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Does the EU ETS cause carbon leakage in the manufacturing sector of Finland?

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ABSTRACT:
Climate change is one, if not the most pressing issues of our time, and decreasing GHG emissions is vital in mitigating its impact. This thesis aims to determine if the EU ETS has a carbon leakage inducing effect on the manufacturing sector of Finland. The EU ETS is the main instrument of the EU to reach zero net emissions of GHG by 2050. The EU ETS's purpose is to make polluting more expensive, which leads to concerns of firms relocating their operations to less stringent regions. These so-called pollution havens have been extensively covered in scientific literature but have not been convincingly demonstrated to exist in practice. The EU ETS has previously suffered from the insufficient price of carbon and the excessive allocation of free permits but seems to have started working as intended. By using regression analysis, I find that the implementation of the EU ETS has not led to an increase in net imports from sectors covered by the EU ETS, i.e., there is no observable carbon leakage caused by the EU ETS.

KEYWORDS: EU ETS, carbon leakage, pollution haven, climate change, greenhouse gas emissions

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Abbreviations

CGE	Computable General Equilibrium
CIF	Cost, insurance, and freight
GHG	Greenhouse gas
GTAP	Global Trade Analysis Project
EU	European Union
ETS	Emissions Trading Scheme
EEA	European Economic Area
FDI	Foreign direct investment
FOB	Free-on-board
LRF	Linear reduction factor
LWC	Low-Wage Country
MLR	Multiple linear regression
MNE	Multinational Enterprise
MSR	Market stability reserve
OLS	Ordinary least squares
PAC	Pollution Abatement Costs

PHE	Pollution Haven Effect
PHH	Pollution Haven Hypothesis
SVAR	Structural vector autoregressive model

1 Introduction

Climate change is one of the most pressing issues of our time, and reducing greenhouse gas emissions is a critical component in mitigating its impact. The European Union (EU) has been a leader in the global fight against climate change, and its flagship policy and main instrument in reaching carbon neutrality is the EU Emissions Trading System (ETS). The EU ETS is a cap-and-trade system that limits the total amount of greenhouse gas (GHG) emissions emitted by covered sectors and allows companies to buy and sell emissions allowances to meet their targets.

However, there is concern that the EU ETS may cause carbon leakage, whereby industries may relocate to countries with less stringent environmental regulations to avoid the cost of emissions allowances. This could result in a net increase in global emissions and undermine the effectiveness of the EU ETS in reducing emissions.

Generally, implementing unilateral policies to reduce GHG emissions is difficult because the abatement costs are borne mainly by the country or region implementing, but benefits are shared globally (Carbone & Rivers, 2017). The abatement costs may be substantial in some cases, and the situation encourages free riding because of fears that others will not engage in similar environmental practices (Carbone & Rivers, 2017). This is evident, for example, in the case of the United States refusing to implement the Kyoto Protocol because of concerns about the loss of competitiveness.

Many have found that because GHG emissions are global, unilateral, national, or regional environmental policies could be more efficient (Aichele & Felbermayr, 2015; Harstad, 2012). A metric ton of GHG emitted anywhere in the world has the same global effect.

The manufacturing sector, including that of Finland, is crucial in greenhouse gas emissions within the EU. This thesis examines whether the EU ETS causes carbon leaks in Finland's manufacturing domain. Specifically, the research question is: "Can carbon leakage occur in Finland's manufacturing sector because of the EU ETS?"

Based on the economics of pollution and the efficacy of the EU ETS, this research documents its theoretical framework. The assumption is that the EU ETS could lead to carbon leakage in Finland's manufacturing sector, because the cost associated with emissions allowances may raise production costs for local manufacturers, and compromise their competitiveness on a global scale.

This study seeks to contribute to the existing knowledge of the EU ETS' capabilities in lowering greenhouse gas emissions, and explores the possibilities of unintended results of this policy. This study seeks to provide a framework for consideration by other countries and sectors through a case study of Finland's manufacturing industry, as they evaluate the outcome of the EU ETS on their economies.

In the following section, the theoretical framework for the empirical part of the thesis will be presented. The approach is explained in section 3, followed by a summary of data and descriptive statistics in section 4. Part 5 looks at regression results and addresses the policies associated with those findings. Section 6 concludes.

2 Theoretical framework and related literature

In this section, the theoretical framework of the thesis is covered. The main theories on which the thesis's empirical work relies are introduced.

2.1 Economic theory and environmental policies

Countries and regions have various reasons for decreasing their GHG emissions, such as mounting pressure from activist groups and international organizations like the Intergovernmental Panel on Climate Change. Then, once a political decision on the reduction of emissions has been made, it is the responsibility of economists to provide solutions for the most efficient way of implementing measures to reach the desired reductions (Erdmann & Praktiknjo, 2019).

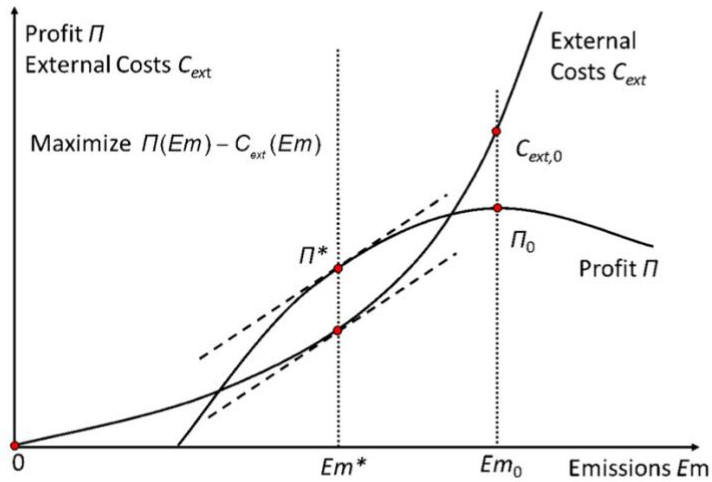

Figure 1 Optimal level of emissions (Erdmann & Praktiknjo, 2019).

The above picture illustrates the maximation problem of a firm between profits and emissions. If we assume that the firm in question is a facility, which while producing the good, also produces emissions that harm its neighbor, i.e., cause a loss of value, then we have two functions that describe the situation:

$$\Pi = \Pi\ (Em) \quad (1)$$

Is the profit function of the company, and then:

$$C_{ext} = C_{ext}(Em) \tag{2}$$

It is the damage function of the neighbor. Both (1) and (2) are functions of the emissions Em, which are assumed to vary in proportion to the company's production. Nothing is then produced at the emissions level $Em = 0$, but as the facility has running fixed costs, the firm would make losses equal to these costs at this production level. Maximum profit is achieved at Em_0, leading to a profit of Π_0 and damage to the neighbor of $C_{ext,0}$. If the firm is allowed to neglect the damages to the neighbor, the firm then chooses production and emissions accordingly. (Erdmann & Praktiknjo, 2019).

However, this is not a socially optimal outcome. If the facility were to produce less, the loss, in terms of profit, would be less than the benefit of damage avoided to the neighbor. (Erdmann & Praktiknjo, 2019)

The problem of a negative externality (in this case, GHG emissions) is a problem that has been introduced previously in economic research. First introduced by Pigou (2017) in the 1920s, a Pigouvian tax is a tax on a market activity that generates negative externalities. A government sets a tax equal to the marginal cost of the negative externality. As emissions are a negative externality, a flat tax on emitted carbon could entail carbon leakage, as will be argued in the following sections.

On a global scale, a better alternative to a Pigouvian tax is an ETS, such as the EU ETS. Zapf et al. (2019) note that a cap-and-trade system on global emissions is the best market-based instrument for reducing global emissions. They describe a global ETS, much like the EU ETS, but without the shortcomings of the EU ETS, as described in more detail in section three.

The problem with the Pigouvian tax is that the regulator must determine the optimal tax rate for the current year and predict the optimum tax rate for the coming years. To do this, the regulator must know the marginal damage of emissions over time, to be then able to set the tax to the level of the marginal cost of the externality. (Zapf et al., 2019)

When marginal costs are uncertain, quantity control (ETS) is preferable over price control (Pigouvian tax). In essence, if the increase in marginal damage costs is higher than the increase in marginal abatement costs, or to put it in another way, if the benefits are highly nonlinear and the costs are close to linear, ETS is a better solution to reach the desired level of social welfare. (Zapf et al., 2019)

The egalitarian problem of fighting climate change is highlighted in the study by Feindt et al. (2021). They studied European carbon pricing and found that a carbon tax is neutral or even progressive for most EU member states. However, a carbon tax becomes regressive for the EU as a whole. They note that an ambitious climate policy, such as the one the EU describes in the Green Deal, needs to address the disproportionately high burden on low-income households. (Feindt et al., 2021)

This can be extrapolated to the world scale as well. Since inter-country differences are the main drivers in the regressivity of a European carbon tax, it could be suggestive of an analogous problem on the world scale, where differences in income are substantial, and transfer payments from rich countries to poorer countries are likely to be an integral part of a global climate deal (Feindt et al., 2021). This is also evident from the recent actions from countries such as India and China in the Climate Change Conference of the Parties (COP) 26 in Glasgow in 2021, where lots of compromises had to be made due to resistance from India, China, and Saudi-Arabia.

