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THE MAGNITUDE OF CARBON LEAKAGE AND ADDRESSING IT IN THE EU ETS

Bachelor's Thesis
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Abstract

This literary review discusses the phenomenon of carbon leakage in the European Union emissions trading system (EU ETS). I present the main principles of emissions trading applied in the EU ETS and how the current ETS policy is build. These lay the groundwork for assessing the magnitude of carbon leakage in the EU ETS and how it should be tackled. Assessing the magnitude of carbon leakage and ways to tackle it are the two key questions of this paper. As presented in this paper, carbon leakage might not be that big of a problem for the ETS as the European policy could insist. This suggests that the policy is partly created on political basis ignoring the environmental and economic principles beneath it.

I also present two solutions to carbon leakage presented in the literature. Out of the two alternatives, the use of border adjustment is supported by the economic literature. The downside of this environmentally and economically effective solution is its legal restrictions that lower its effectiveness. Despite these restrictions the proposed solution and the other alternative, output-based allocation, deliver better results than the current European policy to fight carbon leakage.

Keywords EU, ETS, carbon leakage, border adjustment, output-based allocation, leakage ratio, carbon price, emissions allowance, benchmarking, energy channel, competitiveness channel, macro leakage

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Introduction

Ambitious climate targets have been largely discussed towards the end of the 2010's. Growing frustration amongst climate researchers and the youth in developed countries have increased political pressure to European leaders to seek for more effective climate policies. However, a large proportion of EU citizens are also against stricter targets as the gains from such targets might flow towards developing countries and hurt Europe's economy and its workers. One such fear is carbon leakage, where the emissions reductions in Europe are backfired with emissions increases in the rest of the world. At the same time this could imply a similar shift from Europe to the rest of the world in terms of wealth and jobs. These fears are a counterforce against more ambitious climate targets and could diminish the political will to enhance climate policies. This gives the motivation for this paper to investigate the importance of carbon leakage in the EU emissions trading system (ETS) and how carbon leakage is and could be addressed in the EU ETS.

This paper goes on to review the effect of carbon leakage on the EU ETS in the terms of effectiveness of the emissions trading system. The second subject of interest is, how the leakage can be addressed in the EU ETS. The primary framework under which the importance of carbon leakage is studied is a simple theory model representing a well-functioning emissions trading system. Here the emissions trading system is a tradable rights-based policy instrument that will under some assumptions lead to optimal pollution prices and quantities (Harstad & Liski 2013, Liski 2019).

In addition to the simple theory model, the two questions are analyzed with the help of literature and foremost econometric studies diving deeper into the effects of carbon leakage and the mechanisms in the solutions presented in the literature. These studies have some key take-aways to add to the contribution of theoretical reasoning. Above all they give an overall understanding over the magnitude of carbon leakage in the EU ETS. They also give some guidance to how different effects compare to each other and to which direction the final outcome might shift when the different effects might lead to different directions.

The paper is built as follows: first I will introduce the theory model used to analyze the EU ETS and then introduce the reader to the EU ETS, the EU emissions trading system. After that, the paper will continue to the introduction of carbon leakage, the actual problem at hand. After these introductions the paper will analyze the magnitude of carbon leakage in the EU ETS using the theory model aside a literary review on the matter. I will also discuss the econometric results in the literature estimating the gravity of carbon leakage to the EU ETS. Towards the end of the paper I will discuss two primary ways the literature has proposed to solve the issue of carbon leakage, border adjustment and output-based allocation. These solutions will be analyzed with the theory model presented in the beginning and through the estimations in the literature. The final part of the paper will draw some conclusions and summarize the findings in the literature.

1. Theory behind emissions trading systems

This paper will use a simple theory model to examine the effect of carbon leakage on the effectiveness of the EU ETS and to examine the proposed solutions. This theory model builds on the problem of the commons and follows the derived model by Harstad & Liski (Harstad & Liski 2013, Liski 2019). First, I will define the cause of the externality problem with the maximization problem faced by each player. Then I will introduce the emissions trading system used to tackle the problem.

1.1. Utility from a public resource

The model is defined as follows. The public resource, in our case pollution, is denoted by $s \geq 0$ and the set of players is $I = \{1,2, \ldots, n\}$. Each player, $i \in I$, has a private action z_i impacting s. Variable x_i denotes other decisions made by the player i. With these variables, player i, has a utility function:

$$U(x(i), z(i), s) = u\big(x(i), z(i)\big) - d(s), \qquad s = \sum_{i \in I} z(i)$$

Equation 1. (Liski 2019)

The model assumes that u() is concave in x_i and d(s) is convex. The intuition behind these is that that the utility from using a resource increases in x_i and d(s) is the damage from the pollution for each agent. (Liski 2019)

1.2. The first-best solution

Harstad and Liski define the the first best solution to be an allocation that maximizes the total utility: $\{x_i, z_i\}_{i \in I}$ is the allocation from

$$\max_{x(i), z(i)} \sum_{I} U(x(i), z(i), s)$$

$$\Leftrightarrow$$

$$\frac{\partial u(x(i), z(i))}{\partial z(i)} = n \frac{\partial d(s)}{\partial s}$$

$$\frac{\partial u(x(i), z(i))}{\partial x(i)} = 0$$

Equation 2. (Liski 2019)

$\frac{\partial u(x(i),z(i))}{\partial z(i)} =$ private gain from extracting the resource, $n\frac{\partial d(s)}{\partial s}$ = total damage from using the resource

(Harstad & Liski 2013, Liski 2019)

1.3. The problem of the commons

The problem is that in a common-pool problem the players don't take the social damages into account leading them to choose larger z(i) than what would be socially optimal. The player optimizes z(i) as follows:

$$\frac{\partial u(x(i), z(i))}{\partial z(i)} = \frac{\partial d(s)}{\partial s} < n\frac{\partial d(s)}{\partial s}$$

(Harstad & Liski 2013, Liski 2019)

In the above-mentioned optimization problem, each player optimizes their z(i) with respect to the damage they personally face. In the case of pollution and climate change this case is naturally not optimal for the society. As greenhouse gases (GHGs) spread across the planet, there are only minimal local effects from polluting and the individual damage can be seen rather low. However, when this damage is multiplied across all players as it's done above, the total social damage gets larger and each player sets their action z(i) in a non-optimal way from the perspective of the society. This means that the Nash equilibrium is worse for the society than the first-best solution.

1.4. Emissions trading

The policy instrument to tackle this problem in the EU is an emissions trading system or a quantity instrument. The logic behind the solution is to internalize the social cost of polluting to the players' maximization problem as they don't take it into account in a Nash equilibrium without some policy instrument. There are generally two types of policy instruments used, tax and tradable rights. This paper will use the tradable rights instrument as the model framework as it's the choice by the European union.

