

# INVESTMENT LEAKAGE AND RELOCATION UNDER THE EU ETS: MYTH OR REALITY?

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**Abstract**

Concerns on carbon leakage, i.e., the rise of emissions in non-regulated regions due to a loss in the competitiveness of firms facing environmental regulation, have been voiced for decades as environmental stringency has increased to respond to the ongoing climate crisis. However, the risk of carbon leakage has recently been deemed especially high for industries and firms under the unilateral European Union Emissions Trading System.

This literature review aims to investigate whether leakage has occurred in the EU ETS. The specific focus is on leakage through the investment channel, so-called investment leakage. An increase in outward investment flows could mean that EU ETS firms are relocating to non-regulated regions, also offsetting a part of the emissions reduction in the EU. These leakage rates have generally been predicted with partial and general equilibrium models, but an empirical approach has also been adopted in the recent years. However, both ex-ante and ex-post research suffers from a variety of challenges, which also shows in the ambiguous results thus far. Regardless of the lack of evidence on investment leakage, the EU ETS has taken vast measures to ensure that the threat of carbon leakage is not realized, for example by adopting various protection mechanisms.

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**Keywords** carbon leakage, investment leakage, firm relocation, European Union Emissions Trading System, emissions trading, unilateral climate policy

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# 1 Introduction

Climate change and the ongoing climate crisis are some of the most prevalent challenges we face in political decision-making this century. To limit climate change for example by reducing CO<sub>2</sub> emissions, several agreements and treaties have been adopted, both nationally and internationally. One of the most notable ones is the European Green Deal. In 2021, the European Union set the goal of reaching climate neutrality by 2050 and a reduction of greenhouse gas (GHG) emissions of at least 55% by 2030. (European Commission, 2022c) To achieve these ambitious climate goals, the EU uses its main tool in emissions reduction, the European Union Emissions Trading System (EU ETS).

In short, the EU ETS puts a price on emissions to make polluters bear the cost of pollution and internalize their negative externalities. However, unilateral climate policies like the EU ETS also raise concerns from a global point of view. (LIFE ETX, 2021) Pricing carbon unilaterally can, at least in theory, cause so-called carbon leakage. Industries facing regulation at home incur additional costs relative to foreign industries, which could mean competitiveness losses for regulated firms. This could lead to losses of market share or relocation which in turn would lead to rising emissions in non-regulated regions, essentially offsetting a part of the emissions reduction in the regulated region. (Dröge et al., 2009)

Carbon leakage can also be further divided into three different channels.<sup>1</sup> Firstly, leakage can occur through the energy channel. Since fossil fuels will be reduced in the regulated region, energy prices will drop which will in turn incentivize consumption in non-regulated regions, increasing emissions. The second channel identified is the technology and policy spillover channel. Carbon pricing can also incentivize technological innovation, increasing the competitiveness of regulated companies, reversing the carbon leakage effect. The third channel is the competitiveness channel. (Dröge et al., 2009) The competitiveness channel puts emphasis on energy-intensive and trade-exposed (EITE) sectors (Böhringer et al., 2012). In the EU, sectors are classified as exposed if their costs increase by no less than 5% of gross value added because of the implementation of the EU ETS, and they have trade-intensity of over 10%, outside of the regulated EU region (European Commission, 2022b). The assumption is that stringent environmental policy weakens the competitiveness of EITE sectors.

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<sup>1</sup> It is noteworthy that the vast amount of literature groups these channels differently and might find less or more carbon leakage channels. For the purpose of this study, we will use the segmentation above.

Out of the three channels identified above, the competitiveness channel has by far sparked the most interest, both in public discussion and among policy makers, since its effects are likely to be irreversible or at least particularly binding. In addition, competitiveness is a direct indicator of firm and sector performance and therefore the performance of the entire economy. Therefore, I will be focusing on the competitiveness channel, which can be further sectored into investments and trade flows. In short-term, changes in trade flows could indicate carbon leakage and relocation since firms might outsource part of their production, increasing imports. However, changes in trade flows could also indicate that regulated companies are losing market share, and an increase in over-all imports – or decrease in exports – as a result. Therefore, it is more useful to look at changes in investment patterns that could relate to relocation. Generally, these occur in long-term. (Reinaud, 2008) The investment channel, or investment leakage, is the specific focus of this paper, although location decisions are also studied with the help of different indicators, as I will present.

Carbon leakage is seen as a serious threat to the EU ETS. In a speech in 2020, shortly before the European Green Deal was implemented, The European Commission’s President Ursula von der Leyen claimed that the Commission was “ready to protect our European industry from the risk of carbon leakage” (European Commission, 2020). If realized, leakage could have severe implications from the point of view of both the environment and the economy. Emissions reductions would be offset, and climate efforts hindered, both in the EU and globally. Furthermore, this could decrease confidence in the EU ETS as an efficient climate policy, amplifying the negative effects. Relocation of firms would imply for example job losses and losses in tax revenues at home, in the European Common Market, decreasing overall welfare. If we assume that specifically firms in EITE sectors have an incentive to relocate, industrial restructuring could also happen over time. Therefore, studying long-term changes in investment patterns is particularly interesting.

In addition to the interest received from policy makers, many researchers have tackled carbon leakage through the competitiveness channel in their studies. For example, Porter (1991) and Copeland and Taylor (1994) formed hypotheses about the possible effects of unilateral climate policies on competitiveness well before the EU ETS was launched. Recently ex-ante research has tried to predict carbon leakage rates in the EU ETS with the help of equilibrium models, and ex-post studies more specifically on investment leakage and relocation have also been conducted. However, the evidence remains inconclusive for various reasons, for example due to the vast range of assumptions used in ex-ante modeling and the small sample sizes of empirical studies.

## 1.1 Objective and Structure

This study is a literature review, aiming to shed light on the complex issue of carbon leakage as a result of environmental stringency. I will survey academic literature to answer the following research question:

1. Does the EU ETS incentivize investment leakage and relocation?

Specifically, this study aims to find out, what impact has the EU ETS had in possibly incentivizing or, on the other hand, limiting the relocation of firms to unregulated regions. Therefore, this paper contributes to the vast amount of literature exploring the economic and environmental effects of unilateral climate policies and, more precisely, the growing interest in the EU ETS's effects as the world's first international cap-and-trade system.

This literature review focuses on leakage through the investment channel. Relocation is generally studied through medium- to long-run changes in investment patterns, which is what the empirical research focuses on, while theoretical research generally shifts focus to short-run changes in for example trade flows. The aim of this thesis is to solely focus on relocation due to competitiveness losses, thus the challenges of the compatibility of different approaches will be addressed later in this paper.

The paper is structured as follows: Chapter 2 introduces the EU ETS as policy background. In Chapter 3, I present two theoretical frameworks and hypotheses on changes in competitiveness and potential firm relocation due to environmental stringency. Chapter 4 presents equilibrium models that study the implications of the EU ETS ex-ante while Chapter 5 surveys empirical studies on leakage and relocation. Then, Chapter 6 provides a brief discussion on general limitations of studying investment leakage and relocation while also discussing potential reasons behind inconclusive evidence, for example due to carbon leakage protection mechanisms. This paper therefore also contributes to the growing amount of literature exploring the efficiency of carbon leakage protection mechanisms and investigating, what the optimal strategy for protection should be, if any. Finally, Chapter 7 concludes. Any abbreviations used in this paper are listed in the Appendix.

## 2 The European Union Emissions Trading System

To understand the risk of leakage and firm relocation as a result of environmental stringency in the EU, it is crucial to understand the policy background. Since the European Union Emissions Trading System is the world's first international emissions trading system, and the second largest ETS in the world, it has acted as a cornerstone in the fight against climate change and has set the premise for other emissions trading systems of greenhouse gases (European Commission, 2022c).<sup>2</sup> In the next sections, I briefly explain (1) how the EU ETS functions and how it relates to relocation and investment leakage and (2) the design and practices of each of the scheme's phases.

