Competitive disadvantage as an argument for a carbon border adjustment mechanism: an empirical investigation of EU-15 countries, 1996-2020

Auteur : Andriamaromanana, Voahary Iangotiana
Promoteur(s) : Gautier, Axel
Faculté : HEC-Ecole de gestion de l'Université de Liège
Diplôme : Master en sciences économiques, orientation générale, à finalité spécialisée en economic, analysis and policy
Année académique : 2021-2022
URI/URL : http://hdl.handle.net/2268.2/14339

COMPETITIVE DISADVANTAGE AS AN ARGUMENT FOR A CARBON BORDER ADJUSTMENT MECHANISM: AN EMPIRICAL INVESTIGATION OF EU-15 COUNTRIES, 1996–2020

Jury:
Supervisor:
Pr Axel GAUTIER
Readers:
Pr Joseph THARAKAN
Ms Kelly CIOPPA

Master thesis by
Voahary Iangotiana ANDRIAMAROMANANA
For a Master in Economic Analysis and Policy
Academic year 2021/2022

Acknowledgements

"Give thanks in all circumstances" 1 Thessalonians 5:18

At the very beginning, I would like to thank and praise God for the completion of my research master thesis, which marks also the end of this journey. The process was laborious, but the following persons made it more constructive and enjoyable.

I would like to express my sincere gratitude to Pr Axel Gautier, my master thesis supervisor whose valuable support and guidance provided me the necessary insight and paved the way for the meaningful completion of this work.

I am also thankful to my readers, Pr Joseph Tharakan and Ms Kelly Cioppa, for their time and helpful contribution, as they made themselves available when I had questions.

My special thanks go to all the resource persons, that took the time to share their opinion and expertise about the subject, namely Mr Antoine Dedry from ACV-CSC METEA, Mr Benjamin Denis from IndustriAll European Trade Union and Mr Bart De Wit from the FPS Economy, thanks to whom I could develop a better apprehension of the topic.

Last but not least, I would like to extend my sincere gratitude and thanks to my family for their unfailing and continuous support during my academic years.

Contents

List of abbreviation

BAT: best available technology

CBAM: Carbon Border Adjustment Mechanism

CO2: Carbon dioxide

CU: Customs Union

EFTA: European Free Trade Agreement

EIA: Economic Integration Agreement

EITE: Energy-Intensive and Trade-Exposed

ETS: Emissions Trading System

EU: European Union

FTA: Free Trade Agreement

GATT: General Agreement on Tariffs and Trade

GDP: Gross Domestic Product

GHG: Greenhouse gas

GtC: Gigatonnes of carbon

IPCC: Intergovernmental Panel on Climate Change

LDC: Least Developed Countries

MFN: Most Favoured Nation

MPB: Marginal Private Benefit

MPC: Marginal Private Cost

MSB: Marginal Social Benefit

MSC: Marginal Social Cost

OLS: Ordinary Least Squares

PSA: Partial Scope Agreement

RTA: Regional Trade Agreement

UNFCCC: United Nations Framework Convention on Climate Change

WTO: World Trade Organization

Introduction

The more time passes, the more alarming the situation is. Despite the global pandemic, the global average amount of carbon dioxide hit a new record high in 2020, 412.5 parts per million (Lindsey, 2021). Carbon dioxide concentrations are rising mostly because of the fossil fuels that people are burning for energy. The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases. It absorbs less heat per molecule than the greenhouse gases methane or nitrous oxide, but it is more abundant, and it stays much longer in the atmosphere. Increases in atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise. In turn, the phenomenon of global warming generates serious alterations for any living creatures, which are better described by Hughes (2000) as effects on their physiology, distribution, phenology and adaptation. Hence, consequences are real and deadly. Therefore, it is today more important than ever to take serious actions, change the way we produce and consume, to solve this environmental problem.

Fortunately, ambitious countries and country groups such as the European Union, has already put in place their carbon market more than 15 years ago. Such a market allows to set a cap on CO2 emissions of different sectors, as well as to buy and sell emission certificates, based on individual firms needs. In addition, with a new "Fit for 55" package launched in the summer 2021, the EU aims to cut its emissions by 55% compared to 1990 level, and that by 2050. However, as long as many international partners do not share the same climate ambition as the EU, it is not possible to reach optimality. In fact, in a world with uneven climate policies, the carbon price differentials across regions could shift the production of energy-intensive goods from carbon-constrained countries to countries with laxer climate policy (Branger and Quirion, 2014). This would reduce the environmental benefits of the policy, via actual carbon leakage, while potentially damaging the economy, through competitiveness effects. If this risk materialises, there will be no reduction in global emissions, and this will frustrate the efforts of the EU and its industries to meet the global climate objectives of the Paris Agreement.

