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Addressing the concerns about carbon leakage in the implementation of carbon pricing policies: a focus on the issue of competitiveness

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Abstract

This article investigates whether the implementation of asymmetric carbon pricing policies leads to carbon leakage. We first present the theoretical mechanisms behind carbon leakage. Secondly, we conduct a review of the existing empirical results of carbon leakage. We focus on the competitiveness channel and therefore rely on papers analysing the effects of asymmetric carbon prices on both trade and investment flows. Lastly, we discuss solutions to reduce carbon leakage, so that acceptability towards ambitious carbon pricing policies can be maximized.

Keywords Carbon leakage · Competitiveness · Climate policy

JEL Classification Q54 · Q58

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1 Introduction

In the recent years, the urgency to reduce carbon emissions in order to tackle climate change has been acknowledged by numerous scientific reports published by the Intergovernmental Panel on Climate Change (IPCC). This scientific consensus has led to growing public concerns about environmental issues, which in fine was reflected in many public elections. The federal elections held in October 2019 in Switzerland testified of this trend: Out of the 200 seats at the National Council, Greens gathered 28 seats (+17), becoming the fourth largest represented political party in this chamber.

Reducing carbon emissions will require effective and efficient policy instruments. Among all available policy instruments, economic instruments (carbon pricing, which includes both carbon taxes and cap-and-trade mechanisms) have been recognized as the most cost-efficient tool to reduce carbon emissions (Perman et al. 2003, pp. 202–238). Despite a "near-universal agreement among economists" that carbon pricing is needed to lower carbon emissions at a reasonable cost (Parry et al. 2015, p. xxv), most countries remain reluctant to apply carbon-pricing policies. When looking at the findings from Métivier et al. (2017), it appears that only 25% of the world's greenhouse gazes are covered by a carbon pricing mechanism. More alarming, more than 75% of emissions regulated by carbon pricing are covered by a price below ten USD. It is thus well below the price range of 40–80 USD recommended by Stiglitz and Stern (2017) in order to stay under the two degrees variation. This perfectly shows that only a few ambitious carbon pricing schemes have been implemented so far. At a time when public awareness towards climate change has grown substantially, as well as scientific evidence of its enormous costs for the mankind, it is important to understand why policy makers are still reluctant to apply strong carbon pricing policies. Since public opinion has been identified as a "key element of policy changes in democratic countries" (Drews and Van den Bergh 2015, p. 856), it therefore follows that citizens' concerns regarding carbon taxes should also be investigated.

One of the main reasons behind this slow implementation is the concern that in a world where carbon prices are applied unevenly across countries, the reduction of carbon emissions achieved in abating countries may be partly offset by an increase of emissions in non-abating countries. This issue is called carbon leakage (CL) and can be defined as "the increase in emissions in the rest of the world when a country or a region implements a climate policy, compared to a situation where no policy is implemented" (Branger and Quirion 2014a, p. 54). It can be measured as the following ratio (Barker et al. 2007, p. 6284): $CL = -\Delta CO_{2\,N}/\Delta CO_{2\,M}$ with: $CO_{2\,N}$ being the level of emissions in non-mitigating countries, and $CO_{2\,M}$ being the level of emissions in mitigating countries. Therefore, a CL ratio of 20% would mean that 20% of the mitigation of CO_2 emissions achieved in mitigating countries is undermined by an increase of emissions in non-abating countries. It is important to note that any ratio under 100% still means that the policy has globally been able to reduce CO_2 emissions.

We will see that asymmetric carbon prices can lead to carbon leakage through three channels: an effect on the global energy market, a competitiveness channel and technological spillover effects. We have chosen to center this article on the competitiveness channel because it seems to play a large role on people's acceptability for carbon pricing policies. Recently, a growing part of the literature has focused on understanding which reasons affect people's acceptability for carbon pricing policies. Carattini et al. (2017) provide an updated review of literature on the aversion of people regarding carbon tax. One of the strongest explanation which they have found is the fear for negative effects on competitiveness and employment. Stiglitz also perfectly emphasizes the importance of the question of the competitiveness channel (see definition further below) in terms of public acceptability: "Even if the quantitative effects (of carbon leakage) are limited, the political consequences of plants and jobs moving to another jurisdiction because of its lower carbon price can be significant, and undermine support for strong carbon policies" (Stiglitz and Stern 2017, p. 23).

This article investigates whether those concerns for carbon leakage are justified or not, based on economic theory and empirical results. The paper is organized as follows: We first describe the mechanisms through which carbon leakage takes place across countries. Then, we present empirical evidence of the importance of carbon leakage across countries, focusing on the competitiveness channel. Finally, we discuss which policy instruments could be used by policy-makers in order to tackle carbon leakage.

2 The main channels through which carbon prices may affect CO_2 emissions of partner countries

The implementation of unilateral (or asymmetric) carbon pricing policy can have three different effects on the level of emissions in the other countries (Dröge 2009). Those three channels are summarized in the Fig. 1. When added together, those three channels represent what we have defined as carbon leakage. Two of those channels lead to an increase of CO_2 emissions in non-abating countries. The last channel goes in the other direction and contributes to reducing carbon emissions in non-abating countries.

The first channel is the effect of carbon pricing policies on the global energy market. The intuition behind this mechanism is the following: when a country (or group of countries, i.e. the European Union) implements a carbon pricing policy, firms in those countries reduce their demand for CO_2 intensive energies (for instance fuel). This lower demand drives down the price of those energies in the global market. Therefore, firms located in countries who do not impose a price on emissions can benefit of lower prices. Theoretically, those latter are thus expected to increase energy consumption and increase output in non-abating countries. However, this mechanism is subject to a few assumptions. First, countries must be large enough to have a market power on the energy market. Otherwise, there is no reason why carbon pricing policy in a country would affect the price of energy faced by other countries. Secondly, it assumes that other source of energies do not also become more affordable. This latter assumption is questionable, as recent reports on the energy market are starting to present renewables energies as cost competitive substitutes for fuel-based energies (McKinsey 2019). However, it has to be noted that the extent to which both sources of energy can be substituted will depend on the technological flexibility of production processes. Lastly, the supply response of the fossil-fuel producers will also likely affect the overall results.