The basic principle in emissions trading is to achieve cost efficiency in the abatement of GHGs. Cost efficiency means that the total cost is minimized, and all players face an equal marginal cost. This is indeed what happens when we apply the quantity instrument and we assume that everything works as the theory predicts. This also allows the policy maker to set the optimal quantity for emissions in order to balance the cost of abatement and the benefits from polluting.

First step to figure out with the quantity instrument is to figure out the socially optimal quantity of GHGs, s^{FB}. The quantity, s^{FB}, is set so that it will balance the benefits from polluting and the damages by the GHGs. After this the quantity is allocated amongst the players: $s^{FB} = s_1 + s_2 + \ldots + s_n$. Each permit s_i means that the player i can release GHGs up to s_i, $z_i \leq s_i$. In an emissions trading system, the players can trade with these permits. This means that if the player wants to release less GHGs it can sell the remaining allowances to other players. On the contrary, a player who wants to release more GHGs can buy more allowances from players selling them. This creates a market for GHG-permits, with a price p determined in the market. In this model we also assume the market for permits to be frictionless for simplicity. (Harstad & Liski 2013, Liski 2019)

All players maximize their utility as follows when the allowance price, p, and the allocated quota s_i are given to player i:

$$\max_{x(i),z(i)} U(x(i), z(i), s) - p(z(i) - s(i))$$

$$\Leftrightarrow$$

$$\frac{\partial U(x(i), z(i), s)}{\partial z(i)} = p$$

$$\frac{\partial U(x(i), z(i), s)}{\partial x(i)} = 0$$

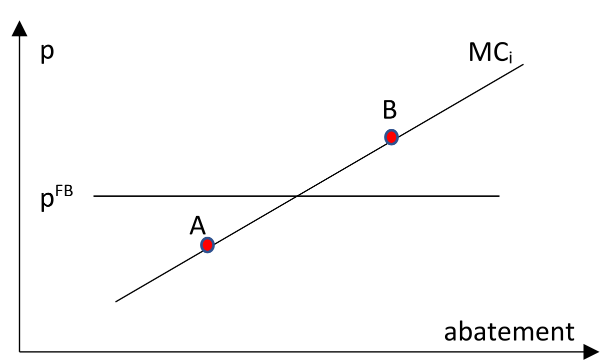
Equation 3.

From the above equations we can see that that higher prices lead to more significant reduction in GHGs. Furthermore, we can find the price for the allowances because the sum of z(i)s minus the sum of s(i)s is zero and the sum of actions $z_i(p) = s^{FB}$ (Liski 2019). Another important thing to notice is that all players face the same marginal cost of abatement that equals the market price for allowances.

$$\frac{\partial U(x(1), z(1), s)}{\partial z(1)} = \cdots = \frac{\partial U(x(n), z(n), s)}{\partial z(n)} = p$$

Equation 4.

The equation above follows from two things: the allowances are tradable, and all players will maximize their surplus. The second assumption means that any player that can lower its emissions with a cheaper price than p, should cut down its emissions until the cost reaches p and sell the remaining allowances to others with a price p to gain some extra profit. These sold allowances will then be bought by players with high costs of abatement leading to a situation where GHG-reductions are made there where it's the cheapest. The great thing about the tradable permits is also that the initial allocation of permits shouldn't matter, and the cost efficiency is reached with all initial allocations. However, the initial allocation seems to be a great matter in the phenomenon of carbon leakage, and that will be analyzed thoroughly later in this paper.



Picture 1. represents a situation where the players' costs of abatement are drawn from a uniform distribution, the cost is assumed to be increasing and the market price for allowances is p^{FB}. If the player i would be in point A, it means that it could earn higher profits by abating more and selling the free allowances until its MC reaches p^{FB}. In point B, the player i would buy more permits and abate less. This reasoning leads to cost efficiency amongst all players.

2. Introduction to the EU ETS

The EU ETS is the largest international emissions trading system for GHGs covering 31 countries and 45% of EU's emissions (European commission 2015). EU ETS is a cap-and-trade system where the cap is the limit for GHGs emitted in the air. This cap is reduced annually to lower emissions, meaning that the emissions covered by the system will be 21% lower in 2020 and 43% lower in 2030 compared to the base year of 2005 (European Commission 2015). The EU ETS can be seen the EU's most important instrument to fight climate change.

In the beginning the EU ETS was set up to ensure that the EU and its member states would achieve the climate targets set by the Kyoto Protocol (KP), in which all member states had committed (Ellerman et al. 2015). After the EU ETS was first implemented it has proceeded in phases consisting of a couple of years. The first phase (phase 1) was a three-year pilot for the whole system and lasted from 2005 to 2007. The second phase (phase 2) was the first time the system was fully implemented and lasted from 2008 to 2012 (Ellerman et al. 2015). A notable distinction to be made here, is that most of the literature related to the EU ETS covers phase 2, as phase 3 is still running until 2020. This means that the phase 2 is easier to analyze as it has already ended. This of course might have some negative implications to the external validity of the literature. The EU ETS will continue to phase 4 in 2021.

2.1. Sectors covered by the EU ETS

The EU ETS covers electric power plants, major energy intensive industries and all domestic airline emissions in the EU (Ellerman et al. 2015). Some major industries are for instance steel, cement, refineries, chemicals, aluminium and paper (European commission 2015, European Commission 2019). The minimum size of the combustion plant covered by the system is 20MW thermal rated input (European commission 2019). Also, it's possible for the participating countries to exclude some small industrial plants from the emissions trading to simplify monitoring of emissions (European Commissions 2019).

2.2. Auctioning in the EU ETS

Auctioning is to be the main principle of allocation of GHG permits in the phase 3 (European Commission 2019). However, today auctioning covers only a part of the allocation of the permits. The EU follows four principles in allocating free allowances:

- Electric power plants aren't given free allowances
- Manufacturing industries receive free allowances according to EU-wide rules
- Free allocation is based on benchmarks, that represent the most efficient plants
- EU has a reserve (NER) for new entrants and plants increasing their capacity

(European Commission 2019)

Furthermore, sectors considered to be under a great risk of carbon leakage, defined in section 3, will be set to carbon leakage list and given 100% free allowances based on the industry benchmarks (European commission 2019). To give an idea of just how small part of the allowance allocation is auctioning to date, the European Parliament agreed in 2003 that 90 percent of allowances should be allocated for free in the phase 3 (Ellerman et al. 2015). On the other hand, a positive note from the perspective of climate targets is that the electric utility sector doesn't receive any free allowances, even if it's responsible for roughly half of the EU ETS emissions (Ellerman et. al 2015). After excluding the electricity sector and some other reviews on the free allocation, the total allocation of free permits in phase 3 is expected to be around 41 percent of the total allocation of allowances (European Commission 2015).