2.2 Pollution Offshoring and the Pollution Haven Hypothesis

The Pollution Haven Hypothesis (PHH) suggests that similarly to so-called tax havens, there should also exist pollution havens, where companies, especially those with high pollution abatement costs (PAC), relocate their operations from economic areas where the environmental regulations are more stringent to places with laxer regulations. When maximizing their utility function, firms find that when facing high PAC, it is optimal to move their manufacturing processes to countries or economic areas with less stringent environmental regulations.

The argument behind the Pollution Haven Hypothesis (PHH) in the classical economics context can be described as a result of firms in perfect competition passing down the costs in full in the value chain. Meanwhile, New Trade Theory (NTT) based approaches to the impact of environmental regulation on trade flows are more nuanced. On the supply side, emissions costs enter through higher input prices and increased imports while reducing exports. On the demand side, the environmental policy can impact relative domestic prices, making the domestic region relatively poorer. (Naegele & Zaklan, 2018).

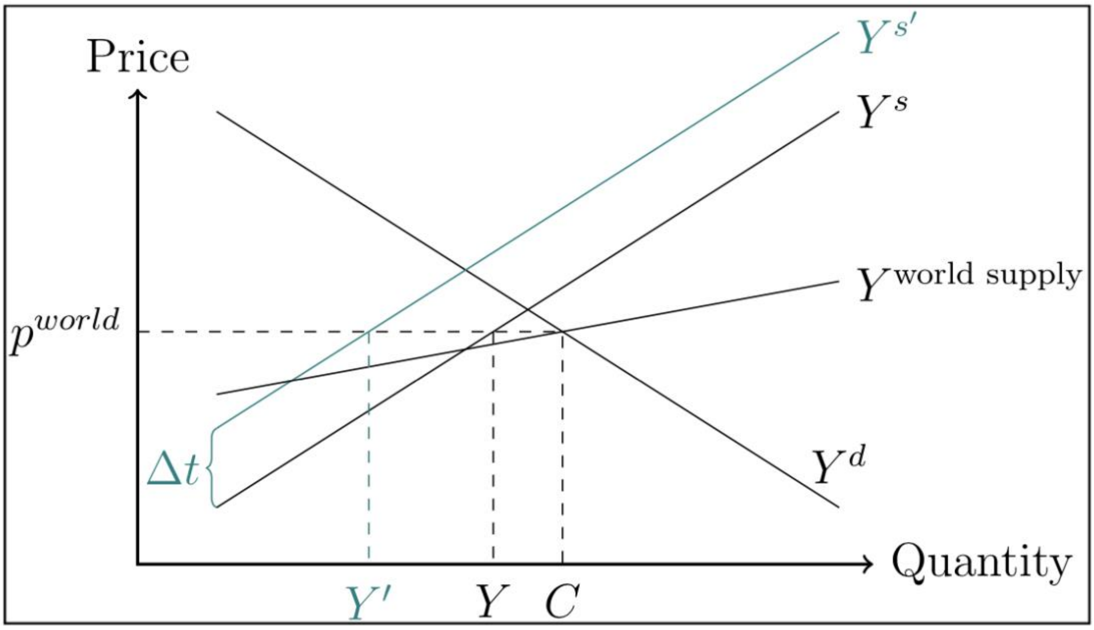

Figure 2 Stylized illustration of the PHH (Naegele & Zaklan, 2018).

Illustrated above is a simple one-sector economy of a large country in a neo-classical model, where a homogenous good with immobile production factors is produced. Country s produces Y quantity of the good and consumes C. The difference between Y and C is then imported. A supply shock (such as an environmental policy) shifts the supply curve upwards by Δ amount, and the new production level is Y'. Per ceteris paribus, consumption does not change, but imports increase. Suppose the production of the good is emission-intensive everywhere. In that case, the effect of the unilateral environmental policy is entirely offset by the increase in foreign emissions; thus, carbon leakage is 100%. (Naegele & Zaklan, 2018).

Another insight of NTT is that firms may have a comparative advantage in certain products due to their production technologies, which can be influenced by their R&D, economies of scale and scope, and other factors. The theory suggests that firms will trade when they can produce at a lower cost than their domestic competitors, and that trade can be driven by differences in firm-level productivity rather than factor endowments (as traditional trade theory suggests). Naegele and Zaklan (2018) note that where classical models are criticized for failing to explain intra-industry trade, new trade theory considers it. For simplicity, in this thesis, the classical approach is taken to omit intra-industry trade, and only net trade flows (the difference between exports and imports) are used in the empirical section.

PHH is sometimes used to argue against strict environmental regulations. Much like it is often suggested that increasing income taxes will lead to upper deciles of income classes relocating somewhere with laxer tax rates, the PHH suggests that strict environmental standards and regulations decrease domestic producers' competitiveness and lead to relocation to countries with less stringent standards. However, Bommer (1999) argues that strong environmentalism makes "dirty" technology required by foreign competitors to mimic domestic production less attractive than the cleaner alternative and that strong environmentalist groups deter strategic relocation [of manufacturing processes].

Although widely believed, there have been difficulties in demonstrating the PHH, and Levinson & Taylor (2008) find that firms that face high PAC are sometimes net exporters. Others find mixed results, e.g., De Beule et al. (2022) find that under the EU ETS, multinational enterprises (MNEs), facing compliance costs they are unable to pass on in the value chain easily, are more likely to locate their international investments outside the EU in pollution havens. Brunel (2016) finds that fears of offshoring pollution in the EU were unfounded because the relationship between EU manufacturing and imports was precisely opposite to what pollution offshoring would predict. Brunel (2016), however, finds more evidence of pollution offshoring in the US manufacturing sector but concludes that there is little evidence for the PHH.

Porter’s hypothesis (Porter & van der Linde, 1995), which states that regulation brings cost-reducing innovation, is often offered as an explanation for the non-existence of the Pollution Haven Effect (PHE) and as the reason for finding a positive relationship between stringent regulations and exports (Levinson & Taylor, 2008). However, Levinson and Taylor (2008) show statistically significant evidence of a positive relationship between net imports and PAC. PAC and net imports can be negatively correlated in panels of sectoral-level data, which is a biased estimate against finding PHE.

In line with the assumptions of the PHH, Li & Zhou (2017) find that US plants produce fewer toxic emissions when their parent firm exports more from low-wage countries (LWCs) and that these imports are in the more pollution-intensive industries. They also find that the negative effect of imports from LWCs is more profound with US plants located in counties with more stringent environmental regulations and weaker for more capable plants (Li & Zhou, 2017).

De Beule et al. (2022) study the PHE and investment within the EU ETS during its third phase and find evidence of the PHE, which enables both investment and carbon leakage outside the EU. They note that because of the leniency in the free allocation of allowances during phases one and two, and the price of allowances being insufficiently high, the EU ETS was rendered practically ineffective. However, since in the third phase, the price of allowances went up from 6,45 € to 32,57 €, the cost of non-compliance became much more concrete for firms. They conclude that MNEs from sectors that cannot easily pass on EU ETS-related costs in the value chain are more likely to locate their foreign direct investment (FDI) projects outside the EU ETS regulatory framework. (De Beule et al., 2022)

Madiès et al. (2022) study tax havens and pollution havens through a sequential game, and find that when setting emission caps, countries internalize their pollution on the corporate tax set by competing nations. Their study also suggests, that smaller countries can gain a competitive advantage by acting as tax/emission havens, and that large and industrialized countries can perform better than smaller ones, even though they have higher corporate taxes and stricter environmental regulations. Furthermore, their study contrasts the traditional view that globalization leads to an arms race with corporate tax rates and a general relaxation of ecological regulation and emission caps. (Madiès et al., 2022).

Levinson (2000) concludes, that the missing PHE might be explained simply by the fact that the most pollution-intensive industries are also the least agile in terms of geographical mobility. Authorities in these cases find themselves in a position where they can tax the most pollution-intensive sectors without having to worry about capital flight or competing economic areas. These, to say the least, mixed results make it hard to determine whether the PHH is feasible. Nevertheless, as it is very prevalent in the scientific literature, in this thesis it is assumed that the PHH could hold some merit.