### 2.1 The EU ETS in Practice

The European Union Emissions Trading System was launched in 2005. With an ambitious goal to achieve a 55% emissions reduction by 2030 and become climate neutral by 2050, the EU ETS acts as the main tool in EU's efforts against climate change (European Commission, 2022c). In 2022, the EU ETS covers all EU member states, and Iceland, Norway, and Liechtenstein.<sup>3</sup> The three main sectors under EU ETS regulation are electricity, energy-intensive industry – e.g., production of iron and oil refineries – and aviation. While CO<sub>2</sub> emissions are generally the most notable ones, the EU ETS also covers 5 other GHGs, for example methane and nitrous oxide. (LIFE ETX, 2021)

The grounds of the EU ETS, and EU's environmental policy in general, are set on the basic polluter pays principle (PPP). The PPP simply states that the polluters must internalize their negative externalities by bearing the costs of pollution. In practice, this is achieved by pollution permits called EU Allowances (EUAs). To pollute, companies must surrender EUAs equating to the amount of their emissions. One EUA entitles the firm to one ton of CO<sub>2</sub> emissions. The amount of EUAs distributed each year corresponds to an overall limit of emissions, called a cap, set by the EU ETS. In 2021, the cap was 1.57 billion allowances. To achieve the goals set by the EU, this cap is lowered gradually. In theory, this should incentivize companies to reduce their emissions over time, since EUAs will become scarcer and more expensive. (LIFE ETX, 2021)

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<sup>2</sup> Launched in 2021, China's national ETS is the world's largest emissions trading system as of 2022 (International Carbon Action Partnership, 2022).

<sup>3</sup> The EU ETS also covers power stations in Northern Ireland and is linked with Switzerland's ETS, for bilateral cooperation (LIFE ETX, 2021).

The distribution of EUAs happens through different channels and is not clear-cut. Firstly, companies can acquire EUAs by buying them at auctions. This is the default method of purchasing EUAs. Secondly, EUAs are also free to trade, so companies can purchase them on the open market. If a firm reduces its emissions below the acquired amount of EUAs, it can sell the leftover allowances or keep them for future needs. In principle, this drives cost-effectiveness since emissions are cut where it is cheapest. (LIFE ETX, 2021)

The third channel through which companies acquire EU Allowances is highly related to the research question of this paper. Companies operating in sectors that have been identified at high risk of relocation, causing investment leakage, receive EUAs for free (European Commission, 2022e). These are the EITE, i.e., energy-intensive and trade-exposed sectors we defined above – for example aluminum production, manufacturing of pulp and mining of hard coal. In addition, the aviation sector and some companies in the energy sector benefit from free allocation. (Official Journal of the European Union, 2019). Free allocation is deemed especially important for EITE industries since relocation will also shift pollution outside of the EU and could lead to higher overall emissions. Essentially, free allocation is justified by leakage. I explore this allocation method as a leakage protection mechanism further in [Section 6](#).

## 2.2 The Different Phases of the EU ETS

The EU ETS and its protocols have also changed throughout its existence. In this paper, I survey literature spanning across different phases of the system and thus it is beneficial to also have a brief look at the history of the EU ETS. As is illustrated in [Figure 1](#), the EU ETS has undergone four phases, with the newest one in place since 2021. The ETS is, however, being revised constantly to conform to the European Green Deal and its targets.<sup>4</sup>

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<sup>4</sup> While working on this paper, the European Parliament agreed on a legislation proposal that would allow for the inclusion of maritime transport activities into the EU ETS. The legislation is yet to be adopted. (European Parliament, 2022)



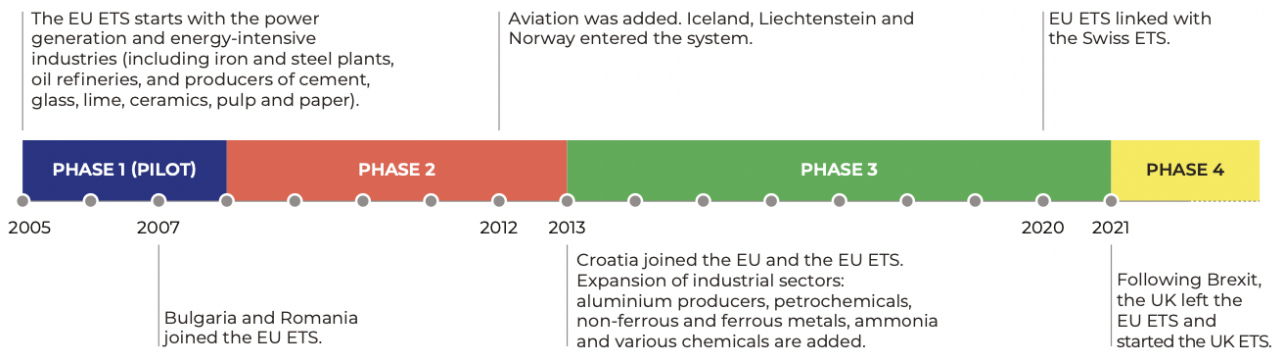


Figure 1. The coverage of the EU ETS (LIFE ETX, 2021)

The EU ETS pilot phase spanned for just three years, from 2005 until the end of 2007, and was characterized by an almost 100% free allocation strategy. The cap set for emissions was determined by the aggregate of national caps of member states. Subsequently, the cap was too large to further EU’s climate goals and caused an oversupply of allowances, driving the price of the small number of allowances auctioned to zero. (LIFE ETX, 2021) When surveying empirical research later in this paper, it is important to note that the characteristics of phase 1 imply, in theory, a low risk of leakage. I discuss this further in [Section 5](#).

Phase 2 adopted auctioning of allowances and a smaller overall cap, even though almost 90% of EUAs were still under free allocation. The EU ETS was again burdened by an oversupply of cheap allowances, notably since the financial crisis of 2007-2009 decreased economic output and emissions, while the amount of EUAs stayed constant. All in all, phase 2 faced the same problems as phase 1. (LIFE ETX, 2021)

As [Figure 1](#) shows, the EU ETS saw significant changes at the start of its third phase, in order to correct the issues from previous years. The EU ETS’s coverage expanded to more sectors, auctioning was implemented as the main allocation method and the number of free allowances decreased. An EU-wide cap, not based on the national caps of member states, was established. The Market Stability Reserve (MSR) was also inaugurated during phase 3, aiming regulate the number of allowances in the market and stabilize their price. (LIFE ETX, 2021)

The fourth phase of the scheme was launched in 2021. As one of its main goals, phase 4 also aims to target carbon leakage by continuing free allocation of EUAs. (European Commission, 2022e) Free allocation is now based on production levels, more specifically on what firms emit from production. Firstly, from phase 3 onwards, benchmarking has been used to determine the free allocation of EUAs.

This simply means that the number of free EUAs each establishment at risk of carbon leakage receives is based on benchmarks for greenhouse gas emissions. Each product has its own benchmark that is calculated by looking at the average emissions of the top 10% most efficient producers of that specific product in the EU. Companies that reach these benchmarks will receive all allowances for free, covering their full needs, while those that don't will have to reduce their emissions and/or buy EUAs. (European Commission, 2022a)

For sectors that are at smaller risk, the number of free allowances will gradually decrease to meet the target of 0-30% free allocation by the end of the current phase, i.e., by 2030. The European Commission estimates that more than 6 billion allowances will still be subject to free allocation in phase 4. Furthermore, phase 4 sets to increase the rate of emissions reduction and reinforce the Market Stability Reserve by reducing the number of allowances. It also focuses on funding clean-energy innovation and supporting investments in the energy sector by setting up two funds, the Innovation Fund, and the Modernisation Fund. (European Commission, 2022b) This strengthens the idea that carbon leakage is a significant risk in the EU and that it needs to be addressed.