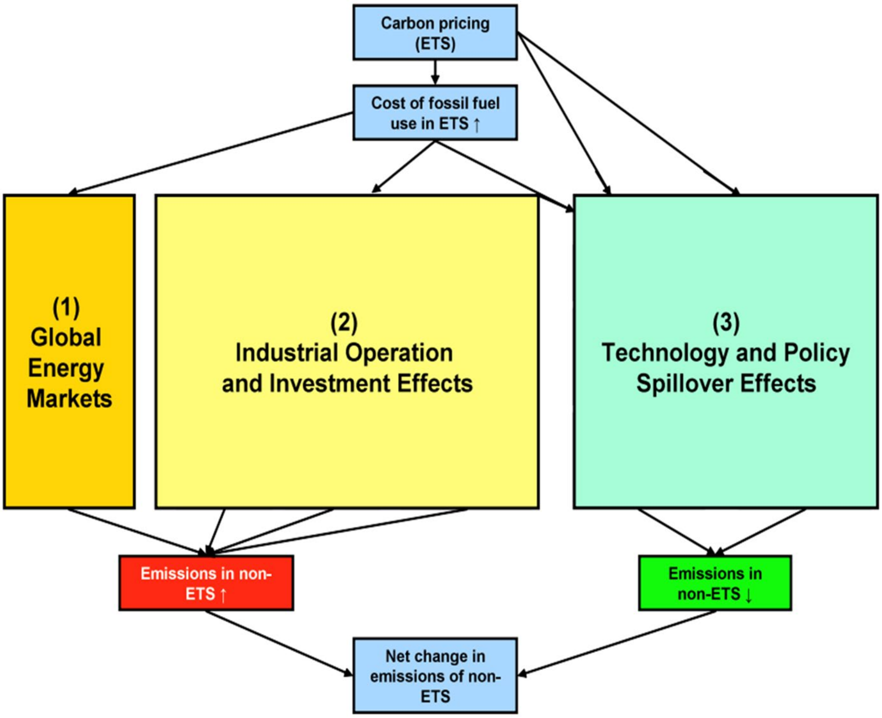

Fig. 1 Carbon pricing and the channels for carbon leakage. Source: Dröge (2009, p. 16)

The second channel concerns the effects of carbon pricing on both industrial operations[1] (i) and investments (ii). It is also commonly called the competitiveness mechanism. The key idea behind this channel is that "the cost of compliance gives a comparative disadvantage for regulated firms vis-à-vis their competitors" (Branger and Quirion 2014a, p. 55). In other words, firms located in countries with strong carbon pricing policies automatically face higher costs of production than firms in other countries. This creates a change in relative prices, which can then have effects, at least theoretically on various outcomes (economic, technological, international and environmental), as shown in the Fig. 2.

If we focus on international outcomes, two major consequences can be observed. First, the change in relative prices leads to "a change in the trade balance" (Ibid, p. 55): countries with stricter carbon policies will export less and import more. The direct (short-term) modification of the trade balance is what Dröge defines as the "operational leakage". In other words, this operational leakage simply refers to "domestic firms losing market shares to unregulated foreign competitors" (Naegele and Zaklan 2019, p. 126). Secondly, in the medium or long run horizons, the change

[1] Industrial operations simply mean "production".

First-order effect	Second-order effect	Third-order effects			
Cost impacts	Firm responses	Economic outcomes	Technology outcomes	International outcomes	Environmental outcomes
Changes to relative costs (direct and indirect costs)	– Production volume – Product prices – Productive investments – Investment in abatement	– Profitability – Employment – Market share	– Product innovation – Process innovation – Input-saving technologies – Total factor productivity (TFP)	– Trade flows – Investment location – Foreign direct investment (FDI)	– Pollution levels and intensity – Pollution leakage

Fig. 2 Competitiveness effects due to differences in the stringency of environmental regulations. Source: Dechezleprêtre and Sato (2017, p. 186)

of relative prices leads to a relocation of investments in non-abating countries.[2] Indeed, investments are driven by profitability, and high carbon prices reduce profitability. This element is called the "investment leakage". Those two types of leakages (operational and investment) therefore affect trade flows between countries (Ibid, p. 2). Therefore, it is possible to assess this competitiveness channel by looking at variations in both trade and investments flows after the introduction of carbon pricing policies.

This competitiveness channel is also by far the most debated in current debates, and was in fact at the heart of the policy process of the EU emissions trading system (ETS) (Dröge 2009, p. 6). Therefore, it is worth making an important precision about it. It does not concern all economic sectors, but only those actually facing the risk of carbon leakage. Sectors at risk meet the following two characteristics. First, "the carbon cost must be high" (Branger and Quirion 2014a, p. 55), meaning that a large share of their activities releases CO_2. Therefore, carbon policies increase the costs of production of those sectors. Secondly, "international competition in this sector must be fierce" (Ibid, p. 55). Indeed, without international competition, there can be no relocation of industries in other countries (and therefore no carbon leakage). The major sectors at risk in the European Union, based on those two criterions, are: iron and steel, cement, refineries and aluminium. This is consistent with the findings by Branger and Quirion (2014a, p. 55).

The third channel of carbon leakage actually has the opposite effect on emissions abroad: the implementation of unilateral carbon policies can also reduce emissions in non-abating countries through innovation spillover effects. This dynamic effect originates from the capability of environmental regulations (including carbon pricing) to induce innovation. Michael Porter was one of the first economists to highlight this innovation effect (Porter and van der Linde 1995). The so-called "weak" form of the Porter hypothesis (PH) reports that well-designed environmental regulations could in some cases induce innovation (but still generates regulatory costs

[2] This is in line with the economic theory of the pollution haven hypothesis.

for the firms). In its "strong" form, the PH states that in other cases, the innovation effect can more than offset the regulatory costs, meaning that the environmental regulation ultimately increases the competitiveness of some firms (Ambec et al. 2013, p. 4). Well-designed market-based policies (carbon pricing) reduce the uncertainty faced by firms on whether investments to reduce CO_2 emissions are valuable. The additional cost of the regulation also gives stronger incentives to reduce inefficiency in their productions. By increasing innovation and deployment of energy-friendly technologies, carbon pricing can help to reduce the costs of those technologies (for instance solar panels in Europe). Those technologies are then available at a lower cost for non-abating countries as well. Therefore, innovation in abating countries (induced by carbon policies) can lead to more efficient production (in terms of energy) in non-abating countries. However, Dröge (2009, p. 20) mentions high difficulties to measure this innovation spillover effect. Indeed, it is difficult to isolate the effect of carbon pricing policies on innovation since abating countries tend to implement additional policies which try to foster energy-friendly technologies (ex: feed-in tariffs or public spending for R&D).

