along the same line, the EU parliament voted in favor of assigning the revenue in the general EU budget. However, it also adopted an amendment requiring ***investing, at least in financial value, this revenue in the decarbonization of industries in less developed countries***. On the other hand, the phase-out of free allowances will further increase the revenue from auctioning allowances, which is already assigned to member States, under the requirement of devoting at least 50% of it to climate and energy-related purposes.[15]

Policy papers such as Canada's Ecofiscal Commission (2016) provide a typology of the options to recycle the revenue from carbon pricing. They distinguish between transfers to households (in particular the more vulnerable ones), investment in low carbon technologies, tax cuts, investment in infrastructure, reduction of public debts, transitional support to the industries (to mitigate or alleviate the harmful impact of carbon pricing). Similarly, Aberola and Vaidyula (2016) document how the revenue from auctioning allowances has been spent in several ETS. In the EU, during the period 2013-2015, most of it has been devoted to support renewables (29.5%) and energy efficiency (28.5%), followed by international climate finance (12.7%) and infrastructures (12.2%). In California and Québec, the higher share was used to invest in public and decarbonized transportation (59% and 67% respectively).

3.5. WTO compatibility

Adherence to international trade commitments is another element that the EU needs to take into account when designing the CBAM. The goal of the CBAM should be to level the playing field between domestic producers and importers, and not to give either one of them an unfair advantage. In other words, the CBAM should abide by the GATT principle of non-discrimination (Cosbey et al., 2021; Droege and Fischer, 2020). This principle states that when comparing like products, countries should give one another the "***most favoured nation treatment***" as per GATT Article I. For instance, imports from a country A should be treated the same as imports from country B if country B has better treatment. In addition, GATT Article III states that foreign products should be given equal treatment as similar domestic products, the so-called "***national treatment***". A CBAM designed as a border adjustment tax on imports will thus have to abide by these clauses. The adjustment to the carbon intensity of the product fails to comply with these clauses because it imposes different tariffs to the same product. Products should be categorized differently based on their carbon footprint to be compatible with WTO rules. Similarly, adjusting the carbon price on imports to the carbon price differential with the country of origin makes the carbon tariff per ton of CO2e country specific. Even if the same rule is applied to all countries, the price differential varies. Both carbon adjustment rules, at the product and at the country level, open the door to litigation against the EU CBAM at the WTO.

[15] https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/auctioning_en.

Exceptions to the above can be applied to the non-discrimination principle as per Article XX of the GATT, and the chapeau requirement. Exceptions which are pertinent to the CBAM include those on environmental protection: protection of animal or plant health and conservation of natural resources (Cosbey et al, 2019). The CBAM, being a tool to aid in fighting climate change, might be considered eligible for these exceptions. However, there remain additional challenges for WTO compatibility of the CBAM. The Subsidies and Countervailing Measures of the WTO rules out subsidies on exports. Free allowances, especially applied only on exports as in the EU's CBAM, can be seen as another form of subsidy to domestic producers, this could be problematic for WTO compatibility, although defense arguments (e.g. eligibility to the SCM footnote 1 exception) exist as well.

3.6. Relationship with Nordhaus' Climate Club

To overcome free riding in climate change mitigation, Nobel prize winner William Nordhaus has proposed the concept of ***Climate Club*** (Nordhaus, 2015, 2022). Instead of trying to reach an international agreement of emission reduction involving all countries as in the UNFFCC's COPs, a Climate Club would involve a coalition of countries in a structure that encourages both participation and climate mitigation. ***It combines uniform carbon pricing within countries part of the coalition with trade penalties for outsiders***. For practical matters, in a Climate Club, the countries within the coalition share a substantial carbon price to foster decarbonization. They also set up tariffs on products imported from countries outside the coalition. To trade free of tariffs in the Climate Club's domestic markets, a country would have to implement a carbon price and a tariff on imports on outsiders.

Using an extended version of DICE, Nordhaus (2015) has simulated several scenarios of both carbon prices and tariffs to form a Climate Club. The results suggest that high tariffs are needed to obtain high participation and effective emission reduction induced by carbon pricing. Figure 7 below summarizes the effectiveness of the Climate Club in reducing CO2 emissions as targeted for several combined carbon prices with the coalition and tariffs at the coalition's borders.