### 3 Economic Theory

Concerns on reduced competitiveness, carbon leakage, and relocation due to unilateral climate policies have been a focal point in both public and economic discussion on environmental policy, especially in recent decades as more stringent actions have been adopted. However, theories on the possible effects of climate measures combined with open trade have been explored well before that. In the next sections, I examine two theoretical frameworks, The Pollution Haven Hypothesis and the Porter Hypothesis, to form a better understanding of the predictions concerning leakage.

#### 3.1 The Pollution Haven Hypothesis

Copeland and Taylor's (1994) Pollution Haven Hypothesis (PHH) is the basis of a large portion of literature concerning investment leakage. By employing a simple, two-country computable general equilibrium (CGE) model, the authors form a hypothesis on the effects of international trade and environmental policy: they argue that, under open trade, aggregate pollution may increase since stringent climate policies can incentivise trade and ultimately relocation by affecting Foreign Direct Investment (FDI). In other words, especially EITE industries might shift production from regulated regions to non-regulated regions, so-called pollution havens. As Taylor (2005) notes, the hypothesis, however, does not rule whether this increases aggregate welfare or not.

The Pollution Haven Hypothesis should also be differentiated from the Pollution Haven Effect, Taylor (2005) argues. The hypothesis is mainly a prediction on open trade and trade patterns and, because of that, the possible effects of climate policy. The effect itself, however, occurs if changes in environmental regulation affect trade. The hypothesis can then only hold if the effect is strong enough.

The effect, and therefore hypothesis, have, however, had mixed results in empirical studies. For example, Jaffe et al. (1995) find no evidence of the Pollution Haven Hypothesis when looking at U.S. manufacturing firms while Cole (2004) finds that trade flows between OECD and non-OECD countries have increased because of stringent regulation in OECD countries. Cole (2004), however, also concludes that the effect found is relatively small and conclusive evidence on the existence of the PHH is difficult to argue.

One reason for the lack of evidence on the PHH might be the setting of Copeland and Taylor's (1994) study. The two-country CGE model relies on a large set of assumptions, which may not hold true when trying to demonstrate the Pollution Haven Hypothesis empirically. Firstly, the North-South framework relies on income inequality between the regions, and it is assumed that environmental stringency is also based on the level of income of each region: North is the high-income, stringent policy region while South is the low-income region with no environmental stringency. Copeland and Taylor (1994) assume that the low-income region is then willing to deal with emissions and pollution. Furthermore, in the model, the location of firms is solely determined by environmental stringency. Location choices are usually affected by other factors as well, for example the cost of relocating, abatement costs or the sustainability efforts of a firm.<sup>5</sup> The PHH is then more likely to hold when looking at a simplistic model of trade, where the role of investment and regulation is also unambiguous, but not when studying a more realistic one (Eskeland & Harrison, 2003).

### 3.2 The Porter Hypothesis

One of the main arguments against the Pollution Haven Hypothesis is the Porter Hypothesis (PH). It hypothesizes that, on the contrary, stringent environmental policy leads to an increase in the competitiveness of firms. While policy-induced costs are generally high in short-term, reducing

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<sup>5</sup> Abatement costs are the costs firms face when they – as a result of regulation – reduce pollution, e.g., recycling costs or the cost of implementing a new method or process to reduce the amount of GHG emissions. (Guerriero, 2020)

competitiveness, long-term effects are positive, if environmental regulation is well-designed. The main argument is that well-designed policies encourage companies to innovate and make technological advancements which lower the level of pollution and hinder costs or improve the quality of produced goods. In addition, innovations improve competitiveness since they are highly valued in the international market. (Porter, 1991)

Porter and Van der Linde (1995), however, underline that only well-designed climate policies increase competitiveness. In their study, they give six theoretical assumptions in support of the PH:

- 1) Well-designed policies incentivise innovation by signalling of inefficiencies
- 2) Regulation gathers information and gives room for improvement
- 3) By signalling of inefficiencies, regulation removes uncertainty: firms can be sure, that innovation is needed and will likely improve competitiveness
- 4) Regulation acts as outside pressure for innovation, in the same way as increased competition or strong demand
- 5) Environmental regulation makes sure that firms cannot achieve gains by not playing their part – it levels the playing field by requiring all regulated companies to comply
- 6) Stringent regulation is needed to improve the quality of the environment, since the cost of compliance may otherwise be high in the short run

Much like the Pollution Haven Hypothesis, the empirical results of the Porter Hypothesis remain unclear. Porter & Van der Linde (1995) find several case studies where regulation has led to an increase in competitiveness. Lanoie et al. (2008), however, argue that the impact of environmental policies is based on the pollution-intensity of a particular industry: polluting industries will likely see a decrease in competitiveness because of environmental stringency, while the opposite applies for firms in less carbon-intensive industries. Lanoie et al. (2008) also find evidence that trade-exposed firms have an incentive to innovate and therefore increase their competitiveness as a result of environmental policy.

However, most of the empirical studies on the Porter Hypothesis usually examine the Pollution Haven Hypothesis in effort to overturn it, and, as concluded above, the literature on the Pollution Haven Hypothesis finds mixed evidence on its existence. The matter is further complicated by the definition of well-designed regulation given by Porter and Van der Linde (1995) – we cannot be certain, whether the environmental measures and policies studied in literature so far are classified as “good” or “bad” in the Porter Hypothesis without extensive research on other possible effects of said policies.

Therefore, empirically, both the Pollution Haven Hypothesis and the Porter Hypothesis would seem to be unverifiable when looking at current literature.

## 4 Estimating Leakage with Equilibrium Models

The effects of unilateral climate policies and environmental stringency have been widely studied in economic research. A notable amount of literature aiming to predict or simulate the effects of unilateral climate policies on firm competitiveness exists. These ex-ante studies are almost always conducted with the help of equilibrium models that predict carbon leakage rates. Equilibrium models account for e.g., international trade, substitution effects and capital mobility. These models are largely calibrated based on historical datasets. Furthermore, two approaches can be distinguished. Most ex-ante literature predicts leakage rates using Computable General Equilibrium, i.e., CGE models. These allow us to form an economy-wide perspective and explore macroeconomic impacts on multiple sectors and regions. The other approach is using partial equilibrium models that only consider one or a few sectors – usually those most prone to leakage.

Results from equilibrium models help us quantify the impact of climate policies and estimate possible carbon leakage rates. These models have predicted quite substantial leakage, although the estimates vary greatly between partial and general equilibrium, and even between studies employing the same approach. The considerable number of assumptions made can also explain the vast range of different estimates. This chapter presents both a partial and general equilibrium approach, to quantify the implications of the EU ETS. First, I explore Monjon and Quirion's (2011) partial equilibrium model and then move on to a more comprehensive analysis of CGE models by Böhringer et al. (2012). In addition, I discuss potential challenges that might affect the estimates of ex-ante studies.

### 4.1 Partial Equilibrium Model

Unlike many other partial equilibrium models aiming to explore carbon leakage in a particular industry (e.g., Demailly & Quirion, 2006; Mathiesen & Maestad, 2004), Monjon and Quirion (2011) employ a multi-sector model. The authors argue that CGE models are too vague to appropriately assess leakage since they don't show sectoral features like trade-exposure, and on the other hand, sector-specific partial equilibrium models fail to show for example intersectoral trade. Monjon and Quirion's model called CASE II considers period 3 of the EU ETS. The model encompasses four major ETS sectors, which are usually presumed to be at risk of carbon leakage. These are cement, aluminium, steel and electricity.

The authors explore different policy scenarios from auctioning all allowances in every sector to purely output-based allocation. I will focus on the scenario “OB exposed direct”, which is the closest one to the current EU ETS permit allocation strategy, where the exposed sectors’ allowances are mostly allocated based on benchmarks of production emissions and the rest are auctioned. In the scenario “OB exposed direct”, allowances are auctioned in the electricity sector while output-based allocation is employed for the other industries’ direct emissions. Since the EU ETS is gradually limiting the number of free allowances and increasing auctioning, I also look at the policy scenario “Auctioning”.