As we just saw it, the three channels of carbon leakage have different effects. The effect on the energy market as well as on competitiveness can lead to an increase of emissions in the rest of the world, while diffusion of new technologies can reduce emissions in the rest of the world. Theoretically, the overall net effect of carbon pricing on leakage is then unknown (Dröge 2009, p. 21). The uncertainty about this net effect of asymmetric carbon policies (or more generally of environmental policies) on competitiveness is shown by the existence of two opposing views in the literature (Dechezleprêtre and Sato 2017, p. 183). The well-known Pollution Haven hypothesis argues that firms active in energy-intensive sectors will attempt to avoid the cost of stringent environmental policies by relocating in laxer countries. Therefore, we see that the Pollution Haven hypothesis assumes that the competitiveness channel and the effect on the global energy market are stronger than the technology and spillover effects. On the contrary and as mentioned earlier, the Porter hypothesis argues that "environmental regulations can actually trigger innovation that may more than fully offset the costs of complying with them" (Ibid, p. 187). According to this view, technology spillover effects would be the strongest mechanism; allowing environmental regulations to even increase competitiveness. If this Porter hypothesis happens to be correct, we should see no evidence of carbon leakage in real cases.

3 Empirical evidence of carbon leakage through the competitiveness channel

We now conduct a review of empirical evidence on the existence of carbon leakage through the competitiveness channel. We focus on this particular channel for two reasons. First, it is by far the most debated one in political and public discussions on carbon pricing: "Concern for industrial competitiveness is often put forward as a key barrier to more ambitious carbon pricing policies" (OECD discussion paper 2017, p. 9). Relocation of firms abroad, even if rare, are used by opponents of carbon pricing policies as proof of their negative economic impacts. Secondly, it is, among the three channels presented earlier, the one which has been the most clearly investigated empirically.

Even though the definition of carbon leakage is rather simple, empirical assessment is challenging. Indeed, it requires accurately "differentiating the shift in emissions and the changes in production and investment patterns caused by climate policy, from what is attributable to other drivers" (Marcu et al. 2013, p. 3). There are two possibilities to assess empirically the carbon leakage phenomenon. The first one is to use *ex-ante* CGE modeling. Papers by Elliott et al. (2010) and Carbone and Rivers (2017) are representative of this approach. The second option is to run *ex-post* econometric studies, based on actually implemented carbon policies (see below: Naegele and Zaklan 2019). We here focus on ex-post analysis, as they provide a more meaningful insight on whether carbon leakage should currently be a concern of policy makers. We will first focus on estimates of the effects of carbon prices on trade flows, which are one possibility to measure competitiveness. This is by far the approach chosen by the largest numbers of empirical studies. We will then briefly present studies analyzing the effects of carbon pricing on flows of foreign direct investments (FDI).

3.1 Effects of carbon prices on trade flows

Ex-post estimations allow analyzing the impact of a carbon pricing policy on real economic indicators (trade, employment, investments). Unfortunately, those empirical set ups are limited by three key issues (Carbone and Rivers 2017, p. 29). First, there are only a few examples of ambitious carbon policies, and those are relatively recent. Therefore, there is only limited evidence on real-world cases. Secondly, data are often hard to gather, especially for "environmental policies and economic performances in less developed countries" (Ibid, p. 29). Lastly, estimating the effect of carbon policies on competitiveness requires treating those policies as exogenous. This is a questionable assumption, since economic conditions at least partly affect the adoption of climate policies.

Still, the rapid development of carbon pricing initiatives in the last five years provides new case studies for empirical assessment. At the same time, data availability and empirical methods are also being improved, which has led to the publication of new ex-post studies. In this chapter, we analyze whether ex-post estimations find significant evidence of carbon leakage. First, we will present the recent paper by Naegele and Zaklan (2019), which analyzes carbon leakage in the case of the EU ETS. Then, we will briefly review the ex-post literature on carbon leakage.

The paper by Naegele and Zaklan (2019) has two mains interests: First, it explains clearly how the stringency of a carbon pricing policy can be measured. Second, it performs numerous sensitivity analysis, which all confirm their initial conclusion.

Their goal is to analyze carbon leakage in the manufacturing sector,[3] after the introduction of the EU ETS. They focus on trade flows between countries. Precisely, they test if "parts of the evolution of sectoral trade intensities can be explained by the stringency of environmental policy" (Ibid, p. 126). Their methodology is to regress a measure of trade (dependent variable) on the stringency of carbon pricing policies and other control variables. The first empirical question is how to construct their main repressors: *policies' stringency*. They measure it with the following equation (Ibid, p. 130):

$$\theta^{tot}_{ist} = \theta^{d}_{ist} + \theta^{i}_{ist} - \theta^{a}_{ist}$$

The first term (θ^{d}_{ist}) is the direct cost of the ETS, basically the allowance price multiplied by the emissions covered by the EU ETS. The second one (θ^{i}_{ist}) is the indirect cost of the ETS, measured by the increased price of electricity which all sectors face. The last term (θ^{a}_{ist}) is the level of free allowances offered to some sectors, which reduce the total cost. Therefore, this equation measures the total cost of the cap-and-trade for a particular sector, which is used as a proxy for its stringency.

Two possible indicators measure *bilateral trade*. When they are available, Naegele and Zaklan use the trade flows in "embodied carbon". This is simply the amount of CO_2 emissions that were used to produce a traded product. When those data are not available, they simply use trade flows in US dollars. Therefore, the equation estimated is the following:

$$y_{xmst} = \alpha^{m}\theta_{mst} + \alpha^{x}\theta_{xst} + \beta\tau_{mst} + \gamma F_{mst} + \delta t_{mst} + v_{mt} + v_{xt} + v_{st} + v_{mxs} + \varepsilon_{mxst}$$

where Y_{xmst} is the trade flow (=exports of country x—imports of country x) from country x to country m, in year t and sector s. θ_{mst} and θ_{xst} are the stringencies of the carbon pricing policy, respectively in the country m (importer) and x (exporter). τ_{mst} (tariffs on imports) in the importer's countries, as well as transportation costs (t_{mst}) automatically protect some sectors from carbon leakage. Therefore, they are also included. The other elements are control variables (year-fixed effects, as well as sector-country and sector-country fixed effects).

Concerns of endogeneity (as well as omitted variable bias) are addressed in further details by the authors (pp. 130–131), but the details presented here should be sufficient to understand the intuition of their regression.

What should be the results of the equation if the EU ETS caused carbon leakage? In this case, θ_{xst} should have a negative effect on Y_{xmst}: If the stringency of the policy is increased in country x, then his exports towards country m will go down (therefore Y_{xmst} also goes down). On the contrary, θ_{mst} should have a positive effect on Y_{xmst}: If the stringency of the policy is increased in country m, then the imports of country x from country m will go down (therefore Y_{xmst} will increase).