2.3. Benchmarking

Benchmarking is the baseline for free allocation of allowances in the EU ETS (Martin et al. 2014). The benchmarks are set product-wise and the "product benchmark is defined as the average greenhouse gas emission performance of the 10 percent best performing installations in the European Union producing that product, measured in tons of CO_2 equivalent per unit of output" (Martin et al. 2014). These benchmarks are then used to determine the amount of free permits all firms in the production of that product will receive.

For each firm receiving free allowances, the number of allowances is determined by a simple rule:

q_i = benchmark * historical activity level * reduction factor * correction factor

Equation 5. (Martin et al. 2014)

The historical activity level scales up or down the benchmark performance to meet up with the capacity of the firm i. It's important to notice that scaling is done by the historical activity, namely capacity, and not by the short-run output. This coefficient is only altered upwards if the installation increases its capacity by more than 10 percent (European Commission 2015). The reduction factor is to decline linearly from 0,8 in 2013 to 0,3 in 2020. For industries in the carbon leakage list, the reduction factor is to remain at 1 (Martin et al. 2014). The correction factor exists only to make corrections if needed to align with the overall cap (Martin et al. 2014).

2.4. Banking and the market stability reserve in the EU ETS

After the implementation of phase 2 in the emissions trading system, banking of permits has been possible (Ellerman et al. 2015). This means that firms can store their leftover permits to be used in the following years when the price for carbon is higher. Benchmarking is beneficial for the system as it sets a floor on prices as the allowances saved today have a future value (Ellerman et al. 2015). Giving the firms the possibility to store allowances also makes it possible that the emissions abatements would be efficient over time. This follows from the firms' willingness to discount the future prices of carbon and make efficient choices also intertemporally meaning that the marginal cost would be in line with the allowance price over time.

Another timely important aspect to the EU ETS is the market stability reserve. The idea behind it is to have a reserve for allowances in case imbalances between the supply and the demand for them occur (European Commission 2015). This possibility makes the system more prepared in case of demand shocks in the future (European Commission 2015). Backloading is a procedure closely tied up with the market stability reserve. Backloading refers to postponing the auctioning of 900 million allowances from the early years of phase 3 to the last years of it (European Commission 2015). This action was taken due to surplus of allowances and to stabilize the allowance price, not to change the total amount of allowances issued in phase 3.

3. Introduction to carbon leakage

The European union defines carbon leakage as a problem in which producers facing a carbon price relocate their production outside the carbon regulated area leading to increased emissions globally (European Commission 2015). The reasoning behind the increasing global emissions is that European industries tend to be amongst the cleanest in the world and outsourcing to the cheapest countries could also mean changing to more polluting installations (European commission 2015). In his paper, Stefano Cló points clearly that the whole problem is a consequence of a unilateral carbon policy in the EU (Cló 2010). This unilateral nature, or the fact that the EU ETS has only cost effects to EU production, is also discussed with the EU policy makers (European commission 2015). Actually, the foundations for carbon leakage lie in the absence of global climate policies leading to this situation where producers face different treatment and costs depending on their location. The introduction of global, or at least large-scale international, climate and carbon policies would diminish this phenomenon.

There's quite some debate on the gravity of carbon leakage to the ETS, and that will be closely discussed in the following part of this paper. At this point it's only necessary to point out that the problem is big at least in terms of policy making as around 85 percent of industrial emissions in the ETS are included in a "carbon list" (Martin et al. 2015). The industries mentioned in that list have a reduction factor 1 in the equation 5 meaning that they receive all their allowances for free based on the industry benchmark.

3.1. How does carbon leakage take place?

Carbon leakage can take place through various different mechanisms, but the two main approaches in the literature seem to be energy prices and competitiveness (Monjon & Quirion 2011, Cló 2010, Kuik & Hofkes 2010). In his study, Cló also comes up with a third possible channel for carbon leakage, investments (Cló 2010).

The energy price channel for carbon leakage is a result of global markets for fossil energy and the unilateral climate policy in the form of the EU ETS. Introducing a price on GHGs increases the production costs when using fossil energy in the production. Assuming that the ETS works, it leads to a decrease in the demand for fossil energy within the EU. This inward shift in the demand curve for fossil energy sources leads to decreasing energy prices globally as the EU is a big consumer for fossil energy and we assume that all else stays the same. Of course, big monopolist sellers of for instance oil could ration the supply side for higher prices, but as profit maximizing players, they should still lower the energy price, at least a bit. These lower prices for fossil energy sources would increase their demand outside the EU ETS diminishing some of the gains achieved with the policy.

The competitiveness channel seems rather obvious but might be the most important one for policy choices. The mechanism works so that increasing production costs lead to higher output costs. These increased costs make EU-production more costly in comparison with non-EU-production and gives the non-EU-producers an edge in terms of competitiveness. This is a big argument for the fear of outsourcing production to areas without climate regulation (Kuik & Hofkes 2010, Cló 2010).

Investments is the third channel for carbon leakage addressed in this paper. At least Cló points out that industrial lobbies often argue that introducing a carbon price will lower financial investments in the areas covered by the EU ETS as outside companies might seem more appealing (Cló 2010). Another distinction to this would be that the return of investment for energy intensive industries will be greater in areas outside the policy, because of this additional price on fossil energy (Martin et al. 2015).

3.2. The impact of carbon leakage on jobs and GDP

A closer look to the impacts of carbon leakage will be taken in the next section of this paper, but it's important to remember that carbon leakage doesn't only harm the environment, rather it has also effects to jobs and the GDP covered by the policy. This is the motivation for Martin et al. to investigate the risk of job loss and carbon leakage simultaneously regard to alternative EU ETS policies (Martin et al. 2015). It's natural to think that outsourcing production will not only lead to carbon leakage, but it will also increase unemployment and decrease the GDP in areas covered by the EU ETS. These latter effects are closely affiliated with carbon leakage and might have even bigger environmental effects than carbon leakage itself. That would happen through political issues that this would cause for more ambitious climate targets. This claim will be analyzed more thoroughly in the following section 4.

3.3. How carbon leakage is addressed in the EU ETS?

In the EU ETS carbon leakage is taken into account through free allocation of emissions allowances. As described earlier all manufacturing industries will receive part of their needed allowances for free in order to relieve their financial burden caused by the policy. Furthermore, industries deemed to be under high risk of carbon leakage will receive all their allowances for free based on industry benchmarks (Martin et al. 2015). These industries are listed in the carbon leakage list (European Commission 2015).