2.3 Embodied carbon in international trade carbon leakage

Carbon leakage is a special case of the PHE (Aichele & Felbermayr, 2015). The mechanism is the same as with PHH and PHE, or as stated by Naegele & Zaklan (2018), "…carbon leakage occurs between a domestic region featuring an emissions policy and a foreign region with no [such] policy or less stringent policy.". PHH, in turn, implies that carbon emissions are then embodied in international trade, because firms choose to offshore their pollution-intensive production into countries with less stringent regulations. Still, with ceteris paribus assumption, the demand for these pollution-intensive products should remain the same. Hence, there should be an observable increase in the net imports of these pollution-intensive products.

International trade causes a geographic separation between the consumption of a product and the emitted pollution from producing said product (Peters & Hertwich, 2007). This can create a misleading reduction in greenhouse gas (GHG) emissions, because the measurement technology differs between countries, and climate accounting does not necessarily account for imported GHG. This causes a problem for regulators, since relative to other pollutants, as a uniformly mixing pollutant, a metric ton of GHG emitted in one part of the world has a global effect. Unilateral stringent environmental regulation, that merely results in shifting economic activity and emissions to another region or country, will not generate any meaningful improvements for the regulated area, and could even result in a global rise in GHG emissions (LaPlue & Erickson, 2020; Aichele & Felbermayr. 2015).

As an example of offshoring pollution while offshoring production, let us look at the study by Judl et al. (2011), where they study the life cycle GHG emissions of pulp production from Finnish boreal hardwood compared to pulp production from South American eucalyptus. Pulp plays a significant role in the Finnish economy and has long roots in manufacturing. Judl et al. (2011) suggest that cheaper production costs of South American eucalyptus pulp could affect the import/export ratio in the future. They find that offshoring pulp production would decrease the global GHG emissions of pulp production, but that the transport to Europe outweighs the benefits, and that transportation accounts for 27% of life cycle GHG emissions of pulp production (Judl et al., 2011).

In this case, we would technically reduce GHG emissions, but carbon leakage would occur, because of emissions from transportation. In line with LaPlue & Erickson (2020), we would actually be worse off, because of the rise in global GHG emissions. As noted previously, including maritime transport in the EU ETS could lead to the relocation of emissions from shipping (Lagouvardou & Psaraftis, 2022).

Indeed, if carbon leakage occurs, the region implementing the unilateral policy will suffer decreases in outputs and losses in welfare and employment, in addition to having an ineffective environmental policy. This issue is especially prevalent in the manufacturing sector, since their products are often pollution-intensive (Naegele & Zaklan, 2018).

Trying to establish a case for carbon leakage empirically takes much work. Naegele & Zaklan (2018) argue, that for example, the difference between emission costs between Europe and the developing world is relatively modest compared to the more profound difference between labor unit costs, where the former is only 0.65% compared to 0, and the latter is roughly 10-30 times higher in Europe. The effect of the EU ETS, i.e., stringent environmental regulation, is relatively minuscule when considering the total relocation costs to other markets. Naegele & Zaklan (2018) also note that the firm relocating must pay fixed relocation costs, have a weak presence in the home market, and have less influence when bargaining with policymakers.

It is also possible for carbon leakage to occur through a decrease in prices for emission-intensive goods, due to a fall in global demand, because of domestic unilateral environmental policy (Naegele & Zaklan, 2018). Lower energy prices may also lead to increased demand for fossil fuels in foreign regions, causing carbon leakage and a rise in global GHG emissions (Harstad, 2012; Jensen et al., 2015). Jensen et al. (2015) refer to this effect, where climate policies such as carbon taxes (EU ETS can arguably be described as a carbon tax) are aimed at reducing GHG emissions, but instead have the opposite outcome, as the "green paradox."

The evidence for the occurrence of carbon leakage is ambiguous, much like with the PHE and PHH. For example, Dechezleprêtre et al. (2021) find no evidence, that EU ETS has led to a displacement of GHG emissions from Europe to regions with less stringent policies, as is the case with the study conducted by Naegele & Zaklan (2018) as well. On the other hand, Lagouvardou and Psaraftis (2022) find that the inclusion of maritime transport in the EU ETS entails carbon leakage, loss of revenue, and penalization of the European Economic Area (EEA) ports. Their finding also corresponds to the PHH, as agents choose to acquire a competitive advantage by circumventing stricter environmental regulations by using ports outside the EEA.

Aichele & Felbermayr (2015) study the carbon leakage leakage-inducing of the Kyoto Protocol through the CO2 content of international trade. They find that the embodied carbon of imports from non-committed countries has increased by roughly 8 %, concluding that the Kyoto Protocol has indeed led to carbon leakage (Aichele & Felbermayr, 2015).

To then be able to measure carbon leakage, it would make sense to use CO2 embodied in international trade as a proxy for carbon leakage. It should also be added that neither I nor the authors of related scientific literature suggest that firms would have nefarious intentions when relocating their production, but instead simply optimize their production.

2.4 Computing carbon embodied in trade

Aichele and Felbermayr (2015) derive a gravity model for embodied carbon in their study. The model is based on the work by Krugman (1980). They describe an economy with K countries that are otherwise similar, but may differ regarding climate policies. Each country then produces and consumes a homogenous good. Preferences are Cobb-Douglas, i.e., a simple algebraic representation of utility functions for agents in the economy. The sectors that produce goods in this economy have monopolistic competition, free entry, and increasing returns to scale. Energy prices for each country differ from the world prices because of taxation. With these considerations, Aichele & Felbermayr (2015) derive the following equation:

$$Q_{mx} = Z \times (1 + g_m) \times L_m \times (P_m)^{\sigma-1} \times N_x \times (c_x)^{-\sigma} \times (t_{mx})^{-\sigma} \qquad (3)$$

Where Z is a constant, $g_m > 0$ is a multiplier accounting for trade in intermediaries, $L_m \times (P_m)^{\sigma-1}$ is country *m*'s market capacity in a sector, $(t_{mx})^{-\sigma}$ is iceberg trade costs, and $N_x \times (c_x)^{-\sigma}$ is country *x*'s supply capacity.

Next, using Shephard's lemma, which is used to give a formulation for the demand for each good in a market concerning prices and level of utility, they derive a sector's CO_2 demand, which is:

$$e^x = \beta c_x / t_x \qquad (4)$$

Where e^x is a row vector of all sectoral CO_2 intensities, using the exporter's domestic input-output (I-O) table denoted B_x, they compute the vector of embodied CO_2 intensities using the Leontief inverse.[1], thus:

$$\boldsymbol{\eta} \equiv e^x (\mathrm{I} - B_x)^{-1} \qquad (5)$$

Then, the CO_2 content of imports of *m* from *x* is given by:

$$E_{mx} \equiv \eta_x \times Q_{mx} \qquad (6)$$

By substituting equation (3) with (6), a gravity equation for the CO_2 content is obtained.

[1] Leontief inverse is a mathematical object in I-O analysis that represents the amount of output from sector *a* used to satisfy a unit of final demand *y* from sector *b*.

Naegele and Zaklan (2018) use trade flows in value and embodied carbon as their outcome variable. Embodied carbon is calculated as the sum of CO_2 emissions from all combustibles used as inputs to the traded goods. Net imports are then scaled with output value, and net CO_2 imports are scaled with total sectoral CO_2 emissions.

For simplicity, in this thesis, only net trade flows in value are used as the outcome variable to limit the scope of the thesis.

3 The EU ETS

In this section, the EU ETS is introduced. The cap-and-trade mechanism of the EU ETS is explained, and the performance of EU ETS so far is assessed through scientific literature.

3.1 Cap-and-trade

The EU ETS is a cornerstone of the EU's policy to combat climate change, and is an essential tool for the cost-effective reduction of greenhouse gas emissions. It is the primary tool in the EU's Green Deal, an initiative to reach climate neutrality by 2050. Set up in 2005, the EU ETS is the first international trading scheme in the world. (European Commission, 2022).

The EU ETS works on a “cap and trade” principle, where a cap is set for the maximum amount of greenhouse gases that can be emitted. Firms then buy or receive emissions allowances, which they can use or trade to other installations within the scheme. Each agent must then annually give up allowances to match their emissions. If an agent fails to present enough allowances, fines are then imposed. The remaining allowances may then be used to cover future emissions, or traded to other parties within the scheme. (European Commission, 2022).

Every year, fewer allowances are released into the market, so even though unused allowances can be saved and used in the next period, the number of allowances is finite. Countries could also, for example, in their efforts to reduce emissions within the EU ETS, opt to buy allowances and not let them enter the market, decreasing the number of allowances and thus lowering total emissions (Beck & Kruse-Andersen, 2020). This is much in the spirit of a strategy proposed by Harstad (2012), where a coalition of countries could choose to purchase deposits of fossil fuels, and prevent them from being consumed, thus increasing market prices for fossil fuels by decreasing supply, and decreasing global emissions by lowering consumption.