[3] This term refers to production activities in which raw resources are transformed into finished goods. Those activities are often energy intensive and exposed to trade, therefore matching the definition of sectors at risk of carbon leakage.

The period analyzed by the authors goes from 2004 to 2011. Since the EU ETS was implemented in 2005, this also allows having data for one year prior to the implementation. Their data on trade is drawn from the Global Trade Analysis Project (GTAP), while measure of stringency comes from the EU Transaction Log (EUTL).

The authors conduct this estimation for both measures of trade ("embodied carbon" and value in US dollars). In both cases, their results show no evidence of an effect of carbon prices on trade flows (Ibid, pp. 136). In the estimation with embodied carbon, neither θ_{xst} nor θ_{mst} are statistically significant. With US dollars, θ_{mst} is significant at the 10% level, but has the wrong sign (it is negative, while it should be positive in the case of carbon leakage). The authors conduct multiple robustness checks (pp. 138–146), as well as a second estimation with a simplified version of the initial equation (pp. 134–136). The results remain the same: "The EU ETS did not have a systematic impact on trade flows" (Ibid, p. 137).

This result is in line with other ex-post estimations of carbon leakage in the EU ETS. For instance, Branger et al. (2013) analyze consequences of the EU ETS on the competitiveness of cement and steel industries. They also find that the price of the allowances does not affect trade flows in those two industries. More generally, ex post empirical studies do not provide convincing evidence of carbon leakage. Branger and Quirion (2014a) conduct a review of ex-post analyzes of carbon leakage. They fail to find any significant negative effect of the EU ETS on competitiveness. More recently, Dechezleprêtre and Sato (2017) carry out a review of all the most recent ex-post estimations. They present an interesting conclusion: There seems to be a validation of the pollution haven hypothesis. Indeed, the few studies which analyze the effects of carbon pricing policies on trade flows tend to find a very limited, but still negative effect. For instance, they report the findings of Sato and Dechezleprêtre (2015), which find that "energy price differences explain 0.01% of the variation in trade flows". Nevertheless, those effects remain extremely limited, as the authors are unable to find any large and significant one. Therefore, they conclude that other factors than stringency play a larger role in trade flows: "The effect of relative stringency on trade flows is overwhelmed by other determinants of trade" (Dechezleprêtre and Sato 2017, p. 191).

This leads to the question of why carbon pricing does not seem to alter trade flows, even when some countries unilaterally impose stricter regulations. The existence of other determinants of trade may be one powerful explanation. Another strong explanation is the low-ambition of carbon pricing policies. In the study that we have presented earlier, Naegele and Zaklan (2019) have estimated the cost generated by the ETS for manufacturing sectors. In average, the total cost[4] generated by the ETS amounts to only 0.10% of firms' material cost. Thus, is it surprising to find no evidence of carbon leakage given the low cost imposed to polluters? Indeed, it means that if producing abroad generates any additional costs of the same amount than the abatement costs (here 0.10% of total production costs), abating countries will not face any loss of competitiveness in comparison with non-abating countries.

[4] See the equation of the cost (or stringency) of a policy presented earlier.

Those additional costs could be transportation costs, or also a fixed relocation costs (Naegele and Zaklan 2019). Another explanation comes from the fact that empirical studies do not account for the technology spillover channel of carbon leakage. Let us remind that this latter states that stricter environmental policies may induce innovation in energy-friendly technologies. Many evidence of such a dynamic effect have been found in the literature (Dechezleprêtre and Sato 2017, pp. 198–199). Whether this effect is sufficient to compensate the increased costs of abatement remains an open empirical question, but it might at least partly explain why evidence of carbon leakage are so rare. The exact answer is probably a combination of those different mechanisms.

3.2 Effects of environmental regulations on Foreign Direct Investments (FDI)

Studies analyzing the effects of only carbon pricing policies on cross-countries FDIs are to our knowledge inexistent, mainly because they require clearly comparing the stringency of two countries' carbon pricing policies. Nevertheless, a growing number of studies are focusing on the effects of general environmental regulation (including, but not only carbon pricing) on FDI locations. We now briefly present some of those studies, asking our readers to remember that they do also cover over types of environmental regulations.

The first question regarding FDI destination is whether lax environmental stringency attracts FDIs ("pull effect"). The empirical answer to this question remains for now limited and mixed. Dechezleprêtre and Sato (2017), in their review of literature, report only one study (Kellenberg 2009), which has found conclusive proof of a pollution haven effect in FDI when assessing US multinationals investment decisions. Recently, Mulatu (2017) has been able to show that a reduction of environmental stringency had a strong impact on British FDI of firms already present in those countries. Their results imply that a variation of environmental regulation will not bring new investors in a country, but that investors already present will tend to increase their stock of investments. On the contrary, other studies such as Raspiller and Riedinger (2008) have found "environmental regulations to be neither statistically nor economically a significant determinant of the location of (French) firms". The second important question for FDI is whether strict environmental policies "push" firms to invest abroad ("push effect"). Once again, the answer remains to be clearly determined empirically: "Whether stringent environmental policies encourage firms to increase foreign assets remains empirically unresolved" (Dechezleprêtre and Sato 2017, p. 193).

On the other side, it will be interesting to see if future empirical studies will be able to find a positive effect of environmental policies on cross-country FDI in renewable energies. If it is the case, they may offset the potential leakage of investments in energy-intensive industries. To our knowledge, very few papers have yet investigated this mechanism. Still, we expect this part of the literature to grow quickly, given the strong international demand for green investments. Ragosa and Warren (2019) failed to show a positive impact of carbon prices on FDIs in the renewable energy sector. On the contrary, feed-in-tariffs had a clear positive impact.

We can conclude this section by saying that at the current level of ambition of carbon pricing policies, there is no clear evidence of competitiveness issue generated by carbon pricing schemes. Even though studies tend to find environmental regulations to have negative effects on competitiveness, those effects are usually extremely moderate. It then clearly appears that "concerns about carbon leakage are not unfounded, but may have been largely overplayed" (Sato and Dechezleprêtre 2015, p. 5).