To understand all the assumptions behind Monjon and Quirion’s model and results, let’s look at the structure of the partial equilibrium model. Like many before, the authors divide the world into two regions: the European Union (EU) and the rest of the world (RoW). Our sectors cement, aluminium, steel and electricity are denoted by  $C$ ,  $A$ ,  $S$  and  $E$  respectively. First, let’s look at the demand side to determine, how customers make consumption decisions between products of different regions. For region  $r = \{EU, RoW\}$ , the representative customer has a two-tier utility function. The upper tier consists of a simple Cobb-Douglas utility function. The lower tier of the utility function gives us the allocation of expenditure in industries  $C$ ,  $A$  and  $S$ . An assumption is made that all industries have both a domestic and foreign variety, and that all domestic varieties – and all foreign varieties – are perfect substitutes for each other. However, domestic and foreign varieties are imperfect substitutes. The representative customer is also assumed to have preferences over these varieties. The electricity industry is left out since almost no international trade occurs in this sector. The demand of  $E$  is then denoted as the sum of the demand of  $C$ ,  $A$  and  $S$  in region  $r$  and a fixed expenditure share of the income of the representative consumer:  $\alpha_r^E \cdot Y_r$ , where  $Y_r$  is the exogenous and growing GDP of region  $r$ .

Using the assumptions above, a sub-utility function is derived:

$$u_r^i = \left( (pref_{rr}^i \cdot Q_{rr}^i)^{\frac{\sigma_i-1}{\sigma_i}} + (pref_{rr'}^i \cdot Q_{rr'}^i)^{\frac{\sigma_i-1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i-1}} \quad (1)$$

where  $r$  and  $r' = \{EU, RoW\}$ ;  $r' \neq r$  and  $i = \{C, A, S\}$ .  $pref_{rr}^i$  is the preference for the EU variety and  $pref_{rr'}^i$  for the imported variety.  $Q_{rr}^i$  is the consumption level of the commodity of industry  $i$ , by

consumers of the region  $r$  while  $Q_{rr'}^i$ , the consumption level of the commodity of industry  $i$ , by consumers of the region  $r'$ .  $\sigma_i$  denotes the Armington elasticity in industry  $i$ .<sup>6</sup>

To obtain the demand curves for both EU and non-EU commodities, the sub-utility function is maximised:

$$Q_{rr}^i = \alpha_r^i \cdot Y_r \frac{(pref_{rr}^i)^{\sigma_i-1} \cdot (p_{rr}^i)^{-\sigma_i}}{(pref_{rr}^i)^{\sigma_i-1} \cdot (p_{rr}^i)^{1-\sigma_i} + (pref_{rr'}^i)^{\sigma_i-1} \cdot (p_{rr'}^i)^{1-\sigma_i}} \quad (2)$$

$$Q_{rr'}^i = \alpha_r^i \cdot Y_r \frac{(pref_{rr'}^i)^{\sigma_i-1} \cdot (p_{rr'}^i)^{-\sigma_i}}{(pref_{rr}^i)^{\sigma_i-1} \cdot (p_{rr}^i)^{1-\sigma_i} + (pref_{rr'}^i)^{\sigma_i-1} \cdot (p_{rr'}^i)^{1-\sigma_i}} \quad (3)$$

where  $p_{rr}^i$  is the price of the EU variety of industry  $i$  in region  $r$  and  $p_{rr'}^i$  is the price of the non-EU variety of the same industry, in the same region.

Now that we have the demand functions, the authors then look at the supply-side to obtain the profit function. It is assumed that firms compete in quantities. Like stated above,  $C$ ,  $A$  and  $S$  operate in the EU and RoW, while  $E$  only sells in the EU.  $C$ ,  $A$  and  $S$  face a per-unit transportation cost denoted by  $tc^i$ . The number of competing domestic firms is denoted by  $n_r^i$ . Therefore, a firm in region  $r$  has the following profit function:

$$n_r^i = (p_{rr}^i - mc_r^i) \cdot q_{rr}^i + (p_{r'r}^i - mc_r^i - tc_{r'r}^i) \cdot q_{r'r}^i - FC_r^i \quad (4)$$

where  $r$  and  $r' = \{EU, RoW\}$ ;  $r' \neq r$  and  $i = \{C, A, S\}$ .  $mc_r^i$  is the marginal cost of firms in region  $r$  while  $FC_r^i$  is the fixed cost of firms in region  $r$ .  $q_{rr}^i$  denotes the quantity sold in the EU while  $q_{r'r}^i$  is the quantity sold outside of the EU. Lastly,  $tc_{r'r}^i$  is the transportation cost from region  $r$  to region  $r'$ .

The authors also assume that there is free entry to the market, meaning that firms in both regions would then have no profits, making firms in one region symmetric. This gives us the number of total firms in each region:  $Q_{rr}^i = n_r^i \cdot q_{rr}^i$ . Similarly, assumptions need to be made about the costs that firms under the EU ETS incur. Abatement costs are part of the firms' variable cost while the cost of

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<sup>6</sup> Armington elasticity refers to the elasticity of substitution that consumers face regarding home and foreign varieties that are imperfect substitutes. It is commonly used in equilibrium models of inter-regional trade. (Hillberry & Hummels, 2013)

purchasing an allowance is seen in the production cost.  $C$ ,  $A$  and  $S$  will also see an increase in their marginal cost when the price of electricity increases.

Monjon and Quirion then employ a 2006 data set to predict if carbon leakage occurs in the above-mentioned sectors. As is noted by the authors, Armington elasticities varies greatly in different sectors and countries, but for the purpose of this study, low values of elasticity are examined. The application of the model finds very low rates of leakage in the “OB exposed direct” scenario, at around 1–2%. Even in the scenario of full auctioning, leakage rates are only at around 4.5%, when using low Armington elasticities. The higher the elasticities, the higher the estimated leakage rates since substitutes will be available more easily (Böhringer et al., 2012). When experimenting with higher values of Armington elasticities, Monjon and Quirion find that the aggregate leakage rate under full auctioning is higher, at 11.4%. Therefore, CASE II does predict some leakage because of the implementation of a cap-and-trade system, but the estimates are highly dependent on the assumptions used.

Although Monjon and Quirion’s model encompasses several sectors and allows us to study sector-specifics, it still only focuses on leakage in industries that are already deemed at high risk, disregarding the rest of the market. The model also takes many macroeconomic variables as given and is a highly simplified of the effects of unilateral climate policies. To study the effects of environmental stringency on the entire economy, it is beneficial to shift the focus to general equilibrium.

## 4.2 Computable General Equilibrium Model

To form a comprehensive view of the estimates of Computable General Equilibrium models on carbon leakage under cap-and-trade systems, Böhringer et al. (2012) provide a unique analysis of 12 computable general equilibrium models based on an Energy Modeling Forum study (EMF 29). The specific expert groups and models analyzed in Böhringer et al.’s study are left out for brevity, although I explore one of the models more closely below. One of the main policies that is overviewed in the study is the EU ETS.

To achieve comparable results, the 12 expert groups participating in the analysis all investigate leakage using the same pre-defined policy scenarios, assumptions and dataset. The sizes and reduction targets of all abatement coalitions have also been harmonized. The study focuses on the



competitiveness channel of leakage specifically, which is the one we are most interested in. Similarly to the partial equilibrium model I studied above, all but one of the CGEs in this study adopt Armington elasticities. Like many other studies on unilateral climate policies, the study employs the Global Trade Analysis Project (GTAP) database. The database spans over 112 regions and 57 sectors and includes national CO2 emissions, trade flows, consumption, and production. The sectors and coalitions covered in the study are depicted in [Figure 2](#). Some of the sectors are EITE industries, which are particularly prone to leakage. For the purpose of this paper, let's focus on the results concerning the EU ETS, that is "EU-27 plus EFTA".