The risk of carbon leakage for each industry is determined by two variables, carbon intensity, CI, and trade intensity, TI (European Commission 2015). CI represents the financial burden under full auctioning, and it's calculated as the sum of direct and indirect costs of auctioning divided by the gross value added (Martin et al. 2015). TI is the value of exports plus the value of imports divided by the total market size (Martin et al. 2015). It represents how vulnerable the industry is for non-EU competition. Industries with either, CI or TI, over 0,3 or CI greater than 0,05 and TI greater than 0,1 are considered to be under a great risk of carbon leakage (Martin et al. 2015).

4. The magnitude of carbon leakage in the EU ETS

The weight of carbon leakage can be assessed in a couple of different ways or from different perspectives. In this section the weight will be analyzed with respect to our ETS-model, in terms of exemption of firms from auctioning with the EU criteria, leakage ratios estimated in the literature and the effect that carbon leakage imposes on the political aspect.

As we shall learn, estimating the effects of carbon leakage are not simple and there's no clear unanimity in the literature about the effects of it. However, numerous studies suggest that the gravity of this phenomenon might lie in the policy making and in environmental results through that channel, rather than direct impacts on the environment.

4.1. The competitiveness channel of leakage and the EU ETS

From the competitiveness perspective the EU ETS increases pressure on the domestic producers as the system is build on production basis and not on consumption basis (Cló 2010). Here, with domestic producers I refer to the ones covered by the EU ETS policy. The EU ETS enhances the non-EU players' stand against the EU players, because non-EU players stay unaffected by it and EU players can easily comply with the current policy just by outsourcing their production outside the EU (Cló 2010).

With our simple theory model, we can assess that which players (or companies) would be most willing to outsource their production. With the exception of electricity production, the industry which can't be outsourced due to the nature of the good, energy intensive industries are most affected by the ETS policy. If we would assume that the players would be IID in their distribution for marginal costs of abatement, we could easily plot their marginal cost curve with a suitable distributional form. Then of course the players with higher marginal costs for abatement would have an intensive to deviate from the policy, or in this context to comply to the policy by outsourcing their production to non-regulated areas. And with the plotting we could easily see magnitude of this phenomenon. Even better, if we could identify the players with higher marginal costs, we could concentrate on them. Unfortunately, that good parameters for modelling are out of reach in this paper.

Players with lower marginal costs wouldn't naturally want to outsource as they could earn additional surplus by selling their unused allowances in return to those emission abatements, they would perform at a lower cost than p, the market price for allowances. In this situation the aggregate market demand for allowances would decrease leading to lower allowance prices. The lower prices would then give less incentives for emissions reductions. The phenomenon can be though in a way analogous to the low allowance prices during the last recession after the financial crisis. For instance, Ellerman et al. show in their paper how the allowance prices dropped at the time with the decreasing demand for EU production (Ellerman et al. 2015). Here the price lowering mechanism would be the same in that sense that the driving force is the decreasing demand for EU production and allowances. In this case of course the reason behind the decreasing demand is different but the rest is rather close.

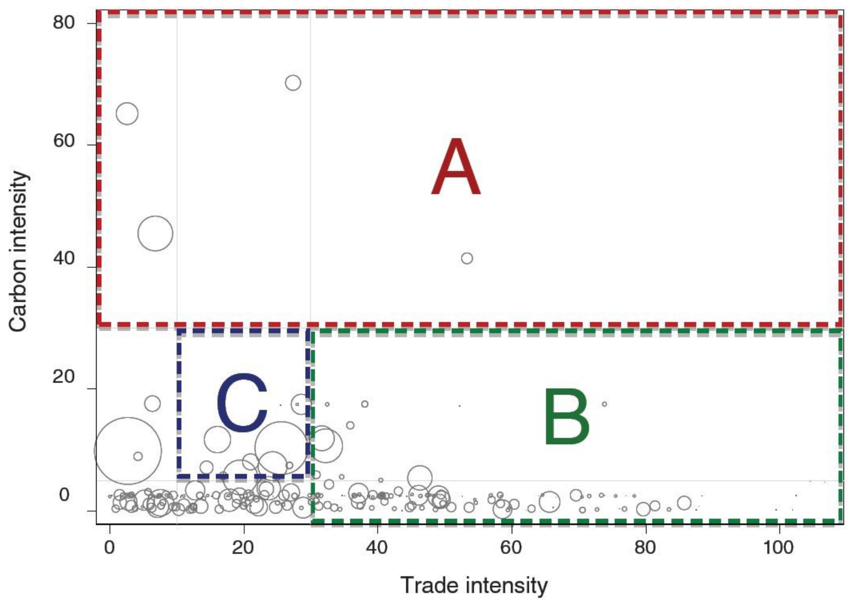
The shift from EU production to non-EU production naturally increases the foreign supply from the EU's perspective. This increase in supply leads to carbon leakage as reductions in the EU emissions are partially diluted by the increase of production elsewhere. To worsen the setting, it's estimated that the non-EU production is more emissions intensive and that would increase the impact (European Commission 2015, Kuik & Hofkes 2010).

4.2. Carbon leakage from the EU ETS criteria's perspective

As described in the section 3.3. the EU has established two criteria for evaluating the risk of carbon leakage for EU industries, CI and TI. When considering the magnitude of carbon leakage on the EU ETS with these criteria, the natural way to go is assessing the number of firms considered to be under risk and their respective emissions. In his paper Cló points out that out of the 257 sectors examined by the European Commission (EC), 98 weren't found to be in risk of carbon leakage and 19 sectors weren't examined due to lack of good data (Cló 2010). This means that 140 sectors, equal to 56 percentage of all the sectors analyzed, were deemed to be under risk of carbon leakage. This shows that in the EC's perspective the magnitude of the problem is rather vast.

To make things interesting, Cló shows that out of these 140 sectors exempted from auctioning, three are left out because of the integrated approach ($CI > 0,05 \cap TI > 0,1$), and three are left out because of the separated approach and their carbon intensity ($CI > 0,3$) (Cló 2010). From the number of sectors exempted by their trade intensity, it's clear that the threat of foreign competition is the driving force in the EU criteria. This is natural in the sense that fierce competition doesn't allow the firms to pass through the allowance costs to the customers and leaves them with worsened competitiveness. On the other hand, many of these exempted sectors and firms are not carbon intensive at all leading to a situation where free allocation of allowances will rule over auctioning also when most firms don't suffer much of a cost from the ETS (Cló 2010).

In another similar approach, Martin et al. investigate the magnitude of carbon leakage from the perspective of the EU ETS criteria. They update the results from Cló and show that only 15 percentage of the emissions aren't exempted from auctioning by the EU ETS criteria (Martin et al. 2015).



Picture 2 (Martin et al. 2015).

The picture 2 shows all the sectors analyzed by the EU in terms of TI and CI. The size of the sector, considered by the number of firms, is represented by the size of the circle. Areas A and B are exempted from auctioning by the separated approach and area C is exempted by the integrated approach.