The EU ETS covers carbon dioxide (CO2) emissions from electricity and heat generation, and energy-intensive industry sectors (such as oil refineries, steel works, and cement production). Nitrous oxide (N2O) from the nitric, adipic, and glyoxylic acids and glyoxal production. And perfluorocarbons (PFCs) from the production of aluminum. Companies in these sectors must participate in the EU ETS, but an agent may be exempted if they meet specific criteria. For example, in some industries, installations below a specific size are exempted, and in the aviation sector, until the 31st of December 2023, only flights between EEA airports are included. (European Commission, 2022).

The EU ETS is divided into trading phases. The EU ETS is in its fourth phase (2021-2030). At the end of phase four, emissions should have been reduced by 40% relative to the 1990 emissions level. (European Commission, 2022).

Many countries also choose to implement other environmental policies besides the EU ETS. However, because they overlap with the EU ETS, their impact on global emissions may be offset by their unintended effect within the EU ETS. If, for example, an EU member state chooses to subsidize the construction of a windmill farm, it could replace fossil fuel production and thus lower emissions. This would also mean fewer allowances are used, but it does not impact the total number of allowances. Therefore, the allowances will be used at different times. (Beck & Kruse-Andersen, 2020)

3.2 Market Stability Reserve

The market stability reserve began operating in 2019, and its purpose is to absorb unused allowances from the EU ETS. It was introduced to offset the effects of many unused allowances in circulation. The MSR absorbs allowances when the surplus is large, and releases allowances back into circulation when the surplus is small. (European Commission, 2022)

The MSR is a mechanism designed to address the problem caused by unused allowances affecting carbon prices within the EU ETS. It also ties in with the free allocation of allowances under the EU ETS, as the allowances distributed for free decrease the demand, thus lowering the price of the allowances.

Naegele and Zaklan (2018) noted that free allocation of allowances is expensive to mitigate carbon leakage concerns. During phase 2 of the EU ETS, the regulator dispensed nearly two million allowances for free yearly, which amounts to an opportunity cost of 20,84 billion € with the average price per allowance during that period (Naegele & Zaklan, 2018). Schäfer (2019) also notes that under the EU ETS, it is suggested that the free allocation of permits causes market saturation, leading to smaller-than-expected emissions reductions.

To combat the homogeneity of total emissions, the EU adopted a new reform of the EU ETS in 2018. The legal framework for the MSR was already introduced in 2015, but previously, the MSR affected the intertemporal availability of allowances, and not the total amount. The reform introduced a cap number of allowances stored in the MSR. When this cap is binding, the allowances that exceed the threshold will be canceled, and never released into circulation. (Beck & Kruse-Andersen, 2020).

Bruning et al. (2020) studied the long-term effect of the MSR on the EU ETS through an equilibrium model. Besides the cancellation policy in the MSR, the reform of 2018 increased the linear reduction factor (LRF) from 1.74% to 2.2% after 2020 (European Commission, 2022). Bruning et al. (2020) found a 41% reduction in cumulative CO_2 emissions compared to cumulative emissions before strengthening the cap, with around 40% of the decrease explained by the tighter LRF and 60% explained by the cancellation policy. However, they note that the effect of MSR on CO_2 emissions strongly depend on other policies, such as allowing (or not) new nuclear capacity or developing investment costs for renewables. (Bruninx et al., 2020)

3.3 Determination of allowance prices

Policymakers tend to use the carbon price to indicate the effectiveness of the EU ETS mechanism (Lovcha et al., 2021). In essence, the EU ETS is based on market forces, where the EU sets and limits the supply of allowances, and the market determines the demand (Lovcha et al., 2021). Therefore, the price of carbon is determined by the equilibrium of these two. Excessively allocated free allowances or exogenous shocks affect the demand for allowances, so the cost could be sufficiently high to incentivize technological innovation.

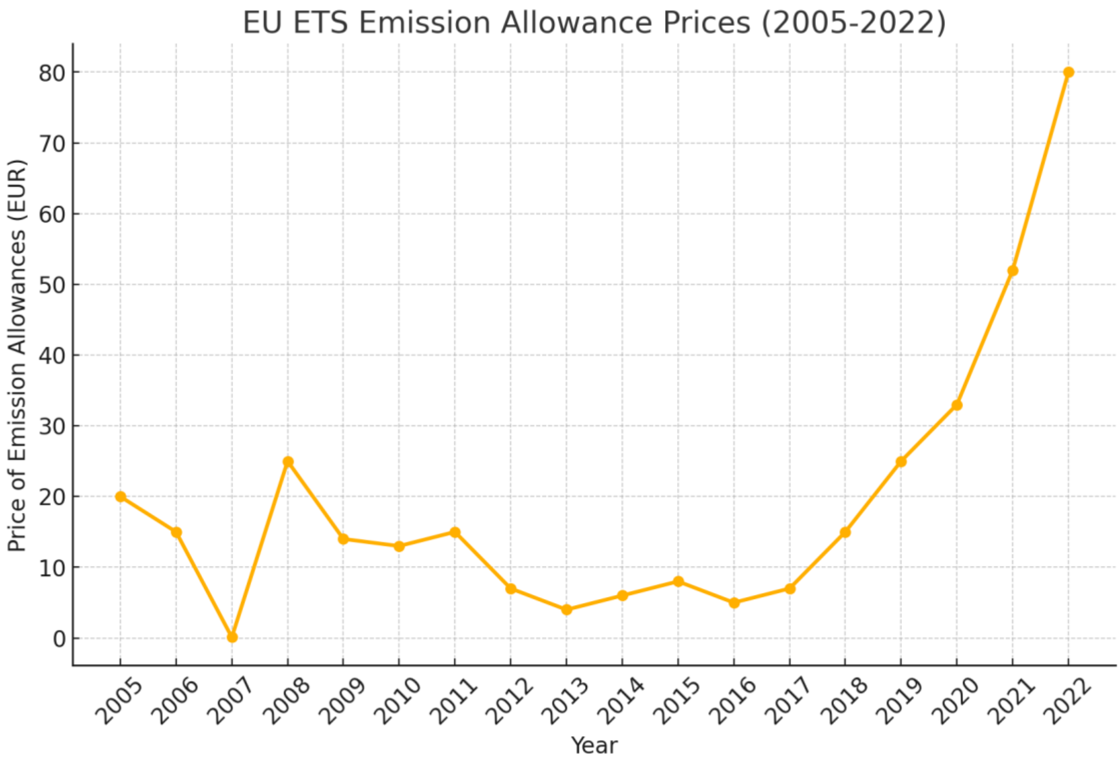

Figure 3 EU ETS Emissions Allowance Prices

As we see from the chart, there is a strong upwards trend in the prices of allowances, especially from 2017 onwards. This is most likely due to the market anticipating the implementation of the MSR. From 2020 onwards there is another spike in the prices, a much steeper one at that, and this most likely is due to allowance auctioning becoming the primary method of allowance distribution.

Allowance auctioning is the primary method of allocating allowances as of 2020. During phase three, 57% of the allowances were auctioned, and the rest were distributed for free (European Commission, 2022). Lovcha et al. (2021) note that the manufacturing sector received 80% of its free allowances at the beginning of phase three, but the number dropped to 30% in 2020.

Lovcha et al. (2021) study the carbon price fluctuations in the EU ETS using a structural vector autoregressive model (SVAR), and find that the oil, gas, and coal markets contribute the most to the price fluctuations, and are effective candidates to affect the ETS prices through regulations. Their results suggest that the EU ETS has started working well (Lovcha et al., 2021).

This is a contrary finding to that of Schäfer's (2019), who finds evidence to support arguments about the sub-optimal performance of the EU ETS regarding the excessive allocation of free allowances. It should be noted that Schäfer's (2019) study uses data from the first two phases, so a conclusion that the EU ETS did not perform as expected during the first two phases but has since started to operate well could be drawn.

3.4 Performance of the EU ETS

The possibility of the EU ETS causing carbon leakage has been studied extensively in scientific literature. Many studies are ex-ante evaluations based on computable general equilibrium (CGE) models that sometimes predict substantial leakage, even as high as 30% (Naegele & Zaklan, 2018). Carbone and Rivers (2017) note that in the absence of historical examples of environmental policies to use in econometric analyses, CGE models have provided most of the evidence on the quantitative impacts of such policies.

In their study, Carbone and Rivers conclude that unilateral environmental policy will decrease exports and employment and that some carbon will be leaked to other regions or countries. The studies' common assumptions could cause the observed consistency within literature using CGE models. (Carbone & Rivers, 2017).