<i>Sectors and commodities</i>	<i>Countries and regions</i>
<i>Energy goods</i>	<i>Annex 1 (industrialized) regions</i>
Coal	Europe – EU-27 plus EFTA**
Crude oil	USA – United States of America**
Natural gas	Russia
Refined oil products*	Remaining Annex 1 (RA1)**
Electricity	
<i>Non-energy goods</i>	<i>Non-Annex 1 regions</i>
Chemical products*	China
Non-metallic minerals*	India
Iron and steel industry*	Energy exporting countries excl. Mexico (EEX)
Non-ferrous metals*	Other middle income countries (MIC)
Transport	Other low income countries (LIC)
All other goods	

\*Included in the composite of *energy-intensive and trade-exposed* (EITE) industries.  
\*\*Included in the composite region A1xR.

*Figure 2. Sectors and regions included in the study (Böhringer et al., 2012)*

The study uses 2004 as the base and target year of abatement to achieve coherence and comparability. Therefore, the results are a simulation of the historical economic situation of 2004. It is crucial to note that using 2004 as a target year does not adequately reflect the target years of climate policies, not least that of the EU ETS which was only launched in 2005. While this creates coherence from the point of view of the model, it complicates things when trying to generalize the results to real-world policy scenarios.

When looking at all the regions and coalitions studied – e.g., Annex 1, EU, and Russia – the models estimate leakage rates of 5% ± 19% (mean 12%) with the target year set to 2004 and the target emissions reduction set to 20%.<sup>7</sup> When only examining the EU ETS, the leakage rate is 23.9% – significantly higher than the partial equilibrium model of Monjon and Quirion (2011) predicts. This

<sup>7</sup> Annex 1 refers to one of the main group of parties of the Kyoto Protocol, committing nations to emissions reduction activities. Annex 1 includes industrialized OECD countries and the so-called EIT parties including Russian Federation. (The United Nations Framework Convention on Climate Change Secretariat, 2022b)

would mean that when emissions in the EU are reduced, almost a fourth of the reduction is counteracted by an increase in emissions outside of the EU. Interestingly, the authors argue that leakage rates are influenced by the size of the coalition and the coalition’s emissions reduction target. Smaller abatement coalitions and higher reduction targets lead to higher leakage rates, *ceteris paribus*. From [Figure 3](#), we can see that the leakage rates in the business-as-usual scenario, *ref*, significantly drop as the coalition size increases.<sup>8</sup> A1xR refers to Annex 1 without Russia and A1xR\_CHN refers to A1xR with China added. This is quite intuitive since a bigger coalition means that the non-abating region of the world is consequently smaller, i.e., there are geographically and economically less opportunities for firms to relocate. Similarly, an ambitious reduction target means increased environmental stringency which is, by definition, what drives leakage and production relocation.

Leakage in *ref* and *bca* cost savings as a function of the coalition size.

Coalition size	EUR	A1xR	A1xR_CHN
Leakage in scenario <i>ref</i> (%)	23.9	11.8	6.7
Global cost savings in <i>bca</i> (% from <i>ref</i> )	14.7	7.7	3.1

*Figure 3. Leakage by coalition* (Böhringer et al., 2012)

To gain a better understanding on leakage estimates in the EU ETS, let’s look at one of the models used in the analysis by Böhringer et al. more closely. Bednar-Friedl et al. (2012) perform an analysis on leakage in the EU ETS by using a CGE model, the base year 2004 and a reduction target of 20%. To complement the GTAP database, they include industrial process emissions from EITE industries into their model in addition to combustion emissions, which are generally considered when modeling carbon leakage. The authors argue that especially EITE industries emit these process emissions and therefore aim to study whether estimates change when examining industrial process emissions as well. Their hypothesis is that the predicted leakage rates are low due to the failure to include industrial process emissions into CGE models. Bednar-Friedl et al.’s model estimates total leakage without process emissions at 28.9% and with process emissions at 38.4%. These leakage rates are substantial, and the inclusion of process emissions seems to have a notable effect on the estimates. The authors argue that process emissions are hard and expensive to be substituted away. In addition, since it is particularly important to account for process emissions when looking at energy-intensive and trade-exposed industries, these emissions are more likely to leak due to exposure to international trade.

<sup>8</sup> The second row “Global cost savings in *bca* (% from *ref*)” refers to the cost savings achieved as a result of implementing border carbon adjustment, i.e., shifting a part of the burden of emissions reduction to non-abating countries. I discuss this mechanism in [Chapter 6](#), but for now, it is not relevant.

Overall, the analysis and simulation by Böhringer et al. (2012) shows that the risk of carbon leakage under EU ETS may be real. By comparing 12 different CGE models under the same set of assumptions, a leakage rate of 23.9% is predicted for the EU. When including model-specific assumptions, like industrial process emissions, the estimate is much higher, at 38.4%. However, these assumptions, whether they concern policy scenarios, model parameters or macroeconomic phenomena, also limit the interpretation of ex-ante studies' results. In the next section, I provide a more in-depth discussion of potential limitations and challenges of ex-ante models.

### 4.3 Challenges and Limitations of Ex-ante Models

As with any economic models, the partial and general equilibrium models used to assess carbon leakage rates face some challenges. Firstly, the results are highly dependent on the set of assumptions made since models react sensitively to different parameter choices. When looking at the partial equilibrium model of Monjon and Quirion (2011), assumptions are made for example on imperfect substitution, homogeneity of firms, and perfect competition.

Especially ex-ante studies employing general equilibrium are also limited by the data they use, since comprehensive data on multiple regions and sectors can be difficult to find. The GTAP database, which is frequently used in CGE modeling of leakage, gives a global overview of for example trade flows and emissions but fails to show sector- or region-specific features. Aggregation of data may subsequently lead to conclusions that are drawn based on summaries.

One of the biggest challenges with equilibrium models is that they almost exclusively study carbon leakage through the competitiveness channel in short-term, i.e., by examining trade flows. As discussed, the matter of relocation is usually studied in empirical research through medium- to long-run changes in investment decisions, which is what we are also interested in. Changes in trade flows can also indicate production relocation away from the EU but they can just as well indicate that European firms have lost market shares at home, in the European Common Market (Naegele & Zaklan, 2019). For the purpose of answering the research question, it is therefore crucial to note that the equilibrium models studied above use different competitiveness indicators than the empirical studies investigated below, possibly causing issues in interpreting and comparing studies. I will discuss these issues in [Chapter 6](#). In any case, since ex-ante models can only give predictions based on a large set of assumptions that may not hold in practice, it is helpful to look at empirical studies with practical applications.

## 5 Assessing the Impact of the EU ETS: Ex-Post Evaluations

In addition to predicting leakage rates with ex-ante equilibrium models, researchers have adopted an empirical approach to study the economic and environmental impact of regulation. The earlier studies focus on environmental regulation regionally. Most of these papers look at the competitiveness of U.S. manufacturing firms, by examining for example net exports, investment decisions and productivity, but little to no evidence is found (Jaffe et al., 1995). On the contrary, some studies find evidence that stringent regulation has a positive effect on the competitiveness of the home country in long-term, which is what the Porter Hypothesis states (Grossman & Krueger, 1995). However, more recent studies find statistically significant, albeit little, evidence on the Pollution Haven Effect (e.g., Copeland & Taylor, 2004; Levinson & Taylor, 2008; Zhang & Fu, 2008).

Empirical studies on investment leakage in the EU ETS have also been conducted. Although few studies are yet of relevance, this ex-post research seems to be growing in popularity. Even so, the evidence varies. In this chapter, I will (1) explore recent ex-post studies on leakage and relocation, and (2) discuss some of the challenges and limitations related to the empirical studies.