If we relate the use free allocation based on the above-mentioned measures to our ETS model, we get at least two important perspectives. First, what does the free allocation of permits to some producers imply to the effectiveness of the ETS policy? And second, how will this work in the eyes of carbon leakage, or in other words, will this mitigate carbon leakage and allow a better performing ETS in terms of environmental effectiveness?

As it was mentioned already in the first section alongside the introduction of the ETS model, the initial allocation shouldn't have an effect on the mechanism and effectiveness of a cap-and-trade system. The firms still have the incentive to adjust their marginal costs to meet the market price for allowances:

$$\frac{\partial U(x(i), z(i), s)}{\partial z(i)} = p, \forall i$$

This implies that the allocation shouldn't have an effect on the policy in terms of effectiveness rather the impacts lie in the payer of the allowances. Granting free allowances for 85 percentage of the industrial emissions would act as a subsidy to the emitters and as a loss of public income for taxpayers (Fischer & Fox 2012).

The more interesting question is the latter regarding carbon leakage. If granting free allowances really dilutes the firms' incentives to outsource their production, this should be a real effective way of dealing with carbon leakage. However, as Cló clarifies, the firms still have opportunity costs regarding the free allocation (Cló 2010). The logic behind this is that after receiving the free allocation, the firms should consider whether it's more profitable to use the allowances themselves and produce within the EU or to outsource production and sell the free assigned allowances forward to other manufacturers (Cló 2010). This reasoning kind of mitigates the effectiveness of free allocation in terms of fighting carbon leakage. The outcome is that the performance of the EU ETS might not increase by altering the initial allocation. On the other hand, the producers need to look far to the future meaning that the opportunity of selling the free allowances and outsourcing at the same time will only be a part of the future profits of the firm. In the long run this output-based allocation (OB) could perhaps be better performing than what the reasoning from Cló insists.

4.3. How large leakage ratios the literature estimates?

There are a few estimates on the leakage ratios for the EU ETS in the academic literature, and their scope is relatively large. The leakage ratio itself is the ratio between the emissions reductions in the regulated area and the increase of emissions outside the regulated area that are due to the emissions policies (Monjon & Quirion 2011). Another much used metric for carbon leakage is the rate of carbon leakage. This metric is the annual increase in the emissions outside the regulation compared to the annual reductions within the regulated area (Kuik & Hofkes 2010). Various of these metrics are estimated using CGE-models (countable general equilibrium) and their variants or other general equilibrium models (ie. Kuik & Hofkes 2010, Monjon & Quirion 2011). Furthermore, not only do the results vary in the macro-level but they seem to vary even more when considering some key industries under relocation and leakage risk. This could suggest that the whole issue should concentrate around these industries.

For the base case, let's start by reviewing the results by Martin et al. (2015). Their paper concentrates on the optimal allocation of free permits in an OB solution to carbon leakage. Here I'll consider their estimates on the carbon leakage risk in the case of benchmarking, the allocation principle of the EU outside electricity installations. In their study they find that only around 23 percentage of the industrial ETS emissions are at risk of leakage (Martin et al. 2014). That share might sound big, but it's only a fraction of the 85 percentage of industrial EU emissions that are granted free permit allocation due to carbon leakage risk with the current EU ETS criteria. The difference is incredibly large and indicates clearly that the magnitude of carbon leakage might be significantly smaller than what the EU policy would imply.

Martin et al. aren't the only ones stating inconsistencies in the current free allocation scheme. Also, Cló discusses the problematic criteria for carbon leakage from the critical perspective that are the thresholds really based on economic evaluation (Cló 2010). In his paper, Cló doesn't give any estimates for carbon leakage, but ends up to the same conclusion that the leakage isn't that vast of a problem and adds that the EU criteria don't seem to be economic rather political grounded (Cló 2010).

In their paper, Kuik & Hofkes simulate both the macro effects of the EU ETS and industry effects for a few carbon intensive industries deemed to be under high risk of carbon leakage (Kuik & Hofkes 2010). They find the overall leakage to be a little shy of 11 percentage and the leakage for steel and mineral sectors to be 35% and 19% respectively (Kuik & Hofkes 2010). The leakage ratio within both sectors can be significantly larger for certain very energy-intensive subsectors. The main argument in this is that the overall leakage isn't nearly as high as the EC evaluates and that a large proportion of the leakage is linked only to few industries. Another significant finding in their results respect to the magnitude of carbon leakage is that the main channel for leakage in the big picture seems to be the energy channel (Kuik & Hofkes 2010). This result is obtained through the general equilibrium effects when considering how certain policies would decrease carbon leakage. These policy measures are more effective in tackling the competitiveness effects and largely only the energy channel is left to cause carbon leakage (Kuik & Hofkes 2010). This is a regular finding for CGE-models and emphasizes the energy channel (Kuik & Hofkes 2010).

A third view to the magnitude of the problem in terms of simulation is the one from Monjon & Quirion (Monjon & Quirion 2011). They try to apply an enhanced CGE-model to analyze the impacts of different policies on carbon leakage. The reference point in their study is the use of full auctioning, a case that is certainly a stricter policy option than the one applied by the EU. The alternatives compared to the reference case are different forms of output-based allocation (OB) and border adjustment (BA). Border adjustment is a means to balance the competition between companies facing and not facing the emissions regulations using import tariffs and/or export rebates (Monjon & Quirion 2011). These policies are thoroughly examined in the following section.

The results from the paper are even more against the implicit assumption by the EC that the EU ETS would result in great carbon leakage ratios. They present two leakage ratios with different parameters to address problems considering model sensitivities. The higher estimate for carbon leakage in the reference case is 11 percentage and the lower estimate is just over 4 percentage (Monjon & Quirion 2011). The estimates are significantly lower also for the simpler OB solutions that are closer to the current EU scheme (Monjon & Quirion 2011). This result emphasizes the common result in the literature that the problem of carbon leakage might not be so vast in its gravity as the current allocation schemes for free allowances would imply.

To summarize the findings in the above-mentioned studies, the problem related to carbon leakage might actually not be of as great magnitude as one might first assume. However, the leakage ratios are still rather high and cause simultaneously job losses, meaning that investigating them further is well justified. A further argument for further studies is that perhaps obstructing leakage is the one of most cost-efficient ways of pursuing climate targets, as obstructing leakage only enhances the performance of existing policies. If enhancing the system is cheap enough, this is an efficient means of pursuing climate targets.

4.4. The political aspect of carbon leakage

As an important side note, this paper provides a brief discussion on the political aspect of carbon leakage and how that perspective affects the current and future EU ETS policies. As can be seen from the previous results provided in this paper, there seems to be quite a distance between the current free allocation quota and the actual carbon leakage and leakage risk. Since we can't justify the gap with strong economic arguments, one could argue that there may also lie something else behind the free allocation quota. Here I'm going to present some possible political arguments to fill in this gap.