Koch & Bausse Mama use firm-level data to study outward FDI of German multinational companies. They find no statistically significant evidence of the EU ETS on outward flows of FDI to countries or regions outside the regulation of the EU ETS. However, they find that a small subset of firms in more agile and less capital-intensive sectors have increased their affiliates outside the EU, which they argue could suggest preparations to relocate in the future. (Koch & Basse Mama, 2019)

A study looking at policy options to improve the effectiveness of the EU ETS suggests that a carbon central bank or EU price floor is a feasible option. The authors note that since the launch of the EU ETS in 2005, the price of carbon has, on multiple occasions, dipped below the expected level. They argue that with a sufficiently high carbon price and a clear long-term price signal, the EU ETS may be able to incentivize the technological innovation of abatement technologies, and the adoption of less polluting manufacturing technologies. (Clo, et al., 2013).

The study by Clo et al. (2013) is another example of ex-ante, as they predict the impact of the suggested policy options on the future performance of the EU ETS. As is the case with the studies using CGE models, their study could suffer from having assumptions that are similar to those of other related scientific literature.

Hu et al. (2014) performed an ex-ante evaluation of EU ETS during 2013-2030 by constructing a baseline scenario without the EU ETS, and comparing it with a scenario where the EU ETS is implemented. Their findings are in line with Lovcha et al. (2021), in that there has been an enormous surplus of allowances within the EU ETS during phase two, and the internal abatement of the EU cannot be guaranteed until 2023 (Hu et al., 2014). They conclude that if the EU ETS's cap on allowances is set ex-ante, the mechanism will not be able to respond to exogenous demand shocks (such as financial crises).

4 Methodology and data

In this section, the methodology of the empirical work is described, and summary statistics are presented.

4.1 Regression analysis

I will be regressing Finland's net imports on environmental stringency to determine if the EU ETS has a carbon leakage-inducing effect on Finland's manufacturing sector. Net imports are used instead of carbon embodied in trade for simplicity's sake.

An econometric model must first be constructed to determine the relationship between variables. In the simplest terms, a relationship between two variables, a dependent variable and an independent one, can be written down as:

$$y = \beta_0 + \beta_1 x + u \tag{7}$$

Where y is the dependent (or outcome or explained, etc.) variable, β_0 is the intercept parameter, also known as the constant, and β_1 is the slope parameter, i.e., the coefficient measures the effect x has on y. u is an error term that captures the impact of other factors.

In its simplest form, an econometric model explaining the effect of environmental stringency on trade flows would then be:

$$net\ trade\ flows = \beta_0 + \beta_1 environmental\ stringency + u \tag{8}$$

The linearity of equation (7) implies that a one-unit change in x has the same effect on y (Wooldridge, 2015). However, in this equation, we also assume that all the factors in the error are uncorrelated with $environmental\ stringency$. In the context of a complex system, this is highly unlikely. It is preferable to use multiple regression analysis, in which other factors are taken out of the error term and appear explicitly in the model.

A standard tool used to estimate the coefficients of linear regression is the ordinary least squares regression (OLS). The term ordinary least squares comes from the estimates of coefficients obtained to minimize the sum of squared residuals (Wooldridge, 2015). OLS minimizes the sum of the squares of the differences between the observed values of the dependent variable in the input dataset, and the output function of the independent variable(s).

I must make certain assumptions to obtain unbiased OLS estimators and ensure that my model (the regression equation) meets them. These are called multiple linear regression assumptions (MLR), i.e., MLR.1 through MLR.4.

MLR.1 is "Linear in parameters." This describes the regression model, as presented in equation (7). However, we have multiple explanatory variables instead of a simple regression. Linear in parameters means that the coefficients, i.e., $\beta_1, \beta_2, \beta_3 \dots \beta_j$ must be of first order. The variables themselves can be higher-order terms.

MLR.2 is "Random sampling," meaning there is a random sample of n observations.

MLR.3 is "No perfect collinearity." This means that the independent variables cannot be constant or *perfectly correlated*. It is essential to distinguish between perfect collinearity and correlation. MLR.3 does not restrict *correlation* between independent variables. They just cannot be perfectly correlated.

MLR.4 is "Zero conditional mean." States that the error u has an expected value of zero (Wooldridge, 2015). Algebraically:

$$E(u|x_1, x_2, \dots, x_k) = 0 \qquad (9)$$

The MLR.4 assumption can fail if a crucial explanatory variable correlated with other explanatory variables is omitted from the model (Wooldridge, 2015). This is nearly always possible since an econometric model, even at its best, is a simplified representation of a complex real-world phenomenon.

I employ an OLS regression model to assess the potential carbon leakage effect of the EU ETS on Finland's manufacturing sector. The dependent variable is net imports, serving as a proxy for carbon leakage, while the primary independent variable of interest is the EU ETS cost, representing environmental policy stringency. The model is specified as $net\ imports_{ist} = \beta_0 + \beta_1 \cdot tariff_{st} + \beta_2 \cdot transport_{ist} + \beta_3 \cdot ets\ cost_{st} + \beta_4 \cdot ets\ dummy_s + \epsilon_{ist}$, where I denotes a country, s denotes sector, and t denotes the year. The EU ETS cost is calculated using data from the Finnish Energy Authority, multiplying annual emissions by average allowance prices and adjusting for partial coverage. I include controls for tariffs, transportation costs, and an ETS dummy variable to distinguish regulated sectors. Country and time-fixed effects (αi and γt) are incorporated to account for unobserved heterogeneity. The coefficient β1 is the primary focus; a positive and significant value would suggest that higher EU ETS costs are associated with increased net imports, potentially indicating carbon leakage.

Naegele and Zaklan (2018) note that endogeneity concerns and a possible omitted variable bias must be accounted for when regressing trade flows on environmental stringency. Omitted variable bias is of concern in most OLS regressions because the phenomenon explained is rarely as simple as the model used to predict linear relationships between variables. Endogeneity concerns come into play because the explanatory (in this case, environmental stringency) variable could be correlated with the error term. Naegele and Zaklan (2018) note that this model's risk of endogeneity seems limited.

4.2 Data

This study utilizes a comprehensive dataset covering 2013 to 2021, encompassing trade flows, EU ETS costs, tariffs, and transportation costs for Finland's manufacturing sector. The selection of this time frame is particularly relevant as it covers the third phase of the EU ETS (2013-2020) and the beginning of the fourth phase (2021-2030). This period is characterized by significant changes in the EU ETS, including introducing the Market Stability Reserve and a more stringent emission cap, making it an ideal timeframe for analyzing potential carbon leakage effects.

4.2.1 Data Sources

The data for this study is compiled from several authoritative sources:

1. Finnish Customs: Provides detailed import and export data for Finland.
2. Statistics Finland: Offers complementary trade data and economic indicators.
3. Finnish Energy Authority: Supplies data on emissions and EU ETS costs.
4. World Bank: Provides tariff data for manufactured products.

Multiple data sources allow for a more comprehensive and robust analysis, capturing various aspects of trade, emissions, and regulatory costs.

4.2.2 Trade Flow Data

Trade flow data obtained from the Finnish Customs and Statistics Finland forms the backbone of this study. This dataset includes 500 observations across ten countries, accounting for approximately 83% of Finland's imports. The comprehensive nature of this data allows for a thorough examination of Finland's trade patterns and their potential relationship with EU ETS costs.

The dataset includes import and export figures, allowing for the calculation of net imports, which serve as the dependent variable in our regression analysis. Net imports are particularly relevant for studying carbon leakage, as they capture the overall trade balance in potentially carbon-intensive goods.

4.2.3 Country Coverage

The countries included in the dataset are:

1. European Union (treated as a single entity)
2. Russia
3. China
4. Indonesia
5. Japan
6. Turkey
7. Democratic Republic of Congo
8. South Africa
9. Ukraine
10. Egypt

This selection of countries provides a diverse representation of Finland's trading partners, including both EU and non-EU countries, developed and developing economies, and countries with varying degrees of environmental regulation. The European Union, while not a single country, is treated as one entity for simplicity and because intra-EU carbon leakage is not the focus of this study.

The share of imports from each country or region is as follows:

1. European Union: 56%
2. Russia: 14%
3. China: 7%
4. Indonesia: 3%
5. Japan: 2%
6. Turkey: 0.6%
7. Democratic Republic of Congo: 0.2%
8. South Africa: 0.2%
9. Ukraine: 0.07%

10. Egypt: 0.02%

This distribution highlights the importance of the EU as Finland's primary trading partner while capturing significant trade flows from countries with potentially less stringent environmental regulations, such as Russia and China. Including smaller trading partners ensures a comprehensive view of Finland's import patterns.