### 5.1 Empirical Evidence on Leakage and Relocation

Since loss of competitiveness and relocation is what we are interested in, the studies I survey in this section focus on leakage through the competitiveness channel, more specifically changes in production location through investment leakage. Most of the literature explored examines outward Foreign Direct Investment flows with a focus on different countries and sectors, all subject to the regulation imposed by the EU ETS, although other approaches are investigated as well. Carbon leakage through the competitiveness channel has been studied with the help of numerous indicators of competitiveness, e.g., employment, productivity, and international trade flows, meaning imports and exports (Wagner et al., 2014; Commins et al., 2011; Branger et al., 2017). However, most of these would indicate short-run changes in competitiveness. By studying FDI flows, we shift the focus to medium- to long-run changes in production activity, possibly giving evidence of relocation. I discuss this further in [Chapter 6](#).

Using firm-level data of German multinationals firm, Koch and Basse Mama (2019) study leakage by looking at outward FDI flows. The authors argue that German multinationals are particularly export-orientated and have high Foreign Direct Investment activity. The study employs a sample of

232 EU ETS firms, almost all in the manufacturing industry, and a difference-in-differences approach to account for firm, sector and country heterogeneity and control for any unobservable factors.<sup>9</sup> When looking at the entire sample, no statistically significant evidence of relocation is found in phases 1-3 of the EU ETS. However, some sub-results do indicate possible investment leakage. Relative to control firms, the number of non-EU affiliates of regulated firms increased by  $28\% \pm 24\%$  in the period of 1999-2013. While causality is hard to argue, this could imply that German multinational EU ETS firms plan on relocating in the future. However, what is more indicative evidence of investment leakage is that a subsample of geographically mobile firms has increased their outward FDI flows by  $52\% \pm 47\%$  compared to the control firms. These firms operate in footloose industries with small relocation costs.<sup>10</sup> Even if their need for pollution permits is small relative to big polluters, it might still be more cost-efficient to relocate.

Similarly to Koch and Basse Mama's (2019) focus on German companies, Borghesi et al. (2020) conduct a study on the outward FDI flows of Italian manufacturing firms to explore if relocation takes place due to the imposed regulation by the EU ETS. Italy is not only one of the main polluters in the EU, but also has a higher outward FDI rate than the average EU country. The authors also argue that – since Italian firms suffer from a lack of environmental innovations compared to many other nations under the EU ETS – concerns of relocation may be especially relevant for firms at the margin. The authors employ a dataset of 22 000 firms out of which 283 are regulated in phases 1 or 2 of the EU ETS. In addition to those phases, the pre-ETS period is considered. Both the extensive and intensive margins of Foreign Direct Investment are examined, meaning that the study looks at the number of new subsidiaries and the level of production abroad. The hypothesis is that a multinational firm might open subsidiaries or shift production to non-EU countries. Evidence on both the extensive and intensive margins of FDI is found. Subsidiaries abroad – the extensive margin – increased in the period considered, albeit the effect is very weak. The estimations might also be biased since the analysis accounts for subsidiaries operating in non-ETS sectors as well. In other words, the FDI flows might be affected by unobserved variables in other sectors since the authors aren't able to identify, whether subsidiaries operate in different sectors than their parent companies. A slightly stronger

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<sup>9</sup> A difference-in-differences approach is an econometrical method used when a group is exposed to treatment and others are not. It is especially useful when trying to estimate changes in the economic environment or policies. (Angrist & Krueger, 1999)

<sup>10</sup> Footloose industries are industries that are geographically mobile, i.e., not tied to a certain location. Industries that are not footloose usually face for example high transportation costs, plant fixed costs and agglomeration externalities. (Ederington et al., 2005)

effect is found on the intensive margin, i.e., production seems to have shifted to non-EU countries, although the evidence is little.

Martin et al. (2013) conduct a broader study by also examining manufacturing firms, this time in 6 countries under the EU ETS's regulation.<sup>11</sup> The authors gather data based on a survey where managers are asked to evaluate the likelihood of the firm relocating a part of production or completely closing production in the EU in the future, in response to climate policies. The study includes 761 companies. Based on the answers, each firm is given a vulnerability score (1-5), where 1 means no changes in production and 5 means ending production in the EU completely. The authors then study two permit allocation strategies: grandfathering in phase 2 and benchmarking in phase 3. As briefly discussed in Chapter 2, grandfathering means free allocation of allowances based on past emissions and benchmarking means free allocation based on calculated product benchmarks. Under grandfathering, the risk of leakage through relocation is found to be 15.66%. The respective number is 22.79% under benchmarking. The most vulnerable industries are for example cement and iron. These significantly higher predicted rates of leakage are likely explained by the setting of the study. This is a survey-based study, and the survey question is on the expectations of a firm when it comes to future relocation, not on relocation decisions already made.

One of the most recent studies on relocation under the EU ETS is by Dechezleprêtre et al. (2022). Most of the literature surveyed above assumes that outward Foreign Direct Investment flows are a direct indicator of relocation and leakage. However, Dechezleprêtre et al.'s (2022) study directly investigates shifts in production activity, i.e., shifts in the location of emissions. The research uses a dataset of 1,122 multinational companies. The authors identify 261 regulated firms in the period of 2007-2014, i.e., phases 2 and 3 of the EU ETS. Most of these companies operate in manufacturing or energy sectors. As the authors argue, multinationals are intuitively most likely to relocate and cause leakage since their costs of operating in several countries are already sunk. The dataset used – which gives the annual firm-level emissions – also benefits from a unique feature: the emissions' geographic location is tracked, allowing for precise measurement of the change of emissions outside of the EU as result of pricing carbon in the EU. By employing a constant elasticity of substitution production function, the study finds no statistically significant evidence of firm relocation as a result of the EU ETS. The external validity of the study is hindered by the sample, since multinationals are larger than the average EU ETS firm. However, this feature leads us to believe that the average amount of leakage

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<sup>11</sup> The countries analyzed in the study are Belgium, France, Germany, Hungary, Poland and the UK. Since the UK was still part of the EU at the time the research was conducted, it was under the EU ETS's regulation.

that an EU ETS firm produces should then be smaller than what the study shows. The results of the sample used would then act as a ceiling or cap for leakage in the EU, and since no leakage is found, it is intuitive that the same applies for smaller EU ETS firms.

## 5.2 Challenges and Limitations of Empirical Research

Even though the results of empirical studies vary, most of them cannot provide robust and significant evidence on the existence of leakage and relocation under the EU ETS. If ex-ante models show significant leakage rates, why does ex-post research fail to capture that? Firstly, problems related to data and the setting of empirical studies are prevalent. As is the case with most of the empirical studies I examined above, the sample sizes are usually small, with focus on one country and sometimes only one industry. Therefore, the margin of error can be quite significant, and the power of the study and external validity hindered. It would be beneficial to conduct broader studies, for example by examining the same industries in multiple EU ETS countries to possibly provide a pattern for relocation decisions.

It is also likely that estimations suffer from omitted variables. Again, location decisions are also influenced by factors that are unrelated to environmental policy. Anything from transportation costs to the firm's stance on sustainability can affect location decisions. Especially in empirical research, these variables could easily be ignored, leading to bias in estimations. In addition, the impact of the EU ETS can be hard to separate from the impact of any other changes in the economic environment.

However, the lack of empirical evidence is also likely due to features of the EU ETS. The EU ETS has been in place since 2005 but as covered before, it suffered from many problems especially in the early stages of phase 1 and 2. Almost all permits were allocated for free meaning that firms faced virtually no costs for polluting activities. The emissions cap was also too large. The price of the small number of allowances that were auctioned was subsequently too low, in some periods at zero. Therefore, the concerns that increased costs would lead to leakage were never realized since the costs were simply very small to nonexistent. The costs firms would then face if they relocated would almost certainly be higher than abatement costs.