Job losses due to environmental policy are closely linked to carbon leakage as they both are a result from firms outsourcing their production to non-regulated areas to comply with the ETS rules. The job losses may even be a heavier argument than the carbon leakage for the politicians to adjust themselves to the will of the producers and grant them free support from the government. One phenomenon behind this could be the strengthening debate on populism in the EU and the possible response from citizens not willing to comply with unilateral climate targets. Perhaps this is one of the reasons why Cló detects inconsistencies in the guidelines for leakage risk assessment and concludes that the current allocation rules seem more politically than economic or environmentally driven (Cló 2010). In addition to Cló's findings, also Martin et al. investigate the optimal output-based allocation of free permits in terms of job losses on top of carbon leakage (Martin et al. 2015). Also this shows how the literature links job losses closely to carbon leakage.

With this political power behind them, industry lobbies may have an edge when pursuing grandfathering style solutions to fight carbon leakage. Grandfathering, or granting free permits based on historical activity, means low financial expenses to the manufacturing industry (Cló 2010) and is in that sense the solution in the industries' favor. The political power behind the lobbies makes this kind of solutions as a means to gain political acceptance for climate policies (Cló 2010). Martin et al. sum up this finding to that free allocation is regularly used to seek political acceptance for ETS solutions in the early stages of the system (Martin et al. 2015).

One big risk in the political aspect might be the limitations for developing the EU ETS in the future to pursue more ambitious climate targets. This is because the EU citizens might not be willing to take huge leaps forward in this kind of unilateral climate solution, that imposes them costs and welfare loss due to the policy that other countries won't feel, or other countries may instead benefit from in the form of outsourcing production. When considering this perspective and applying a game between the EU and non-regulated areas over production, carbon leakage and addressing it become much more significant than in the light of strict economic analyses on the magnitude of carbon leakage and its economic consequences.

Especially this political view and a view to the lobbying power of the industries' gives us a good reason to look more closely to ways dealing with carbon leakage. This is because, close to what Martin et al. noted, gaining justification for the policy is often needed in the early stages of its implementation. Here it's especially important to gain that justification for a unilateral policy as global agreements to effectively fight climate change could be very hard to agree on with many different political needs at stake.

5. Solutions to carbon leakage in the literature

In this paper I will discuss two most referred alternatives to fight carbon leakage in the literature, output-based allocation and border adjustment. The third obvious solution presented in the literature is expanding the whole EU ETS system to other parts of the world. That solution would wipe out the whole problem related to unilateral policy making and give space to solely concentrate on the effectiveness of the chosen system. As this can be taught as something quite unrealistic, the discussion concentrates on the above-mentioned options OB and BA.

The analysis on the presented solutions will proceed in a couple of phases. First, I will introduce the basics of both alternatives separately. Then, I will compare them simultaneously reflecting them to the theory model introduced in this paper. After that, I will compare the solutions in terms of research findings in effectiveness simulations and how these studies are ranking the alternatives against each other and on what ground.

5.1. Introduction to output-based allocation

Output-based allocation, OB, is a means to support domestic production against foreign competitors with the existence of unilateral environmental policy concerning only the domestic parties. In their paper, Fischer and Fox define the concept as rebating the full value of emissions permits to producers of the domestic good (Fischer & Fox 2012). This rebating can be implemented at different levels and to different kinds of costs. For instance, Monjon and Quirion estimate the effect of output-based allocation on three variants of the policy (Monjon & Quirion 2011).

Output-based allocation can be differentiated at least through two main channels, what emissions are included and what sectors are included in the free allocation (Monjon & Quirion 2011). The reason to this division is that different sectors face different risks for carbon leakage and therefore it might be wise to consider whether full implementation of OB is rational for all sectors. The other consideration is that whether only direct or also indirect emissions should be rebated. Rebating only direct emissions means that the installation should receive only rebates for their own emissions. In the direct and indirect OB variation the installations will also be rebated for their indirect emissions, meaning that they are also rebated for the emissions of the energy sector that the energy sector will pass through to the manufacturing installations.

The three variants introduced by Monjon and Quirion are *OB full*, *OB exposed direct* and *OB exposed direct and indirect* (Monjon & Quirion 2011). The first alternative introduces OB to all sectors, including the energy sector, and all sectors are rebated the same way (Monjon & Quirion 2011). In this case there's no need to think about indirect rebates for the manufacturing sectors as also the energy sector is rebated and there's no pass-through-costs for the installations. The second alternative, OB exposed direct, introduces OB to the exposed industries and uses auctioning for the electricity sector (Monjon & Quirion 2011). This form doesn't rebate for the indirect emissions and the electricity sector might pass through costs to the exposed sectors in the form of energy prices. The third alternative is the OB exposed direct and indirect. That one is equal to the second only adding rebates for the indirect emissions (Monjon & Quirion 2011).

The OB solutions are rather similar to the one applied by the EU ETS in the sense that in the EU ETS the exposed industries are granted free allocation of allowances based on some reduction factor compared to the base year of 2005 (Monjon & Quirion 2011). The EU ETS uses auctioning as the allocation principle for the electricity sector (European Commission 2015) and therefore the second alternative that rebates the exposed industries for their direct emissions can be used as the closest relative to the current allocation scheme. Of course, one should remember the criticism from Cló to the leakage risk thresholds in the EU system, and that they might not be well justified at that level on economic or environmental basis (Cló 2010).

5.2. Introduction to border adjustment

Border adjustment, BA, is the second important solution introduced in the literature to fight carbon leakage. In that solution the base case is that the allowances are fully auctioned in every sector, there are no exceptions (Monjon & Quirion 2011). The competition leveling mechanism is the introduction of additional costs to foreign firms and possible rebates to domestic export industries (Monjon & Quirion 2011). With these adjustments at the regulation border, the competition between regulated and non-regulated firms should be balanced. Compared to the OB solution, BA is quite a bit more complicated to execute and might also face non-economic problems in its implementation. The most significant of these problems are issues with WTO trade law incompatibility (Fischer & Fox 2012) and possible loss of goodwill in trade negotiations.

In the implementation of border adjustment, the following aspects need to be considered: Should import and export be included? What import price should foreign products face? What rebate price should export receive? Should export rebates include indirect costs?