In this context, a Carbon Border Adjustment Mechanism (CBAM) would ensure that the price of imports reflects more accurately their carbon content, and level the playing field between domestic and foreign producers. This was the motivation of the European Commission when its president, Ursula von der Leyen, announced on July 14, 2021, the adoption of a CBAM (Commission, 2021a). This kind of instrument has been discussed and considered since carbon markets are in place, however it has never been actually implemented anywhere in the world. Therefore, a CBAM will be fully effective in 2026, after a three-year transition period for the first time in the European union.

But this raises questions from an international trade perspective. Such an unilateral measure might create international tensions, lead to trade distortion, and even imposition of a retaliation tariff by trading partners. Indeed, the General Agreement on Tariffs and Trade (GATT) was established in a world without climate change on the international agenda, so its rules were not drafted to address climate policies, making the interpretation of legal texts particularly difficult (Zhang and Assunção, 2004). Not mentioning about actual environmental and economic effectiveness, this turmoil that CBAM might generate in the international community is enough to justify an investigation about the motivations behind this measure. As a matter of fact, we may acknowledge from the scientific literature that there is no significant evidence on carbon leakage. Likewise, the system did not prove to have a significant negative impact on economic performance (Verde, 2020), and this when ETS period until 2015 is considered by researchers in their empirical studies. Consequently, the objective of this paper is to update these results and attempt to answer the following question, can ETS competitiveness effects on European economy be an argument for the introduction of CBAM, when considering the complete three first ETS phases (2005 – 2020)? Carbon leakage being highly complex to estimate, we take the argument on competitive disadvantage to verify if CBAM is actually justified.

Therefore, to answer our research question, the paper will be divided into two main parts. In the first one, we will discuss about CBAM from the scientific literature point of view but also from the EU's perspective. We will see in more detail the environmental issue it aims to solve, and the type of instrument that it is according to economic theories. We also conduct a complete policy evaluation, in order to consider other dimensions than economic efficiency in our analysis. And thus we will assess CBAM based on equity, political feasibility, accountability, fiscal sustainability and administrative realism criteria. This will allow us to develop a better understanding of CBAM before to move to an empirical analysis. In the second part, we will start by scrutinizing the empirical literature on the competitiveness effect of CBAM on regulated countries, sectors and individual firms, since this will give ground to our own empirical investigation thereafter. Subsequently, we will apply the widely used gravity model of international trade to a sample data covering 231 countries, for a 25 year-period, going from 1996 to 2020, which is the end of ETS phase 3. In fact, it is relevant to tackle the subject using an international trade approach, because sectors that will be initially covered by CBAM are energy-intensive and trade-exposed industries, but we will develop that later. Thus, we take export as a measure of competitiveness, and we would like to see how the introduction of a carbon price has impacted bilateral trade flow. Once, we obtain our results, we will move to a discussion section in which, we comment our findings and mainly talk about the motivations behind CBAM. Indubitably, it will be important to be able to look beyond what has happened in the past to understand this initiative from the EU, and to try to issue some recommendations. This will at last lead us to a conclusion, in which we will finally answer our research question but also raise one of the most important problematic in international trade economics.

The Carbon Border Adjustment Mechanism

3.1 The environmental issue

3.1.1 Global warming

To properly set environmental objectives, it is essential to understand the nature of the environmental problem. The year 2020 has ranked second warmest in the 141-year record (Lindsey and Dahlman, 2021). This phenomenon is known as global warming, and it is defined as "the long-term heating of Earths climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earths atmosphere" (NASA, 2022). Since the pre-industrial period, human activities are estimated to have increased Earths global average temperature by about 1 degree Celsius as shown in figure 3.1, a number that is currently increasing by 0.2 degrees Celsius per decade (NASA, 2022).

However, global warming does not tell the full story, it is actually just a part of a whole environmental issue known as climate change. The two terms are usually used interchangeably but climate change can be defined as "a long-term change in the average weather patterns that have come to define Earths local, regional and global climates" (NASA, 2022). Therefore global climate change refers to the average long-term changes over the entire Earth. These include warming temperatures and changes in precipitation, but also the effects of Earths warming, such as rising sea levels, shrinking mountain glaciers, ice melting at a faster rate than usual in Greenland, Antarctica and the Arctic, and finally changes in flower and plant blooming times (NASA, 2022).

According to the IPCC, the extent of climate change effects on individual regions will vary with the ability of different societal and environmental systems to mitigate or adapt to change, and over time. The IPCC predicts that increases in global average temperature of less than 1 to 3 degrees Celsius above 1990 levels will produce harmful impacts in some regions and beneficial ones in others (Pearce et al., 2014), but net annual costs will increase over time as global temperature increases. Global climate change has already had observable effects on the environment. IPCC states that "Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time"(Pearce et al., 2014).