Most of the literature surveyed does consider phase 3 of the EU ETS as well, or at least the beginning of phase 3. As discussed in [Chapter 2](#), the EU ETS was widely reformed before adopting phase 3 in 2013. Free allocation decreased as auctioning became the main allocation method of allowances and

active efforts were made to stabilize the market price of allowances. However, in practice, prices of EU Allowances still stayed low for most of phase 3, spanning from 2013 to 2021. At the beginning of 2018, the price per metric ton of carbon was still below 10€ and that only began rising when the fourth phase of the EU ETS was introduced as part of the new EU ETS Directive in April 2018. Arguably, the price of EUAs has then been too low to incentivize leakage and relocation. Recently the price has seen a sharp increase, likely due to the increased stringency of phase 4. Other factors may be relevant too. For example, the increase of gas prices might incentivize firms in the electricity sector to switch to coal-based power, increasing the demand for EUAs. (European Central Bank, 2022). Empirical evidence on leakage in phase 4 does, however, not exist as of now.

If low prices of auctioned allowances are not enough to explain the lack of empirical evidence surrounding carbon leakage, the different carbon leakage protection mechanisms might be. Concerns on reduced competitiveness and carbon leakage were voiced well before the establishment of the EU ETS, for example by the supporters of the Pollution Haven Hypothesis, as established in [Chapter 3](#). Consequently, the EU ETS's policy design has always included measures to combat carbon leakage – even when empirical evidence on the existence of leakage has been scarce. Paradoxically, the efficacy of these mechanisms might explain the absence of empirical evidence. Perhaps the most extensive of these measures is free allocation, which, as discussed, has also burdened the EU ETS since its launch. Other important measures include cost compensation and the Carbon Border Adjustment Mechanism (CBAM). In the next section, I briefly present these mechanisms while also discussing any downsides to researching carbon leakage as a whole.

## 6 Discussion

The results on investment leakage and relocation remain inconclusive, regardless of the amount of research that has recently emerged. As I briefly explained, both ex-ante models and ex-post empirical research face their own problems when it comes to studying leakage and relocation. However, there are also important implications for studying investment leakage altogether, regardless of the approach used. Firstly, investment leakage focuses on long-run changes in competitiveness. Since the EU ETS has only been in place since 2005, and more stringent measures have only been adopted in recent years, the results may not be compatible with the policy at hand. To be able to form a thorough analysis on the risk of relocation under the EU ETS, the research available is likely studying a phenomenon that is too recent to provide conclusive evidence on. It would be beneficial to conduct such analysis after a longer period, to properly assess the impact of the EU ETS.



In addition, studies may not be compatible with each other. As I briefly discussed, carbon leakage through the competitiveness channel has been studied with the help of numerous competitiveness indicators. For example, empirical research on FDI flows and theoretical studies on trade flows are not directly comparable since trade flows can also simply indicate changes in market shares in the European Common Market that don't necessarily have anything to do with relocation. To my knowledge, Computable General Equilibrium models predicting investment leakage do not exist as of now. This makes it difficult to interpret, whether CGE models estimate short-term changes in imports and exports, or if these trade flows could mean production relocation as well, for example due to outsourcing. Interpreting FDI flows is also difficult since they only give us an idea of the pattern of investment. Investment does not necessarily occur due to relocation and relocation does not always occur through FDI. As this branch of research becomes more popular, more conclusive results will surely emerge.

A frequent and important assumption is that the EU ETS is a unilateral climate policy which, as we know, does not hold in the real world. As Ahlvik and Liski (2022) find, over 20% of all carbon emissions in the world are priced in some way, usually by local policies since a global climate treaty with binding carbon pricing does not exist. While it can be argued that firms would still relocate to regulated regions if the regulation is laxer than at home, policies are constantly being revised, as is the EU ETS, and leakage estimates will surely be affected by these changes.

In addition, new emissions trading systems are emerging at a fast pace. This makes it even more difficult to study the question of carbon leakage since, at least in theory, firms would then not be able to avoid carbon pricing and competitiveness losses due to environmental stringency would not be of concern anymore since firms would face increased costs regardless. Some of these systems have also begun co-operation to, for example, harmonize carbon prices, further global climate goals and reduce abatement costs. For example, the EU and China launched a bilateral cooperation project in 2014, to support the implementation of the Chinese ETS and later continue policy dialogue and joint research activities between the EU and China. The Swiss ETS also linked with the EU ETS in 2020. (European Commission, 2022d)

Even though evidence on carbon leakage in the EU remains inconclusive, it has been one of the most prevalent challenges when designing the EU ETS and its different phases. In order to minimize the risk of relocation and leakage, the EU has adopted several mechanisms and policies. The logic behind

these mechanisms is to protect especially EITE industries from the ETS's negative effects. In practice, this has been achieved by lowering the costs of industries at risk of relocating, and therefore improving their competitiveness. Carbon leakage protection mechanisms have also received a fair share of criticism. Critics have argued that protecting against carbon leakage defies the purpose of the ETS: making polluters pay for their emissions (Martin et al., 2013). From the point of view of environmental economics, protecting sectors against carbon leakage might decrease the incentive to cut emissions since, in some instances, firms face no costs at all for polluting. Instead of lowering costs for firms in the EU, it has recently been proposed that leakage mechanisms should instead raise the costs of foreign actors importing to the EU.

Phase 4 has notably introduced auctioning as the default allocation method. Even so, as I discussed in [Chapter 2](#), a significant amount of pollution permits is still allocated for free. In the current phase of the EU ETS, this is the main mechanism used to protect exposed industries from carbon leakage. The introduced benchmarks of greenhouse gas emissions can still be seen as a significant improvement to free allocation. In theory, these benchmarks should incentivize producers to reduce emissions to receive all needed permits for free. It could then be argued that, despite profiting from free allocation, firms would still make the optimal choice of cutting emissions.

However, free allocation has also been criticized, both in public discussion and economic literature (e.g., Branger et al., 2015; Hepburn et al., 2006). Not only does the polluter pays principle not hold but revenues that could be spent on green innovations, reducing emissions, and furthering the EU's climate goals are renounced. If the Commission's estimate holds, and at least 6 billion allowances are handed out for free in phase 4, the EU misses out on potentially hundreds of billions of euros, depending on the market price of EUAs. Other distortions associated with free allocation can also be argued. Branger et al. (2015) find that, if pollution permits are allocated to meet the production levels of companies, free allocation might incentivize firms to increase output to obtain more allowances for free, i.e., make behavioral changes that lead to private benefits. All in all, free allocation seems to decrease the economic efficiency of the EU ETS, especially as the threat of carbon leakage has not been yet realized.

In addition to free allocation, some firms under the EU ETS also receive compensation as state aid. In practice, sectors that consume a lot of electricity and, as a result, face high costs are compensated by their respective member state since the price signals of carbon created by the EU ETS drive the price of electricity even higher. These are called indirect emissions costs. Subsidies are directed at

sectors that are at risk of carbon leakage particularly due to these indirect emissions costs – in other words, EITE sectors. With compensation comes the risk of overcompensation. The price signals could be distorted, making the achievement of climate goals more difficult. To tackle this problem, guidelines have been set on compensation. Namely, firms that could receive compensation only do so if they meet certain requirements and undertake recommendations for example on energy-efficient technology. (European Commission, 2020)

Ahlvik & Liski (2022), however, find that, since firms usually have private information on their compliance or abatement costs, the optimal policy has two parts: one mechanism for compensation and one for taxing the negative externality. Firstly, the price for allowances can be determined in a way that helps reach an efficient outcome. The price should then be differentiated to account for relocating and non-relocating firms. This can be achieved by differentiating prices based on sectors, to account for EITE industries, as it already is due to free allocation. Setting the price of EUAs sufficiently high would incentivize emissions reduction where it is cheapest – for low-cost firms that can effectively cut emissions and that are not incentivized to relocate. Secondly, relocation can be prevented by compensating, e.g., by state aid. This is the local mechanism.