Import adjustment means basically introducing an extra cost to foreign goods to make also them face the polluter pays principle and to avoid substitution effect from domestic to foreign goods. So far, the solution seems very justifiable and easy for implementation. However, the trickier part in this equation is deciding over the right price for imports. Firstly, the price can be collected using the same two basic principles as the whole tragedy of the commons problem can be solved, taxes or emissions allowances. The former is definitely the simpler one to execute, however, the allowance system might be more compatible with the international trade law (Kuik & Hofkes 2010, Fischer & Fox 2012). Here I'll focus on the use of a tax or tariff as the solutions are equivalent in the basic economic sense. The tax itself can be set to different levels and that will surely have effects on the competition between the firms within and outside the EU. The natural alternatives would be the EU specific average emissions for that industry and the average emissions for that industry in the rest of the world, or better, in some emissions-wise uniform area, multiplied by the EU emissions price (Monjon & Quirion 2011, Kuik & Hofkes 2010, Fischer & Fox 2012). From the economic perspective the better alternative would be the use of average area-based taxes (Fischer & Fox 2012) as that would set the competitors to the same line in terms of abatement costs and incentives. However, from the law perspective, the use of EU averages might be the feasible solution as the imports aren't to be treated less favorably than the domestic ones and calculating good emissions coefficients for foreign industries could be rather tricky (Fischer & Fox 2012).

Another thing to consider with the border adjustment policy is to determine whether to support domestic exports or not. This has similar legal problems with unfair government support as the choice of a good import tax (Fischer & Fox 2012). The reasoning in the use of export rebating is that if domestic exports aren't rebated for their emissions, they will be less competitive in the rest of the world without climate policies increasing the production costs. By rebating with the income from auctioning the allowances, the legislator could effectively balance the competition outside the regulated area. This could mitigate carbon leakage and job losses within the EU and earn goodwill from the EU citizens. The downside is of course the loss of public income and the decreasing effectiveness on the environmental side as the firms don't face incentives to cut down their export emissions.

With the use of export rebates, there really exists only one natural choice for the rebate price, the EU emissions price multiplied by the industry specific emissions coefficient in the EU (Monjon & Quirion 2011). This way the export industries would clearly receive back the extra costs they face in the policy. As with the OB solution, it also needs to be decided whether the indirect emissions are included or are only the direct emissions taken into account.

This paper will consider four different types of border adjustment policies: BA full, BA import, BA EU average, BA export. The two first ones are estimated in the papers from Monjon & Quirion and from Fischer & Fox (Monjon & Quirion 2011, Fischer & Fox 2012). The third is only considered by Monjon & Quirion and the last by Fischer & Fox. In addition, I'll use the results from Kuik & Hofkes as far as possible despite they use a bit different division. BA full includes exports and imports, BA import excludes export rebates, BA EU average uses EU average prices for the import taxes and the BA export estimates the effects of using only export rebates (Monjon & Quirion 2011, Fischer & Fox 2012).

5.3. Solutions to carbon leakage in the light of ETS theory

In the eyes of the theory model presented in this paper the two alternatives have rather small effects as the theory model doesn't take into account the risk of outsourcing because of the climate policy. Despite this, we can analyze some implications to the effectiveness of the policy in theory using only that simple model. That analysis needs to take place within the EU and also globally, especially in the case of border adjustment.

The application of either model will increase the coverage of the EU ETS as some companies will keep their production within the regulated area despite their willingness to outsource with full auctioning. This increased coverage will at least to some extent provide improvements to the system as more firms have the incentives to take their abatement costs into account. The environmental effects have to be divided to those within the EU and outside it. Therefore, the use of theory discussion can't deliver an estimate on which effect is greater and what are the total environmental effects. In addition, the theory can only give some insights to the welfare effects of the two alternative solutions to carbon leakage compared to the current EU policy.

First, let's consider OB in the light of the theory. The addition of further firms under the EU ETS will give these firms incentives to cut down emissions if they have lower abatement costs than the current market price for allowances. As explained with the model, the firms have this incentive even if they would receive the allowances for free. This should lead to emissions reduction as the firms will include this opportunity cost to their cost function and produce and price their goods accordingly. However, if the firms don't realize this opportunity cost, these cost-efficient emissions reductions won't take place. As a whole, we can assume that the emissions price will be higher with the OB solution, because of additional demand for allowances.

The final price for the production might on the other hand be lower under OB as some of the costs are rebated by the authorities and domestic producers could pass these rebates through to enhance their competitiveness. This might lead to lower emissions reductions than without the implementation of OB, because the consumers don't get as big incentives to alter their consumption. Lower final price for the products could also imply smaller welfare loss in the EU as both the consumers and the firms could benefit from lower prices and bigger quantities. This lower cost could also boost the exports.

Border adjustment will apply a more complicated mechanism to the welfare in the EU as the imported goods will effectively participate in the ETS. The BA should lead to a situation where less of the EU production is lost to foreign firms when their substitutability is smaller due to the cost that also they will face. With the use of export rebates, also the export of the EU products is greater than with full auctioning. These will add up to a bigger producer surplus than without border adjustment.

As to the environmental effects of the BA, they are two-part. On one hand, there are changes in the supply from the EU side and on the other hand there are changes in the global supply part. The implementation of BA will give domestic and foreign firms incentives to take their abatement costs into account when supplying goods to the European market. This will lead to emissions reduction both within the EU and outside it as now all the firms will optimize their abatement and supply with the principles in equations 3 and 4. As for the EU supply to export, the supply will increase compared to auctioning leading to somewhat bigger emissions. The magnitudes of the emissions reductions related to the EU market and the emissions increase to the EU exports can't be assessed through this model, and I will take a stand on them in the next sub-section with the use of econometric studies.

The application of BA makes also changes to the emissions price and the price level in the EU market. With the BA there's more demand for the allowances as more firms keep their production in Europe. Also, the foreign firms face costs related to their emissions. These two will result in higher prices in the European market and for the emissions allowances. The price increase in the European markets will highly depend on the firms' ability to pass through these costs to the consumers, and this is naturally varying with the elasticity for the given product. One thing is still sure, the prices tend to increase, and that is not good for the consumer surplus. Of course, this surplus loss should be efficient in the sense that the cost increase has occurred in a cost-efficient way. This means that other solutions might decrease the surplus even more. In the welfare sense it's hard to evaluate which is greater, the decrease in consumers' surplus or the increase in producers' surplus.

The increase of prices has also another effect than only the surplus effect, it namely also implies emissions reductions. This is because increasing prices will force the consumers to take the emissions into account in their consumption. Therefore, the firms' ability to pass through costs might be good for the environment but not for the consumer surplus.

To wrap up the theory implication to BA and OB, they both increase the coverage of the ETS and move the EU supply outwards creating bigger producer surplus. The coverage of the policy will be even bigger with the use of BA as also foreign firms will be forced to take their emissions into account. The effects to the export industries is rather similar, as in both cases the firms will suffer less from the cost burden related to the ETS policy, this however, has some negative environmental results. The consumers surplus is rather hard to examine with both cases, but the OB seems to be the better one in that sense. That is because OB could decrease the price in the EU and the BA could increase it. The total welfare impacts are therefore depending on which one is greater, the increase of producer surplus in both cases or the changes in the consumers' surplus. This question is tackled in the next section.