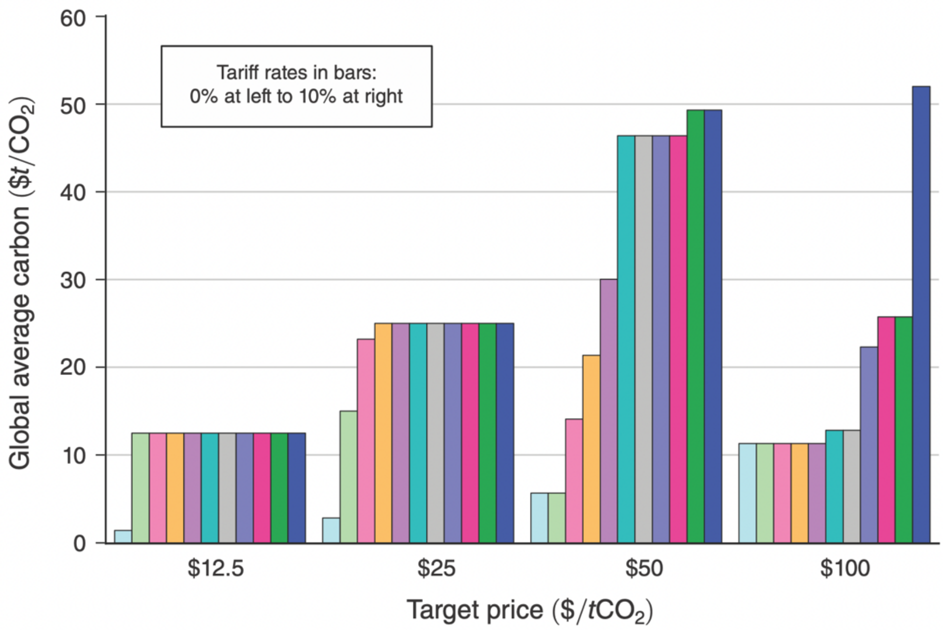

Figure 7: Social cost of carbon achieved with different carbon price and tariffs

The X-axis lays out the carbon price ($12.5, $25, $50 or $100) and the tariff from 0% (no tariff) to 10%, one for each bar from left to right, set up in the Climate Club. The Y-axis reports the global average carbon price achieved with the climate club: what would be the carbon price at the world level that would implement this emission reduction. In other worlds, it yields the social cost of carbon (SCC) of a given emission reduction at the world level. The gap between the global average and the target price for carbon indicates the magnitude of carbon leakage. All countries are members on the Climate Club so there is no leakage if the price difference is nil. Otherwise, membership is partial. The higher the difference, the more emissions leak outside the Climate Club.

The Climate Club cuts emissions without leakage when the SCC is low ($12.5 or $25) even with low tariffs. It indeed induces full or close to full participation to the Climate Club. With higher SCC such as $50 and $100, leakage cannot be avoided even with tariff around 10%. Participation in the climate club is limited to a subset of countries. To obtain an emission reduction corresponding to a SCC of at least $40, a carbon price of $50 or more is required with high enough tariffs. A price of $100 would involve a smaller Climate Club even with a 10% tariff. The emission reduction would be equivalent to a global carbon price around $50.

Nordhaus' Climate Club differs from the EU's CBAM both conceptually and in practice. Unlike the CBAM, the import tariff in the Climate Club is not related to the product's carbon footprint. All imports coming from countries outside the club are charged a percentage of their value as a tariff. The tariff structure is not aimed at leveling the playing field, nor at incentivizing firms to decarbonate their production process. Rather, it is a 'carrot-and-stick' mechanism that induces countries to join the Climate Club despite the loss of competitiveness due to carbon pricing. Nevertheless, one clause of the EU CBAM has this flavor of extending the coalition of countries with climate policy: ***the adjustment of the carbon price paid by importers based on the existing carbon price in the foreign countries***. By implicitly removing monetary barriers to foreign countries with similar carbon price, ***the CBAM***

provides incentives to coordinate carbon prices among jurisdictions. The CBAM might foster the emergence of coalitions with a single carbon price and a CBAM for outsiders.

Concluding summary

The EU ETS is a powerful instrument which contributes to achieve the EU's ambitious climate mitigation targets. However, even if it is good to reduce EU emissions, it comes with some economic costs. By charging to firms the greenhouse gases emitted by manufacturing plants, the EU ETS reduces the competitiveness of the EU's industry. European firms lose their market share both within the EU and outside. The carbon emissions leaks outside the EU. The EU ETS could then turn out to be counter-productive if EU products are replaced by more carbon intensive foreign ones.

Several policy instruments can be implemented to address carbon leakage from a cap-and-trade system such as the EU ETS. The CBAM proposed by the EU Commission and amended by the EU parliament combines a border charge on imports with an export rebate consisting in providing benchmark-based free allowances on the emissions from the share of production that is exported. The CBAM is supposed to replace the free allocation of allowances on total production that are currently in place (after a transition phase during which the two will co-exist).