4.2.4 EU ETS Cost Data

The EU ETS cost data, a crucial component of this study, is derived from the Finnish Energy Authority's records of total confirmed emissions. The calculation of EU ETS costs involves several steps:

1. Obtaining total confirmed emissions for each year from 2013 to 2021.
2. These emissions are multiplied by the average price of allowances for each year.
3. I am adjusting for the partial coverage of the ETS by dividing the result by the number of allowances, as only about half of total emissions are covered by the EU ETS.
4. I map the resulting costs to the corresponding sectors in the Finnish Customs data.

This method allows for a sector-specific estimation of EU ETS costs, capturing the varying impact of the system across different industries. It is important to note that this calculation method may introduce some simplification, as it assumes a uniform distribution of costs across covered sectors, which may only sometimes be the case in reality.

4.2.5 Tariff Data

Tariff data is sourced from the World Bank, explicitly using the simple mean for manufactured products in Finland. This provides a standardized measure of trade barriers across different product categories. Including tariff data is crucial for controlling for other factors that might influence trade flows, allowing for a more accurate assessment of the impact of EU ETS costs.

4.2.6 Transportation Costs

The method for calculating transportation costs uses the difference between the Cost, Insurance, and Freight (CIF) values given by Finnish Customs and the Free on-board (FOB) values from Statistics Finland. The calculation process involves:

a) I am estimating the variation between CIF and FOB values associated with imports.
b) I am dividing this difference by the total weight of imports, which results in an average cost per 1000 tons of cargo.
c) I am adjusting this figure for sectoral import shares and relative country contributions to derive transport costs specific to sectors and countries.

This technique yields a substitute for transportation costs, which are an essential control variable in the study. Still, it is crucial to indicate that this technique can present some bias, considering it neglects the geographical separation of trading partners. Acknowledging this limitation, the analysis mirrors procedures used in research similar to those of Naegele and Zaklan (2018).

4.2.7 Sector Classification

The Finnish Customs provides data on imports and exports divided into ten categories, which forms the basis for our sector classification:

a) Food and live animals
b) Beverages and tobacco
c) Inedible materials of an unrefined nature, fuel not included
d) Mineral fuels, etc.

e) Animal, vegetable oil, fat
f) Chemicals, along with related commodities
g) Basic manufactures
h) Machines and transport machinery.
i) A miscellaneous assembly of manufactured articles
j) Articles not categorized under any other heading

This classification supports a detailed evaluation of possible carbon leakage effects in multiple manufacturing domains. One should note that the EU ETS does not directly cover all these sectors; our analysis includes this by applying an ETS dummy variable.

4.2.8 Data Processing and Integration

The integration of data from multiple sources required careful processing and harmonization. Critical steps in this process included:

1. Aligning periods across all data sources to ensure consistency.
2. Converting all monetary values to a common currency (Euros) and adjust for inflation where necessary.
3. Mapping EU ETS costs and transportation costs to the appropriate sectors and countries.
4. Creating a panel dataset that combines trade flows, EU ETS costs, tariffs, and transportation costs for each country-sector-year combination.

This integrated dataset allows for a comprehensive analysis of the relationship between EU ETS costs and trade flows while controlling for other relevant factors.

4.2.9 Limitations and Considerations

While efforts have been made to create a comprehensive and accurate dataset, there are some limitations and considerations to keep in mind:

1. The treatment of the EU as a single entity, while necessary for simplicity, may need to be clarified in intra-EU trade patterns.
2. The calculation of EU ETS costs based on average allowance prices may not capture the full complexity of how these costs impact different firms and sectors.
3. While consistent with previous studies, the transportation cost calculation method may introduce some bias due to its inability to account for geographical distances.
4. While detailed, the sector classification may still group products with varying carbon intensity levels.

These limitations are acknowledged and considered in the interpretation of results.

4.2.10 Descriptive Statistics

The summary statistics of the dataset provide valuable insights into the nature and distribution of the critical variables:

Table 1 Descriptive statistics

Variable	M	SD	Min	Max
net_imports	69496.59	978601.57	-7037945.0	8412256.0
tariff	2646.1	11741.47	0.0	131167.11
transport	30487.29	118711.89	1.76	1106689.45
ets_cost	757.46	4246.79	0.0	66177.52
ets_dummy	0.4	0.49	0.0	1.0

The EU ETS cost shows considerable variation, ranging from 0€ to 66 177.52€, with a mean of 757.46€. This wide range reflects the diverse impact of the ETS across different sectors, with many sectors having zero cost due to non-coverage. The median of 0€ indicates that more than half of the observations are from sectors not directly covered by the EU ETS. This is consistent with the ETS dummy variable mean of 0.4, indicating that 40% of the observations are from covered sectors.

Transportation costs represent a significant portion of import-related expenses, ranging from 1.8€ to 1106689.40€, with a mean of 30487.30€. This highlights the importance of considering transportation costs when analyzing trade patterns and potential carbon leakage. The extensive range and the difference between mean and median values suggest a skewed distribution, with some observations having high transportation costs.

Tariffs also show significant variation, ranging from 0€ to 131167.11€, with a mean of 2646.10€. The median of 39560€ suggests that the distribution is right-skewed, with a few high-tariff observations pulling the mean upward.

Net imports, the dependent variable, range from -7037945€ to 8412256€, with a mean of 69497€. Negative values indicate that Finland is a net exporter for some country-sector-year combinations. The median of 0€ suggests many observations where imports and exports are roughly balanced.

These descriptive statistics provide a foundation for understanding the data and inform the subsequent regression analysis. They highlight the complexity of trade patterns and the potential for significant variation in the impact of EU ETS costs across different sectors and trading partners.

5 Results and discussion

In this section, the results of the regression are presented. These results are then explored further, and possible policy implications are discussed.

5.1 Results

I conducted an OLS regression in Python to analyze the potential carbon leakage effect of the EU ETS on Finland's manufacturing sector. The regression model is specified as follows:

$$net\ imports = \beta_0 + \beta_1 \cdot tariff + \beta_2 \cdot transport + \beta_3 \cdot ets\ cost + \beta_4 \cdot ets\ dummy + \epsilon \qquad (10)$$

Where net_imports is the dependent variable, the independent variables are tariff rates, an EU ETS dummy variable, EU ETS costs, and transportation costs. The regression call in Python was:

```
import statsmodels.api as sm

# Prepare the independent variables and dependent variable
independent_vars_matrix   =   data[['tariff',   'transport',
'ets_cost', 'ets_dummy']]
dependent_var = data['net_imports']

# Add a constant to the independent variables
independent_vars_matrix_const                              =
sm.add_constant(independent_vars_matrix)

# Fit the regression model
net_imports_model          =          sm.OLS(dependent_var,
independent_vars_matrix_const).fit()

# Display the summary of the model
net_imports_model_summary = net_imports_model.summary()
print(net_imports_model_summary)
```

The results of this regression are presented in table 2 below:

Table 2 Regression results

Variable	Coefficient (B)	Std. Error	t-value	p-value	95% CI Lower	95% CI Upper
Intercept	43023.313	42217.961	1.019	0.309	-39925.186	125971.812
Tariff	54.495	2.8	19.459	0.0	48.992	59.997
Transport	1.256	0.427	2.938	0.003	0.416	2.095
ETS Cost	-68.787	11.805	-5.827	0.0	-91.98	-45.594
ETS Dummy	-259760.944	69084.176	-3.76	0.0	-395495.322	-124026.567

The regression results provide several interesting insights:

1. EU ETS Cost: The coefficient for the EU ETS cost is both negative and statistically significant. The coefficient of -68.79 that with a unit increase in the EU ETS cost, net imports decrease by 68.79 units.
2. EU ETS Dummy: The coefficient is also negative and statistically significant. The coefficient of -259800 indicates that when the EU ETS dummy equals one (i.e. the sector is covered by the EU ETS) net imports decrease by 259800 units. This would suggest that participation in the emissions trading scheme has a highly significant effect on the net imports.
3. Tariff: The coefficient is positive and statistically significant. The coefficient of 54.49 suggests that for every unit increase in tariff, net imports is expected to increase by 54.49 units. This is a logical deduction as more imports mean more tariffs.
4. Transport: The coefficient is positive (1.26) and statistically significant. The coefficient of 1.26 suggests that for a unit increase in transport costs, net imports increase by 1.26 units. This means that transport costs increase at a relatively similar rate as net imports do.
5. The intercept: The Intercept is 43020 and the p-value 0.309. This means that the expected value of net imports is 43020 when all the independent variables are zero. However, the result is not statistically significant.

6. Model Fit: The R squared value is 0.453, which means that approximately 45.3% of variation in net imports is explained by the independent variables. The adjusted R squared is slightly lower at 0.449, it accounts for the number of predictors used in the model. F statistic of the model is 102.6, which is quite large, and the related p-value extremely small (1.43e-63). This means that we can reject the null hypothesis and that the independent variables together significantly predict net imports.