5.4. Solutions to carbon leakage in econometric studies

Output-based allocation and especially border adjustment have received quite some attention in the econometrics literature. In addition to carbon leakage rates, the literature has estimated the policy effects to for instance social welfare and production loss. The estimates for these are important aside the leakage rates as this allows the policy makers make informed decisions knowing more sides to the phenomenon. Another angle to the issue is the division of results to macro and sectoral effects by the policy. That helps to analyze which sectors are more exposed and where could the policy improvements gain better response. This splitting approach also makes it possible to evaluate the importance of the energy channel in comparison with the competitiveness channel.

5.4.1. Macro effects of carbon leakage

The leakage ratio is the key indicator to be analyzed and it tells from the environmental impact. Monjon and Quirion find the leakage ratio with full actioning to be over 11 percentage using high substitutability between domestic and foreign goods (Armington elasticity), which is a cautious approach (Monjon & Quirion 2011). Under BA measures the leakage ratio will drop below zero between -1% and -4% in the variants we're concerning (Monjon & Quirion 2011). This means that the implementation of BA causes emissions reductions also globally. From the environmental point of view this seems clearly the way to go. In the same study, the OB solutions have less impact to the leakage ratios, and the leakage ratios drop between 1% and 4% (Monjon & Quirion 2011). Also, these reductions are significant, but not as effective as the ones from BA.

Considering the consumers utility in the paper from Monjon and Quirion, the results seem rather similar with all the variants but the OB full, which causes significantly less loss of consumers utility (Monjon & Quirion 2011). That is however compensated with the fact that the use of OB full earns no public revenues opposite to similar and high revenues from all the other variants (Monjon & Quirion 2011). From this we can't draw immediate conclusions which is greater. However, with the allowance price we see a clear difference between BA and OB solutions, and the price is a lot higher with OB variants (Monjon & Quirion 2011). This higher price can be seen positive from the environmental perspective, as the opportunity costs for the installations covered by the system rise giving higher incentives for emissions reductions.

In their paper, Kuik and Hofkes find that the macro leakage rate would drop from nearly 11% to 10% or 8% respectively depending on are the foreign emissions calculated using EU or non-EU emissions coefficient (Kuik & Hofkes 2010). This result is clearly somewhat contrary to the one from Monjon and Quirion implying only a minor reduction to the leakage ratio with the use of BA.

5.4.2. Sectoral effects of carbon leakage

The studies over sectoral effects focuses on the energy intensive export industries as they are deemed to be under higher risk of carbon leakage. Important sectors in this analysis are i.e. steel and mineral products.

Monjon and Quirion find the largest production losses to be in cement and aluminium reaching losses of 25% and 14% (Monjon & Quirion 2011). They also find the BA solutions to be more effective in tackling leakage in the high leakage risk sectors, however, also the OB exposed variants give good results (Monjon & Quirion 2011). This argument is backed up with the results from Fischer and Fox as also they find the BA solutions to be more effective (Fischer & Fox 2012).

Kuik and Hofkes only analyze border adjustment compared to the current ETS allocation, but also they find that the leakage ratios for the exposed sectors fall significantly under the use of BA variants (Kuik & Hofkes 2010). The reduction in the steel sector leakage ratio is very significant as it declines from 35% to 29% with an EU-coefficient and to just 2% with a non-EU-coefficient, and the steel sector is estimated to account for roughly a third of the total leakage (Kuik & Hofkes 2010).

5.4.3. The importance of the energy channel

Especially the results from Kuik and Hofkes, are inconsistent in the way that the BA variants cause significant leakage reductions in the exposed sectors accounting for a large proportion of the total leakage, but they don't achieve that significant reduction in the total leakage rate (Kuik & Hofkes 2010). Their leading explanation for this is the importance of the energy channel for carbon leakage (Kuik & Hofkes 2010). In the energy channel effect, the leakage takes place through coal, oil, etc. The prices for these commodities decrease globally through their limited use within the EU causing growth in their usage outside the EU. They conclude that the energy channel is the greatest cause for the macro leakage and the use of BA limits well only the sector leakage as that is caused by the competitiveness effect (Kuik & Hofkes 2010).

6. Conclusions

The EU ETS is undoubtedly a significant tool in fighting climate change in the EU as it covers major industries causing most of the emissions produced within the EU. The ETS however has also some flaws that might mitigate its results in terms of environmental effectiveness. The main concern also regarded by the EU is carbon leakage that gains quite some attention in the ETS design. The real magnitude of the phenomenon on the contrary might not be as vast as suggested by the EU policy.

Carbon leakage can take place mainly through two dominant paths described in the literature, the competitiveness channel and the energy channel. The current carbon list and benchmark-based allocation scheme by the EU tries to tackle the competitiveness channel by using free allocation of allowances to sectors deemed to be under leakage risk. This is close to one major solution presented in the literature, namely output-based allocation. The EU solution differs from that in the sense that the criteria for exemption from auctioning are unclear and don't necessarily contain much economic or environmental basis.

In addition to criticism towards the leakage solution chosen by the EU, there are some contradictions in the gravity of the whole phenomenon. All studies reviewed in this paper indicate much lower carbon leakage or leakage risk than what the total emissions exempted from auctioning in the EU ETS could imply. This means that the whole problem might be somewhat smaller in its gravity than believed. The counter argument for this is that the problem of carbon leakage is closely linked to job and production losses within the EU caused by the ETS. These issues pile up some political pressure against stricter climate policies and gives the authorities reason to investigate measures to tackle carbon leakage.

The main tools against carbon leakage presented in the literature are the use of border adjustment and output-based allocation. They both present a relief for the financial burden faced by the industries to abate emissions. They also have positive implications for the social welfare inside the EU. From the two alternatives the BA solution seems to deliver better environmental and social effects according to all papers comparing the two alternatives. BA might also cause global emissions reductions leading to a negative leakage ratio. The problem with that solution however is that BA might face some severe legal obstacles in its implementation. Clearing these obstacles by altering the parameters used in BA would lead to lower effectiveness balancing the two alternatives, OB and BA.

A common problem with both approaches to carbon leakage is that they foremost fight the competitiveness channel of leakage. The energy channel can't be obstructed with these measures meaning that the problem will stay to some extent even with the implementation of either solution. That of course shouldn't be a reason not to tackle the problem to that extent as possible. This is because both measures would suggest improvements to the current system and mitigate the carbon leakage. The measures to fight carbon leakage could also gain some political goodwill that can be used to enhance the system in the future.

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