Nevertheless, we need to emphasize that all the studies presented in this section are ex-post analyzes of currently implemented carbon prices. From the introduction, our readers should know that current carbon prices are often set at very low levels. In the future, these prices are expected to rise, as the goal of any carbon pricing policy is to increase stringency over time. This can be done by many manners: increasing the price on carbon emissions (raising the tax in a carbon tax), limiting the number of free allowances in a cap-and-trade system, etc. As carbon pricing policies become more costly for local energy intensive sectors, the issue of competitiveness may become stronger. In this regard, ex-ante analysis can provide meaningful insights regarding the levels of carbon leakage, which may happen once carbon prices increase. Indeed, ex-ante analyses allow simulating the effect of a hypothetic carbon price on economic indicators, using CGE models. It is therefore a complete different methodology than the ex-post methodology. Of course, conclusions from CGE models must be analyzed carefully: they depend on the parameters of the model, as well as the scenarios that they simulate. Still, it is interesting to note that while ex-post studies fail to find concrete evidence of carbon leakage, ex-ante analyzes have been able to do so. In their systematic review of literature, Carbone and Rivers (2017) analyze the results from 54 ex-ante empirical studies, which had assessed the effects of unilateral carbon pricing policy on competitiveness outcomes. Pooling those analyzes together allow to have some variation in the underlying features (assumptions) of the CGE models. First, the authors find that "the estimated leakage rates are consistently positive across the studies in the sample—typically in the range 10–30%" (Carbone and Rivers 2017, p. 36). They also witness a slightly positive correlation between abatement effort and leakage rate. This is line with the conclusion of the third assessment report of the Intergovernmental Panel on Climate Change, which also emphasized that carbon leakage is an "increasing function of the stringency of the abatement strategy" (IPCC 2001, p. 59).

Therefore, it is useful to discuss possible solutions that are available. Even though those solutions may not yet be required today, their existence may reduce people's concerns about negative effects on competitiveness. In this regard, they may help increasing acceptability for carbon pricing.

4 Some solutions to avoid (future) carbon leakage

Even though we have shown that carbon leakage is not a major issue in the current situation, it may become one as carbon prices increase in the future. Indeed, if the gap in carbon prices between abating countries and non-abating countries increases,

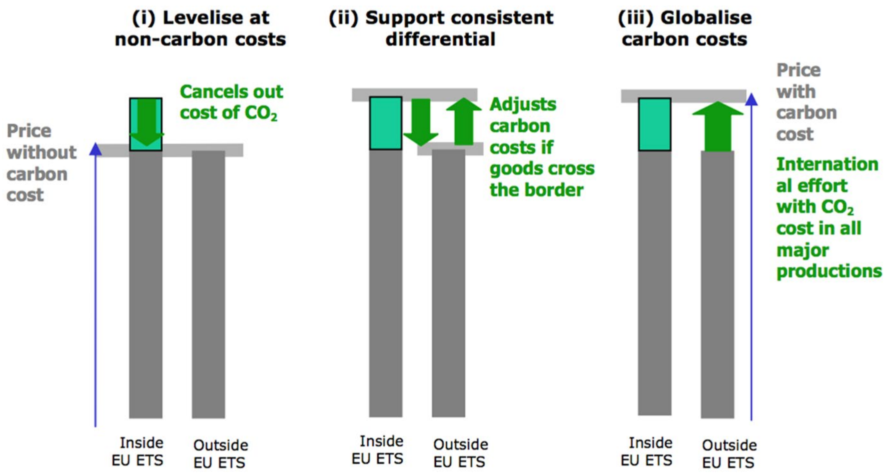

Fig. 4 Options to adjust carbon costs. Source: Dröge (2009, p. 40)

it will become more and more difficult for firms in the abating countries to keep a comparative advantage over firms in the non-abating countries. The literature proposes three different solutions in order to avoid carbon leakage (Dröge 2009, pp. 40–61). Those solutions all try to "level the playfield" of carbon prices, meaning that producers at home or abroad should face the same carbon costs. Those three options are perfectly summarized by the following simple figure (Fig. 4).

The first option (i) is to level the costs downwards. This implies that energy-intensive firms facing international competition should be "protected" by lowering their tax burden. The second option (ii) is to proceed to Border Carbon Adjustement (BCA). The idea is to adjust the carbon costs of goods crossing the border (both exports and imports), based on the costs which are imposed in their country of destination (for exports) or origin (for imports). Finally, the last option (iii) is to increase cooperation from non-abating countries, such that they also start imposing a price on CO_2 emissions. This would automatically prevent carbon leakage. These different options are discussed in the following.

4.1 Downward adjustment of carbon costs

Downward adjustment of carbon costs implies protecting sectors at risk of carbon leakage, by reducing the price of emissions abatement which they face. The most important (and often used) method is "grandfathering". Grandfathering simply consists of freely allocating emission permits to those firms at risk of carbon leakage. Nevertheless, it is clear that this method creates a very important trade-off (Dröge 2009, p. 46). On one side, free allowance preserves local firms' competitiveness compared to international competitors, and thus should reduce incentives for carbon leakage. But on the other side, it strongly undermines polluters' incentives to reduce

GHG emissions.[5] Indeed, they no longer pay the direct cost of abatement (since they receive the emission permits for free), which is the key idea of carbon pricing. This automatically reduces cost-efficiency of carbon pricing. Indeed, in order to reach the same level of abatement, "more abatement must take place in the other sectors, including less cost-effective options" (Branger and Quirion 2014a, p. 61). Note that the carbon price itself is the main signal of the ambition of a particular carbon-pricing scheme. Since free allocation of permits (in a cap-and-trade) basically equals to not imposing a carbon tax on certain sectors, it is clear that grandfathering does not lead to the implementation of ambitious carbon pricing policies. Therefore, it does not appear to be an effective solution, given the urgency to reduce GHG emissions.

Our point here is not to say that grandfathering should never be used. In some cases (when industries truly face risks of carbon leakage), it may be a useful *short-term* solution. But over time and because of the trade-off it creates with the environmental objectives, it should only concern a marginal share of emission permits. Particularly, over-distribution of free emission permits (as we have presented it in Box 1) should be stopped. Indeed, it has multiple negative consequences. First, since we saw that it is similar to granting a subsidy to polluters, it reduces the resources available to invest in green technologies. Secondly, it is very likely that citizens would be even more suspicious against carbon pricing after hearing of those windfall profits made by polluters.

4.2 Border carbon adjustment

A second option to address concerns of leakage is the concept of Border Carbon Adjustments (BCA). BCA is a way to balance carbon costs at the border for exchanged goods. In its initial form, a BCA was to be applied only on imports (border charge on imports). Since then, it has also been proposed for exports (border rebate for exports) and as a combination of both of theses options (full border adjustment). First, we will explain how BCA work and what their advantages are. Secondly, we will present the two limits to the implementation of BCA.