These results contradict the carbon leakage hypothesis. They suggest that implementing the EU ETS has not increased net imports from sectors covered by the scheme. The negative coefficients for both the ETS cost and ETS dummy variables imply that sectors facing higher environmental costs or those covered by the EU ETS are associated with lower net imports.

5.2 Robustness tests

I perform the Omnibus and Jarque-Bera tests to assess the normality of the residuals. The null hypothesis is that the residuals are normally distributed. The Omnibus value is 439.27 and the p-value is 0.0000. Since the p-value is much less than 0.05 the null hypothesis is rejected, and it can be concluded that the residuals are not normally distributed.

The Jarque-Bera test yields a value of 31031.70 and a p-value of 0.0000. Here the null hypothesis is also rejected, and it can be concluded that the residuals are not normally distributed, which could be due to the residuals having significant kurtosis or skewness or both.

The non-normality of the residuals is indicative of some model assumptions being violated. It could be that the coefficients are not fully reliable for making inferences, which can also affect the accuracy of p-values and confidence intervals. It may be the case that there are strong relationships among the independent variables, and that

MLR.3 is being violated. It is likely that both the MLR.3 and MLR.4 assumptions do not hold for this model.

5.3 Visual analysis of the data

This scatter plot displays the trend of net imports over time from 2013 until 2021. Each observation is positive, and the orange line illustrates the total pattern.

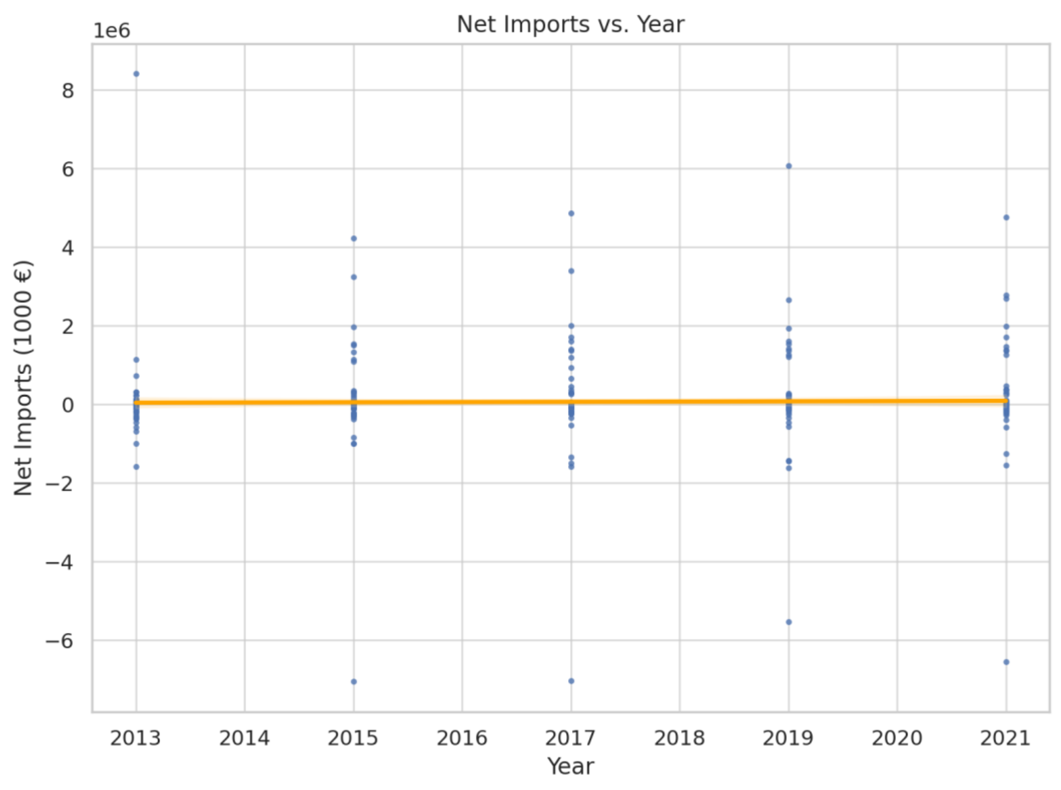

Figure 4 Net imports vs year

Key observations:

1. There has been considerable diversity in net imports over the years.
2. The data shows no significant change in either direction, indicating that net imports have remained relatively constant during that period.
3. The years 2013 and 2019 showcase particular extreme values (positive and negative).

The scatter plot characterizes the link between net imports and whether a sector participates in the EU ETS. On the x-axis is the ETS dummy variable (0 indicating non-coverage, one suggesting coverage), and the y-axis reflects net imports.

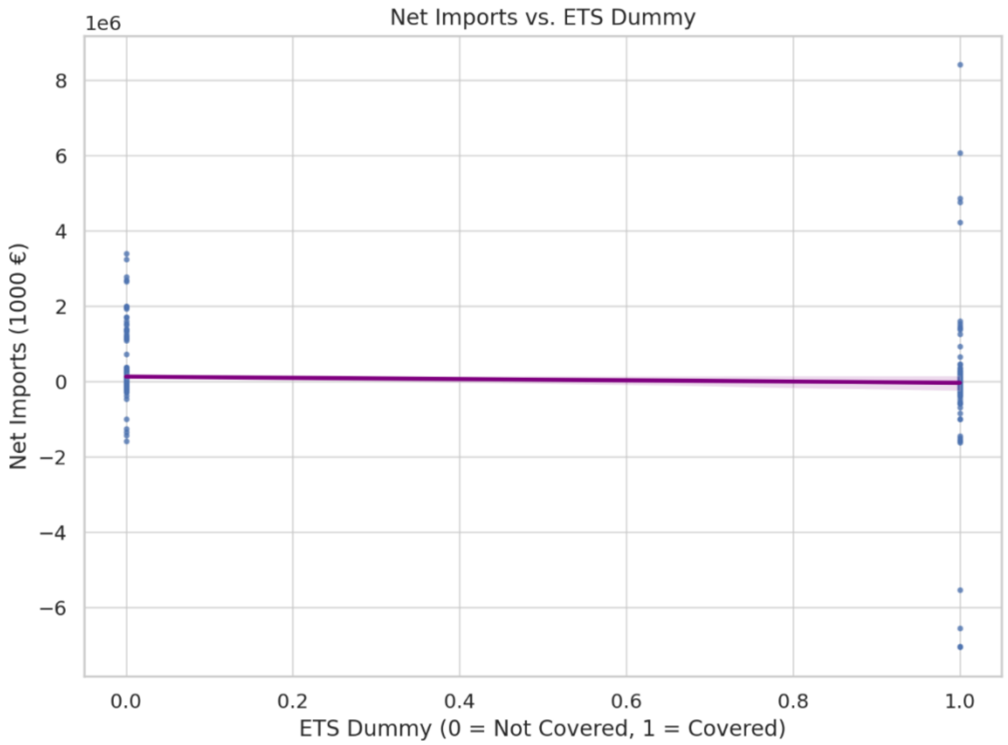

Figure 5 Net Imports vs. ETS Dummy

Key observations:

1. The net import values show a broad range for sectors not part of the ETS.
2. Some of the most notable net import values (in both directions) are within sectors covered by the ETS.
3. There is no apparent variation in the division of net imports between covered and non-covered sectors.

This figure consists of three scatter plots illustrating the connection between net imports and multiple independent variables.