As I discussed above, the assumption that the EU ETS is a unilateral climate policy rarely holds in practice. To account for bilateral policies, Ahlvik & Liski (2022) then suggest cross-border permit trading. This could be achieved by allowing relocating firms to make use of permits at their new location, in order to be able to continue reducing emissions at a smaller price. Then, in practice, two prices would be set: a high local price for firms that do not relocate and a low global price for relocating firms, which would limit carbon leakage. This is the global mechanism. The authors then employ the data set by Martin et al. (2013) to quantify the implications of the proposed mechanisms. When implementing the local mechanism, local emissions are reduced by 82.24 metric tons of CO<sub>2</sub> and leakage is now estimated at only 6.2 metric tons of CO<sub>2</sub>. When implementing the global mechanism, the respective figures are 81.40 and 5.31. In addition, global emissions would be reduced by 1.19 metric tons of CO<sub>2</sub>. For reference, one metric ton of CO<sub>2</sub> is what the average car produces in three months (Conlen, 2021).

Similarly to Ahlvik and Liski's (2022) suggestion, the proposed Carbon Border Adjustment Mechanism (CBAM) would allow for the extension of carbon policies to regions outside of the EU. However, the CBAM shifts the burden to firms importing to the EU. The intuition behind border adjustment is that it allows for domestic products and imports to be priced the same, in order to

minimize the risk of European products being replaced by imported commodities, and domestic firms facing reduced competitiveness as a result. In addition, it incentivizes the reduction of emissions in the rest of the world as well. In practice, importers of commodities in EITE sectors will have to buy permits that correspond to the price that would have been paid if the commodities had been produced in the EU. If the price has already been paid in the importer's home country due to similar climate policies, the carbon price will be deducted. The CBAM will be gradually implemented as part of the EU ETS, with hopes that it will be fully running by 2026. (European Commission, 2021) Border adjustment is also one of the most popular subjects in carbon leakage literature. For example, the equilibrium models I looked at in [Chapter 4](#) quantify leakage rates in order to explore the possible role of border adjustment in limiting leakage. By adopting the Carbon Border Adjustment Mechanism, the EU ETS could gradually phase out other carbon leakage protection mechanisms, i.e., free allocation and indirect cost compensation, while supporting the polluter pays principle and – at least in theory – reaching an efficient outcome.

## 7 Conclusion

The purpose of this thesis is to study the effect of the EU ETS on leakage and find out, if it incentivizes firm relocation to non-regulated regions outside of the EU. This literature review focuses on investment leakage specifically, although leakage through the short-term competitiveness channel, i.e., through changes in trade flows, is also studied. Ex-ante studies employ equilibrium models to predict potential leakage rates. Monjon and Quirion (2011) take a partial equilibrium approach to study carbon leakage in four sectors: cement, aluminum, steel and electricity. They find low leakage rates, at only around 1-2%, for the scenario that resembles the current practices of the EU ETS the most. To form a comprehensive analysis of the effect of the EU ETS on the entire economy, Böhringer et al. (2012) summarize the findings of 12 Computable General Equilibrium models. They predict a much higher carbon leakage rate of 23.9%. However, these equilibrium models usually account for changes in trade flows, not investment flows.

Empirical studies shift the focus to Foreign Direct Investment flows. Some evidence on relocation is found but it is mostly for subsamples, and the empirical research suffers from a variety of problems, e.g., lack of external validity and small sample sizes. Most of the results are not statistically significant. The research conducted by Dechezleprêtre et al. (2022) is also the first one that directly investigates shifts in the location of emissions since FDI flows may or may not indicate relocation.

Dechezleprêtre et al. (2022) find no statistically significant evidence on relocation as a result of environmental stringency caused by the EU ETS.

Even though evidence on firm relocation is vague, the EU ETS has adopted several measures to limit carbon leakage. Sectors at risk receive free permits and state aid, both of which come with their own problems. Most notably, carbon leakage protection mechanisms go against the polluter pays principle, which is the entire basis of the EU ETS and carbon pricing in general. To tackle this issue, a new mechanism, the Carbon Border Adjustment Mechanism, will gradually be introduced in the EU, in order to impose similar costs on importers and hopefully incentivize emissions reduction globally. As interest in carbon leakage grows, other measures have been proposed as well. For example, Ahlvik and Liski (2022) suggest cross-border permit trading and find that it would not only reduce local emissions and limit leakage, but also reduce global emissions. This would seemingly also lead to economic efficiency.

However, existing research namely focusing on relocation still has many opportunities to improve. Future studies making use of the geographic location of emissions, like Dechezleprêtre et al. (2022), would help us get closer to understanding the implications of the EU ETS. In addition, research should be broadened to focus on multiple member countries as opposed to only one nation, which can of course only happen with more extensive data. Emphasis should also be placed on ensuring the comparability of different approaches. Research will most likely improve over time, especially as the EU ETS is a fairly new policy that has seen many changes in a short period of time.

## Appendix: Abbreviations

**A1xR** – Annex 1 excluding the Russian Federation. Annex 1 is one of the main parties of the Kyoto Protocol and includes industrialized OECD countries and the so-called EIT parties. (The United Nations Framework Convention on Climate Change Secretariat, 2022b)

**A1xR\_C** – Annex 1 excluding the Russian Federation and including China.

**CASE II** – CASE II refers to the partial equilibrium model by Monjon and Quirion (2011).

**CBAM** – The Carbon Border Adjustment Mechanism is a mechanism designed to protect against carbon leakage by applying the same costs of carbon that EU ETS members face to foreign economic actors importing to the EU. (European Commission, 2021)

**CGE** – Computable General Equilibrium analysis allows for an entire economy to be modelled by accounting for e.g., household consumption, price information, total production, and income (Bessler et al., 2014). CGE models are widely used in assessing the impact of climate policies on the economy.

**EMF 29** – The Energy Modeling Forum (EMF) is a forum bringing together both policy makers and experts to research energy and environmental issues. Böhringer et al. (2012) base their analysis on the results of the EMF 29, that is, the 29<sup>th</sup> organized EMF.

**EITE** – Energy-intensive and trade-exposed industries are sectors that face increased costs of at least 5% of gross value added, as a result of the implementation of the EU ETS, and have trade-intensity of above 10% with non-EU countries (European Commission, 2022b).

**EU ETS** – The European Union Emissions Trading System is the EU's main tool in achieving emissions reduction and limiting climate change (European Commission, 2022c).

**EUAs** – EU Allowances are the pollution permits that companies must surrender in order to be allowed to emit GHGs. The EUAs must equal the amount of the company's emissions. (LIFE ETX, 2021)

**FDI** – Foreign Direct Investment is the primary way through which economic actors can gain control over assets, usually a company, abroad. This usually happens by transferring property rights to the foreign company. (Lagendijk & Hendriks, 2009)

**GHGs** – Greenhouse gases are the gases that are at the root of global warming and climate change. In addition to carbon dioxide (CO<sub>2</sub>), for example methane and nitrous oxide are classified as GHGs. (The United Nations Framework Convention on Climate Change Secretariat, 2022a)

**GTAP** – The Global Trade Analysis Project provides econometric analysis of different policy issues, as well as extensive data on e.g., bilateral trade patterns and protection mechanisms. It is widely utilized in the quantification of GCE models. (Global Analysis Trade Project, 2019)

**MSR** – The Market Stability Reserve is one of the mechanisms introduced in phase 4 of the EU ETS. It sets out to stabilize the market price of pollution permits, for example by controlling their number in the market. (LIFE ETX, 2021)

**OECD** – The Organisation for Economic Co-operation and Development provides a forum for international co-operation on different policy issues between member countries. There are currently 38 member states. (Organisation for Economic Co-operation and Development, 2022)

**PHH** – The Pollution Haven Hypothesis states that, under open trade, climate policies may increase aggregate pollution by decreasing competitiveness and incentivizing trade and relocation (Copeland & Taylor, 1994).

**PH** – The Porter Hypothesis states that climate policies may increase competitiveness and therefore they do not incentivize relocation (Porter, 1991).

**PPP** – The polluter pays principle states that polluters must internalize their negative externalities by bearing the costs of pollution. (LIFE ETX, 2021)

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