- Definition and advantages of BCA

Let's explain the concept of BCA with a small example. Imagine a situation with two countries A and B trading with each other. A has implemented an ambitious carbon pricing policy, for instance a carbon tax. Country B, on the contrary, is not taxing GHG emissions. As we saw it earlier, such a situation would create the risk for carbon leakage (from A to B), such that a part of the improvement in A would be undermined by an increase of emissions in B. Border carbon adjustments on the imports of country A would work as follows: exporters (located in country B) would

[5] It is important to note that free allowance does not completely delete polluters' incentives to reduce GHG emissions. Indeed, they still have the opportunity to sell those emissions permits. Since reducing GHG emissions automatically increase the number of permits which they can sell, some incentives are preserved.

be required to pay an amount at the border equivalent to the carbon cost applied within country A (Dröge 2009, p. 55). Basically, in order to have access to the market of country A, exporters first need to pay the same carbon price faced by producers in country A. In even simpler words, BCA applied on imports is simply a way to extend a carbon tax on imports. Regarding BCA on exports, we will not discuss it more in details. Indeed, it is nothing more than leveling carbon costs downward for exports of country A. Indeed, it requires reducing the carbon costs for exporters of A, such that they do not face a competitiveness disadvantage. We have already explained why this instrument is not optimal, and therefore will here focus on BCA applied to imports.[6]

The first advantage of BCA is that by equalizing the costs of carbon on both sides of the border, it "levels the playfield" in international trade. Therefore, it should be able to reduce carbon leakage. Using CGE models, multiple analyses have been able to show the theoretical quantitative effects of BCA. Böhringer et al. (2012a) showed that BCA allows to effectively reduce carbon leakage, and particularly for emissions-intensive sectors. Branger and Quirion (2014b) also find that everything else being constant, BCA reduces carbon leakage by 6% (results from a meta-analysis).[7]

In the long term, BCA is supposed to create "political leverage for more climate action across countries" (Mehling et al. 2017, p. 24). Indeed, non-abating countries would have incentives to implement a carbon pricing policy. As a matter of fact, as we saw it with our initial example, exporters from country B are required to pay the carbon price before to access the market of country A. The revenues from this tariff on imports therefore increase the revenues of country A. If B were to implement a carbon pricing policy, those revenues would no longer be perceived by a foreign state (A), but would directly increases their own revenues. However, this argument is also balanced by a potential negative effect of BCA. Indeed, it may "trigger a trade war because of green protectionism suspicions" (Branger and Quirion 2014a, p. 62). Since BCA have so far never been implemented in practice, there is yet no clear possibility to evaluate those arguments empirically.

Also, the introduction of BCA "substantially changes the outcome of climate cooperation game" (Helm and Schmidt 2014, p. 2). Indeed, BCA (both on exports and imports) reduce the costs to impose a carbon pricing policy, while BCA on imports increase the costs of not having implemented a carbon-pricing scheme. Those two effects increase the incentives to implement a carbon pricing policy, and thus should allow increasing cooperation between countries. We do not go any further on this topic, as it will be discussed more in the next subsection.

- The main limits of BCA

[6] For more details on the various forms of BCA, readers can look at Fischer and Fox (2012).

[7] Those studies also show that BCA have negative effects on equity between countries, because it imposes a large cost on non-abating countries (which are often less developped countries). See Böhringer et al. (2012b) for a better discussion of this issue.

The idea of BCA has gathered more and more support over the years, both among researchers and policy makers. For instance, French President Emmanuel Macron has repeatedly said that this instrument is "indispensable to an effective and equitable ecological transition for Europe" (Mehling et al. 2017, p. 9). Therefore, why has it never been implemented yet?

The first limit to the implementation of BCA is its actual feasibility. First, in order to calculate the right level of BCA, countries need to know the level of "embodied carbon" of their imports. The difficulty of gathering such data is often put forward as a limit to BCA. However, this is a solvable issue as underlined by Mehling et al. (2017): "availability of such data has greatly improved in recent years… and provide continuously improving datasets for the determinants of carbon embedded in international trade" (pp. 46–47). The second measurement problem is to accurately assess the net difference of carbon prices between two countries. In the case where the other country has no carbon pricing policy in place, then this calculation is rather simple. But when the two countries have uneven carbon prices, calculating the net difference can be tricky and costly.

But by far, the most debated limit of BCA is its legality under international trade law. Indeed, BCA could be used as some form of protectionism against foreign competitors, and thus may come as illegal under the GATT and WTO laws. Regarding a BCA on imports, the GATT imposes two particularly important elements. First, a BCA should not violate the clause of the *Most Favored Nation Treatment* (art I). As stated by Dröge (2009), a "general border adjustment applied to all imports would be in compliance with the clause" (p. 62). On the contrary, a BCA that varies based on the origin of the product would be questionable under art I. Secondly, a BCA on imports should also not violate the clause of the *National Treatment* (art. III). This clause basically forbids the implementation of any "internal taxes and other internal charges… which would afford protection to domestic production" (art. III, 1). More precisely, any imports from contracting parties "shall not be subject, directly or indirectly, to internal taxes or other internal charges of any kind *in excess* of those applied, directly or indirectly, to like domestic product." (art. III, 2). We insist on the "in excess", because it implies that "the charging of the imported good as such is not forbidden" (Dröge 2009, p. 61). Rather, it only stipulates that imported goods should not be charged of a higher tax than the local products. Since the core principle of BCA is to equalize the cost across the border, it should not violate this second condition. Even if BCA was found to violate one of those two important articles,[8] it could still be legal if it can be proven to fill one of the ten possible reasons for exceptions (art. XX). In the case of the fight against climate change, it can be argued that BCA match with the two following exceptions: measures "relating to protect human, animal or plant life or health" (art. XX, b) or "relating to the conservation of exhaustible natural resources…" (art. XX, g). In the end, the legality of a BCA will highly depend on the design and motives of this particular BCA: "for an environment-related trade measure to be justified, it needs to be drafted and applied in a way that does not unjustifiably or arbitrarily discriminate between domestic and

[8] It is still a debated question in the literature.

foreign products and among foreign products from different origins" (Tamiotti 2011, p. 1208).

Without going in further legal debate, it appears that BCA would not necessarily violate international trade laws. Furthermore, some exceptions (art. XX) could allow the application of BCA.