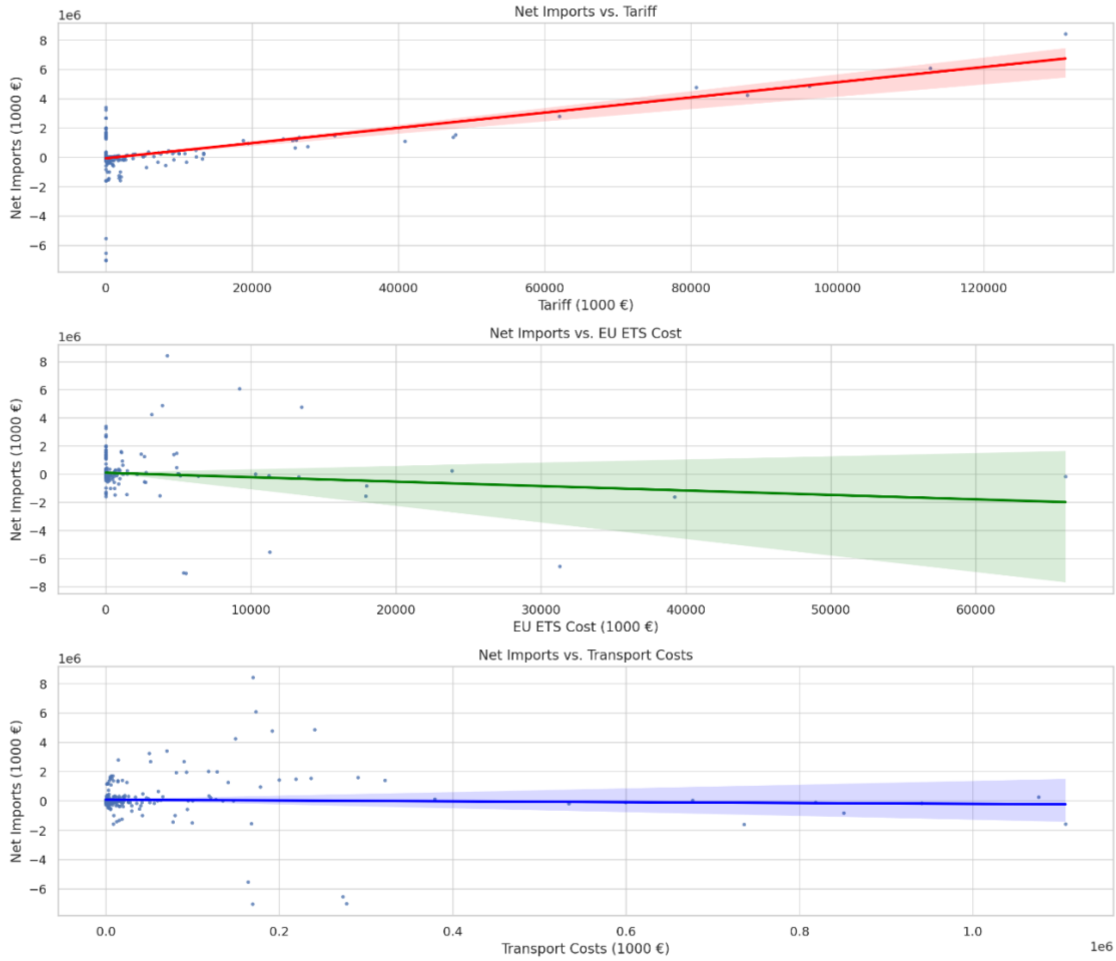

Figure 6 Comparison of Net Imports to Tariff, along with EU ETS Costs and those related to Transportation

Net Imports vs. Tariff:

1. There is a suggestion of a positive connection between tariffs and net imports.
2. A red line depicts a linear trend, covered by the shaded area, the confidence interval.
3. The findings imply that a connection exists between elevated tariffs and an upswing in net imports, which is surprising and could motivate additional research.

Net Imports vs. EU ETS Cost:

1. An analysis shows a slight negative correlation between the costs in the EU ETS and net imports.
2. The green line expresses a falling pattern. However, the expansive confidence interval implies that this relationship may be indistinguishable from random fluctuations.
3. This trend shows that higher ETS costs are correlated with fewer net imports, contradicting the carbon leakage thesis.

Net Imports vs. Transport Costs:

1. There is a weak or non-existent correlation between transport costs and net imports.
2. The nearly horizontal blue line suggests that adjustments in transport costs do not strongly influence net imports.
3. The broad assortment of data points recommends that different factors could be more critical in assessing net imports.

The graphs provide visual evidence for the regression analysis and aid in illustrating the connections between the main variables. They argue that the relationship between EU ETS expenses and net imports is complicated, and that other factors might have critical roles in shaping trade patterns.

5.4 Further discussion

The results of the analysis provide compelling evidence against the hypothesis that the EU ETS causes carbon leakage in the Finnish manufacturing sector. This finding aligns with previous studies, such as Naegele & Zaklan (2018), who found no evidence of carbon leakage due to the EU ETS in European manufacturing more broadly.

Several factors may explain these counterintuitive findings:

1. *Porter Hypothesis*: These results are consistent with the Porter Hypothesis (Porter & van der Linde, 1995), which suggests that well-designed environmental regulations can stimulate innovation and efficiency improvements. Firms facing higher EU ETS costs may invest in cleaner technologies, or to more efficient processes, improving competitiveness and reducing reliance on imports.
2. *Free Allocation of Allowances:* The EU regulations for carbon emission trading provide free assignment of allowances to sectors that may experience carbon leakage. The design element of this policy may have substantially reduced possible negative consequences for competitiveness, allowing businesses to modify the regulations with minimal change to their trade patterns.
3. *Relative Cost Considerations:* Naegele and Zaklan (2018) mention that the differentials in costs resulting from the EU ETS may seem minor compared to other factors affecting trade patterns, notably labor and transportation costs. These results demonstrate that tariffs and transportation charges impact net imports, perhaps overshadowing the influence associated with the costs of the EU ETS.
4. *Sector Heterogeneity:* The negative coefficient on the EU ETS dummy variable (although not robust to clustered standard errors) suggests that covered sectors may have characteristics that make them less prone to carbon leakage. This could be due to capital intensity, technological sophistication, or strong local supply chains.
5. *Policy Anticipation and Adaptation*: Firms may have anticipated the long-term trajectory of climate policy and made strategic decisions to reduce their carbon intensity well before facing high EU ETS costs. This proactive approach could explain why we observe lower net imports in sectors with higher EU ETS costs.

It is important to note some of this study's limitations. The relatively low R-squared value (0.453) suggests other vital factors influencing net imports that this model does not capture. This could include exchange rates, domestic demand conditions, or sector-specific technological changes. Future research could incorporate these additional variables to provide a more comprehensive understanding of trade patterns in the context of climate policy.

Additionally, this analysis focuses on net imports as a proxy for carbon leakage. While this is a common approach in the literature, it may only capture some potential channels through which carbon leakage could occur. For instance, it does not account for possible shifts in global investment patterns or changes in product mix within sectors.

Despite the limitations, these findings have important implications for climate policy. They suggest that, at least in the case of Finland, the EU ETS has maintained the competitiveness of domestic manufacturing to the extent that it leads to increased imports from regions with less stringent environmental regulations. This supports the continued use and potential strengthening of carbon pricing mechanisms to reduce greenhouse gas emissions.

6 Conclusion

This thesis aims to determine if the EU ETS has had a carbon leakage-inducing effect on Finland's manufacturing sector. Based on the regression and data results, it would seem that the EU ETS does not have a carbon leakage-inducing effect. This aligns with the findings of Naegele & Zaklan (2018).

The theoretical basis of the PHH and PHE has been extensively studied, but there have been difficulties in demonstrating them in practice. It seems that Levinson's (2000) argument, that it could be the case that the carbon-intensives producers are also the least agile in geographical terms, holds some merit.

Concerns about the insufficient price of carbon within the EU ETS are mainly related to the first two phases of the EU ETS, as are concerns about the excessive allocation of free allowances, pointed out by Hu et al. (2014), Lovcha et al. (2021) and Schäfer (2019). The price of allowances has increased yearly, and the number of allowances purchased has decreased. For example, in 2017, the total number of allowances allocated to Finland was 16,5 million, and the average price was 5,75 € per allowance (or 1t of CO^2. In 2021, the number of allowances was 7,8 million, and the cost per allowance was 54,18 €. It has become much more expensive to pollute, and since there is no observable carbon leakage, it could be concluded that the EU ETS works as intended and reduces GHG emissions in the EU.

For policymakers, these results should be encouraging. They suggest that it may be possible to implement stringent climate policies without significant risks of carbon leakage, at least in the short to medium term. However, continued monitoring and analysis will be crucial as the stringency of climate policies increases over time.

The lack of observed carbon leakage suggests that the EU ETS is, in fact, a valuable tool for reducing greenhouse gas emissions while preserving domestic industrial competitiveness. This should motivate policymakers to consider possible improvements and even broader expansions of the scheme. The results also suggest an opportunity to bolster climate policies without worrying about significant economic disruption or lessening competitiveness for domestic producers. It is vital to continuously monitor these effects as policies transform and grow more stringent.

Future studies could make use other methodologies to enhance the validation and expansion of these results. Employing Pollution Abatement Costs (PACs) to assess environmental stringency is often used in scientific literature from the United States. This can potentially deliver an alternative angle on how ecological regulations relate to trade patterns. In addition, using more complete databases, including the Global Trade Analysis Project (GTAP) tested by Naegele and Zaklan (2018), could permit a more comprehensive analysis. For example, the GTAP database would facilitate the correct computation of indirect ETS costs resulting from electricity usage in sectors not subject to direct regulation under the EU ETS, thereby revealing more detailed effects of the policy.

In conclusion, I discover no evidence that carbon leakage has occurred in the Finnish manufacturing sector because of the EU ETS. I observe a contradictory relationship between EU ETS costs and net imports, indicating that the policy may be responsible for boosting efficiency or facilitating other favorable adaptations in the covered sectors. These findings are optimistic for those favoring carbon pricing, but also reveal the complicated relationship between environmental controls and global trade trends.

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