Using microeconomic tools, we investigate graphically the impact of free allowances, border charges and export rebates on the economy. Free allowances do not undermine firms' incentive to invest into pollution abatement as long as emission permits are valued in the emission market. What matters in the abatement decision is the price of emission permits and the cost of pollution abatement. Free allowances act as a lump sum subsidy that accrues profits which favors entry in the industry. Consequently, the economic activity is higher than under full carbon pricing. Emissions are higher than they should be, unless more carbon-intensive imports are replaced by cleaner EU products. Free allowances level the playing field within and outside the EU's borders.

In contrast, using the CBAM rather than free allowances to tackle carbon leakage makes EU firms pay the full cost of their emissions. Furthermore, by charging the carbon footprint of imported products, the CBAM incentives foreign firms to invest into pollution abatement for their production destined to the EU market. Like free allowance, the CBAM levels the playing field within the EU. However, it does not level the playing field outside the EU unless it is complemented with export rebates. The benchmark-based free allowances on exports in the EU's CBAM as amended by the European Parliament can be seen as a form of export rebate. Overall, switching from free allowances to the EU's CBAM as amended by the European Parliament is likely to reduce the carbon footprint of products and overall emissions both sides of the EU's borders.

The CBAM requires implementing a product-based pricing of embedded carbon emissions equivalent to the manufacturing plant-based pricing of the EU ETS. How easily it would be depends on the sectors that are targeted, the scope of emissions considered, to what extent the carbon-intensity is firm-specific, or the carbon price is country-specific. By targeting few sectors upstream the value chain, the EU's CBAM limits the complexity burden at the expense of potential carbon leakage downstream the value chain. Similarly, accounting for direct emissions (Scope 1) only is administratively easier but open the door to perverse incentives that might leads to further emission leakage. For instance, manufacturers cut the carbon footprint of their product by switching from self-generated power to grid power regardless of the carbon intensity of the electricity used. The EU Parliament's amendment to include indirect emissions (Scope 2) tries to address the problem but at a cost of more complexity. Similarly, computing firm-specific and country- specific emission factors that acknowledge the diversity of production processes and regulatory environments might be challenging. Although solutions exist, the optimal level of specificity should solve a trade-off between operationality and complexity.

The CBAM is quite different from the Climate Club proposed by William Nordhaus. Even though the Climate Club addresses carbon leakage by building tariff barriers around a coalition of countries pricing carbon, its main goal is to incentivize countries to adopt the same carbon price. Nevertheless, by making importers pay only the difference between the EU ETS price and the carbon price of the country of origin, the EU's CBAM induces similar policy spillovers on carbon pricing among countries.

Appendix

Paper	Region	Method [16]	Leakage rate	Main results	Comments
Without leakage mitigation policies					
Fischer & Fox (2012)	US	CGE	Between 5 to 58% for various industries[17], with an overall leakage rate of 7%	The effectiveness of anti-leakage policies varies significantly and depends on country/sector characteristics	Carbon price of $14/ ton
Fowlie et al. (2016)	California	GE	Less than or equal to 20%	A carbon price of $10 on trade flows reduces exports, increases imports as well as leakage risk	Carbon price of $10/ ton
Cui et al. (2022)	China	GE	44.9%	The ETS increases emissions in non-ETS sibling firms by 9%, driven mainly by relocation of production	Daily carbon price between $1.38- 20.88/ ton with an average of $5.6/ ton
<u>Reduction in leakage</u> with leakage mitigation policies					
Böhringer et al. (2012)	Annex 1 Countries	CGE	Between 3-7 pp with with a difference in means of 4 pp (or 33.33%)	Border adjustment can reduce leakage but it can be costly and may raise other concerns such as on redistribution	Sector- and country-specific carbon coefficients
Branger & Quirion (2014)	World	Meta-Analysis	Between 0-19 pp with a difference in means of 8 pp (or 57.14%)	Border adjustment targets leakage best when including wide sectoral coverage and export rebates	25 studies, of which 20 use CGE models
European Commission (2021)	EU	CGE	29% in CBAM sectors	CBAM as proposed by the European Parliament (Option 4) is most effective at reducing leakage	-
Fowlie et al. (2021)	California	PE	43.79%	Complete regulation most effective but difficult to implement; differentiated CBAM performs worse than uniform CBAM	Incomplete regulation relative to complete regulation
Fowlie & Reguant (2022)	US	PE	29%	Large leakage risk in US Manufacturing sectors, but this can be mitigated with targeted subsidies on production	Carbon price of $25/ ton

Table 1: Studies evaluating emission leakage.

[16] CGE: computable General Equilibrium, GE: General Equilibrium, PE: Partial Equilibrium.
[17] 5% for Electricity, 10% for Refined Petroleum Products, 16% for Chemicals and up to 58% for Iron and Steel.

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