4.3 Increasing global cooperation

The last way to reduce carbon leakage is (simply) to increase global cooperation. Indeed, we saw that the starting point of carbon leakage is the application of uneven carbon pricing policies across countries. However, according to the Westphalian view of international relations, there is no "supra state" which has the authority to regulate global public goods. Rather, all countries must voluntarily agree to cooperate on this issue. As incentives of countries are theoretically to free ride on others' efforts, it is extremely hard to reach effective agreements.[9] In the case of climate change mitigation, this is even complicated by the fact that climate change has different effects on various regions. Therefore, interests of all countries are not automatically aligned. We now present some interesting suggestions from the game theory, which can be applied to environmental cooperation.

- Working in smaller groups

Working in smaller coalitions may first be seen as counterproductive for increasing global cooperation. But this suggestion results from the extreme difficulty to negotiate between all countries. This is for instance one of the major limits to reach agreements within the United Nations Framework Convention on Climate Change (UNFCCC): agreements are based on consensus, thus offering the power of veto to each of the member (175 countries). This requirement is even more problematic given the huge heterogeneity among states' interests. Particularly, the difference between developed and developing countries has led to failures on agreeing on treaties (for instance the Copenhagen agreement). On one side, developed countries have heavily used emission-intensive activities to reach their current level of development. Their high level of income also allows them to react better to consequences of climate change, and to recover from them. On the other side, developing countries have so far produced way less emissions. But their current desire to develop economically creates an increasing production of emissions. Those countries lack the capabilities and resources to protect themselves from the effects of climate change. This creates a situation where the countries who have so far not contributed much to the global warming will be the one suffering the most from its effect. Meanwhile, the economic growth they are witnessing is requiring a large increase of energy (Paavola 2012, p. 420). This divergence between developed and developing countries' interests reached a peaking point at the COPs of Copenhagen (2009) and

[9] Climate change mitigation is also often depicted as a prisoners' dilemma, as it has the same consequences than a public good game. See for instance Barrett (2016, pp. 14515–14516).

Cancun (2010), testifying from this "insoluble conflict of interests" (Brünnengräber 2012, p. 71).

Therefore, authors propose to work in smaller groups to find solutions (Paavola 2012, p. 423 and Wong 2015, p. 273): "Enabling negotiation among a reduced number of parties appears vital to resolve current stand-offs, or at least to minimize disagreement". In addition to regrouping more homogeneous countries, this would also have the advantage of reducing free riding within those smaller groups. This is based on Olson's idea that smaller groups face smaller free-riding incentives. This relates to the "small coalitions paradox" (Nordhaus 2015): coalitions can either be small or shallow. The intuition behind this paradox is that a large and ambitious (with high carbon prices) coalition will not be stable. Indeed, imposing high carbon prices automatically increases the incentives for participants to free ride. Thus, large and ambitious voluntary coalitions will not be stable.

- Making every actor pivotal

The two next propositions are based on Barrett's conclusion that cooperation requires a "pull" and a "push" (Barrett 2016, p. 14521). A pull means that "Countries must understand that they will be better off if they coordinate". On the other side, a push describes the need for countries to understand that "If most other countries cooperate, those that do not will be worse off" (Ibid).

Barrett (2014) discusses the current failure to coordinate. One of his ideas is to try to reach a "coordination game", and not be in a prisoner's dilemma anymore. To do so, we would need to think of climate change as a "dangerous" game. Assume that if the increase of global temperature goes over a certain threshold, the consequences will be disastrous. This is an assumption that is very close to reality. It is agreed that global warming should be kept well below two degrees. In this situation, a treaty should be written this way: "It should assign to every country an emission limit, with each country's limit chosen to ensure that when all the limits are added up, concentrations stay within the "safe" zone. The agreement should only enter into force if ratified by every country" (Barrett 2014, p. 263). This would automatically make every country pivotal, and creates this "push" incentive. If one country slightly emits more than what he should, the catastrophe happens.

Unfortunately, this solution is almost impossible to implement. First because there is a huge scientific uncertainty about how much each country can actually emit, so that climate stays under the two degrees.[10] The second would lead back to the issue of multilateralism. As Barrett states it, driving emissions close to zero would require participation of nearly all countries. Getting all countries to sign a treaty like the one we mentioned would be infeasible. If this treaty was implemented only by a small number of countries, this would open up the door to carbon leakage, and would make it impossible to calculate with certainty how much each country should abate.

- Introducing sanctions to non-participants through climate club

[10] This is mainly due to uncertainty in the carbon cycle.

Another way to create this "push" is to introduce some form of sanctions to non-participants. Graduated sanctions were one of the important characteristics found by Elinor Ostrom's well-known research on Common Pool resources' governance. Here we introduce the idea of implementing sanctions in order to change the incentives structure of countries. This is a key component of any stable solution. In the Kyoto protocol (and also the Paris agreement), "the emissions targets and timetables were chosen in the expectation that they would be met. No consideration was given to whether the treaty created incentives for them to be met" (Barrett 2014, p. 273). On the last idea we discussed, changing incentives (by making every country pivotal) was also the core idea. Unfortunately, we saw that its implementation would be complicated. Here we will consider the idea of Nordhaus (2015) to set up a climate club.

The climate club as envisioned by Nordhaus would be an "agreement by participating countries to undertake harmonized emissions reductions" (Nordhaus 2015, p. 1341). This harmonization would be done by a common carbon price. Countries would be free to choose the mechanism to reach this price (carbon tax or cap-and-trade). The key difference with other proposals is that non-participants would be penalized, through a uniform percentage tariffs on the imports of nonparticipants into the club region. The structure of this sanction is important for two reasons. First, it is an "external"[11] sanction. Since benefits of free trade are usually large for countries, this allows creating strong incentives to enter the club. The second element is that incentives for participants to sanction non-participants are high, as they gain revenues from imposing tariffs. The idea is very close from BCA, but slightly different and easier to implement. Here, the tariffs imposed would be the same for all non-participating countries, and would not necessarily represent the difference of carbon prices.

Nordhaus (2015) has modeled this approach empirically, using a C-DICE model.[12] He was able to show that participation and carbon prices increase with tariffs. Importantly, full cooperation towards a carbon price of 25 USD per ton of CO_2 requires only a 2% tariff. For a carbon price of fifty USD per ton (which would respect what Stiglitz and Stern advice as a necessary price to stay under the two degrees), a tariff of 4% would be required. An interesting finding is also that when no sanction (tariff) is in place, results always lead to no cooperation (even for a very low price of carbon). This statistically shows why the Kyoto protocol has failed.

One of the key issues we see is how to start such a coalition. Is it possible to start with a small number of countries only, or would it require a certain threshold of the world's economy to create incentives to join? If only a few countries are a part of the agreement, then the consequences to non-participate might create only a small cost to the non-participants (because only a few countries impose tariffs on them). Also, participants would suffer of competitiveness issue when exporting to non-participants. Even though neither Barrett (2016) nor Nordhaus (2015) mathematically show how many countries should be required to launch an effective climate club, they both mention the question of a certain threshold needing to be met. With regard

[11] This means that those sanctions are part of a different game, here trade relations.

[12] C-DICE (Coalition Dynamic Integrated Model of Climate and the Economy) is a static economic model which determines whether countries would join a coalition, given this latter's characteristics.

to this aspect, having either China or the United States (by far the two largest polluters in the world) on board seems like an important requirement.[13] Both countries have repeated that they would not engage in binding agreements, which complicated the Paris agreement. The implication of the United States is now extremely weak, with president Trump's decision to back-out of the Paris agreement. On the contrary, China seems to be more and more concerned with the possible effects of global warming. A strong climate club including China and the EU would cover more than 40% of the world's GHG emissions. More importantly, they are two economic powers who could create strong incentives to join the effort by imposing tariffs.

The development above have allowed us to briefly discuss one of the most frustrating failures of international cooperation: Despite a consensus on the negative effects of climate change, countries have yet refused to set up any kind of binding agreement. Even more problematic: none of the currently enforced treaties on climate change include sanctions. According to the literature, this lack of sanctions appears to be the key explanation for the failure of cooperation in this matter (Barrett 2014). We limit ourselves to a basic presentation of a few possible solutions. Nevertheless, it was important to at least mention it, because it is clear that a better cooperation by countries could increase acceptability for environmental policies.

Furthermore, we have found reasons for optimism. Mainly, interesting suggestions in order to reach a cooperative equilibrium are suggested by Nordhaus and Barrett. The core idea is to use trade relations to apply sanctions towards non-participants. Those sanctions should then change the incentives of countries, so that the cost of not cooperating would be too high. Since it was shown mathematically that a small tariff on imports (2%) could lead to cooperation in carbon pricing, this policy could truly be effective. Also, the fact that such a mechanism has already been applied and been successful in the Montréal Protocol shows that this should not remain only a theoretical proposition in the future, but rather be implemented.

5 Conclusion

This article investigates whether people's concerns for carbon leakage through competitiveness disadvantages are theoretically and empirically justified. We showed that so far, ex-post empirical studies have not found significant evidence of a strong impact of asymmetric carbon prices on trade and investment flows. Furthermore, solutions such as BCA or a climate club could prove to be efficient solutions to tackle this issue in the future. Even though those measures have not been implemented yet, policy makers are increasingly mentioning them as credible solutions.[14] Still, already existing trends show that environmental questions will become a focus point of global economic relations. For instance, the importance of environmental issues is already being felt in current

[13] We here assume that the EU would participate in such an effort, since they were frontrunners in the implementation of a carbon pricing policy and would therefore strongly benefit from global cooperation.

[14] For instance, Ursula von der Leyer, the next president of the European Commission, has openly supported the idea of BCA within the framework of a green deal for Europe.

negotiations for Free Trade Agreements (FTA), in which chapters on climate change protection and sustainable development are now included. The FTA between the European Free Trade Association and the Mercosur is the latest example of this trend.

Finally, it is important to mention that this article has addressed only one public concern towards carbon prices. In order to fully understand what affects people's acceptability for this policy, its distributional consequences should also be analyzed. Indeed, they have also been found to be a key determinant of citizens' opinion towards carbon pricing (Carattini et al. 2017). Events all over the globe have showed that the effects of carbon prices on low-income households can create massive protest and in fine leads to less ambitious environmental policies.[15] Therefore, in order to fully maximize acceptability for carbon pricing, it is also important to analyze how the costs of carbon pricing are distributed, both within (low-income versus high-income households) and between (developing versus developed) countries.

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Box 1: Free allocation of emission permits in the EU ETS

The EU ETS has set up large free allowances mechanism in order to protect firms at risk of carbon leakage, following this definition (ETS directive, article 10a)[16]:

I. A sector or sub-sector is deemed to be exposed to a significant risk of carbon leakage if:

• *The sector's trade intensity with non-EU countries* (*imports and exports*) *is above 10%.*

II. A sector or sub-sector is also deemed to be exposed if:

• *The sum of direct and indirect additional costs is at least 30%;* ***or***

• *The non-EU trade intensity is above 30%.*

The first part of the definition matches with the definition of sectors at risk seen previously. Those sectors must be both energy-intensive and trade-exposed. The second part is, to our opinion, more questionable. Indeed, what would be the justification to freely allocate heavily energy-intensive industries, when these latter are active in a sector that is not trade-exposed? Similarly, why granting free allocation of permits for firms which are highly exposed to trade (above 30%), when the direct and indirect costs of carbon pricing are extremely low for them. We have not find any satisfying answers to these questions in the economic literature.

On the contrary, we have found multiple papers mentioning over-allocation of free allowance as one issue of the EU ETS (Joltreau and Sommerfeld 2018). Economists are concerned about the level of free allocation, because it undermines the price signal of carbon pricing policies.

15 This was the case in France with the "yellow jackets" protests, which have forced President Macron to reduce his commitment to an increase of fuel's price.

16 Source: https://ec.europa.eu/clima/policies/ets/allowances/leakage_en.

A very concerning result, particularly in terms of acceptability from the citizens, is that energy-intensive industries have actually freely received more emissions permits than what they needed. In other terms, it means that they are over-subsidized. Over the period 2008–2015, this has allowed heavy industries (in the EU ETS) to earn 25 billions of euros (Carbon Market Watch 2016). Heavy industries are able to generate windfall profits because of two mechanisms (Ibid, pp. 3–4). The first one is a “windfall profit from surplus”: firms who receive too many emissions permits can sell those latter on the market, and thus make a profit. Secondly, “industries have generated profits by letting their customers pay the price for freely obtained emission allowances” (Ibid, p. 4). This is called windfall profits from cost-pass through.

In 2018, the revised EU ETS directive entered into force. It defines the modifications introduced in the EU ETS mechanism for the period 2021–2030 (“Phase IV”). Sectors will now be judged to be at risk of carbon leakage if the product of their trade intensity with third countries and their emission intensity exceeds 0.2—making it a more stringent criterion.[17] This revision should mitigate the issues mentioned above.

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[17] In order for the EU to reach the objectives set in the Paris Agreement, the revised directive has also accelerated the annual reduction of the emissions cap (2.2% versus 1.7% in phase III) and reinforced the role of the Market Stability Reserve to address the surplus of allowances.

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