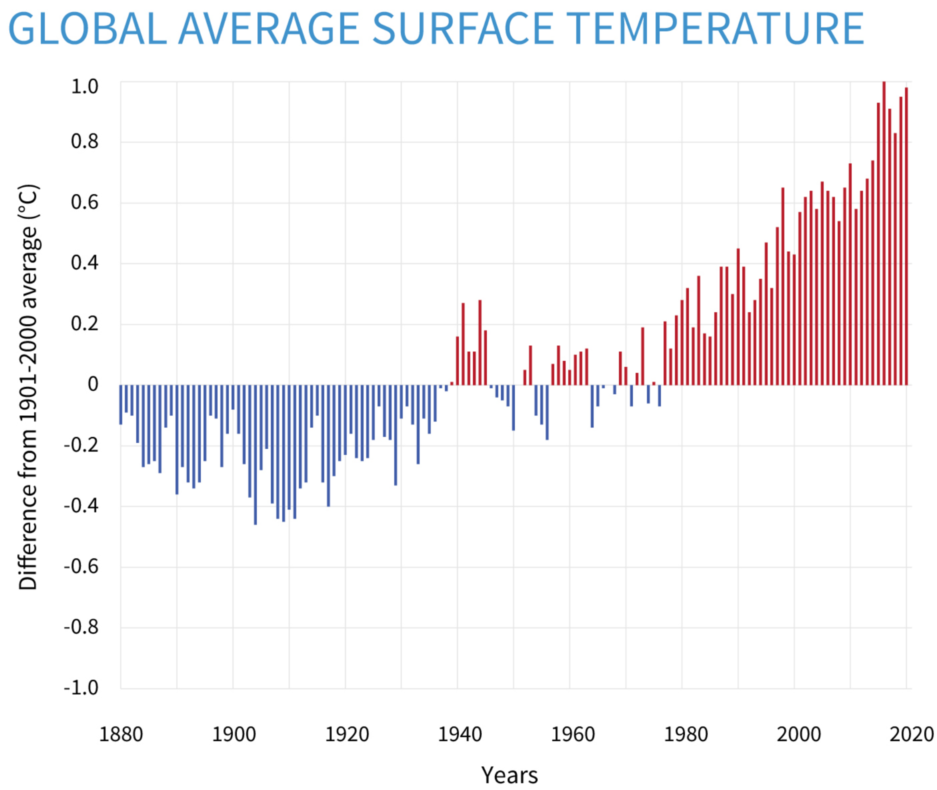

Figure 3.1: Global average surface temperature

Source: NOAA Climate.gov, National Centers for Environmental Information

3.1.2 The pollutant

Our pollutant is known as CO2 or carbon dioxide, and it is an odourless, colourless gas produced by the burning of fossil fuels and organic compounds, by the processes of decomposition and respiration, and by volcanic activity, and then absorbed by plants during photosynthesis OED (2022a). But carbon molecule is also the backbone of life (Mélières and Maréchal, 2015), it is one of the three building blocks that constitute the starting point of all living matter, along with water vapour and sunlight. The number of chemical possibilities it offers, and the both strong and flexible chains that it is able to form gives it a key role in the universe. That is why carbon appears as the most favourable element to form the basis of life. Common examples in which this is demonstrated as already mentioned in the definition of CO2 are photosynthesis and respiration processes. On one hand, photosynthesis is the process by which organisms stay alive, it allows the energy contained in the photons to be stored, and the carbon from CO2 stores this energy in the form of sugar (OED, 2022b). On the other hand, through respiration, the reverse reaction takes place, this energy is released and used by the organism itself, or by another organism (OED, 2022c). The carbon in the sugars is then transferred and recombined with oxygen to regenerate CO2 (Mélières and Maréchal, 2015). Note that we can distinguish three carbon reservoirs on earth, between which exchange of carbon takes place, this phenomenon is known as the carbon cycle. Therefore, carbon may be stored in gas, liquid or solid form in the atmosphere, in the sea and on land(Mélières and Maréchal, 2015).

From the beginning of the nineteenth century, atmospheric CO2 has slowly increased as we can see in figure 3.2, and this has created an imbalance in the carbon cycle. The present situation shows that since then the atmosphere has already stored an additional 240 GtC, and contains approximately 830 GtC today, if before the Industrial Revolution, the atmospheric reservoir contained approximately 590 GtC (Mélières and Maréchal, 2015). For more than a century, the carbon cycle has been perturbed each year by anthropogenic emissions, which is simply additional CO2 emanating from human activities like combustion of fossil fuels, industrial processes, and land-use change. Nowadays, human activity emits almost 10 GtC per year (Peters et al., 2017), about half of which remains in the atmosphere (45%), and the other half is absorbed more or less equally by the ocean (25%) and the land biosphere (30%) (Peters et al., 2017). From this we can conclude that the two other carbon sinks are able to absorb 55% of human-made emissions only, and those 45% left in the atmosphere are the ones at the origin of the environmental issue presented previously.

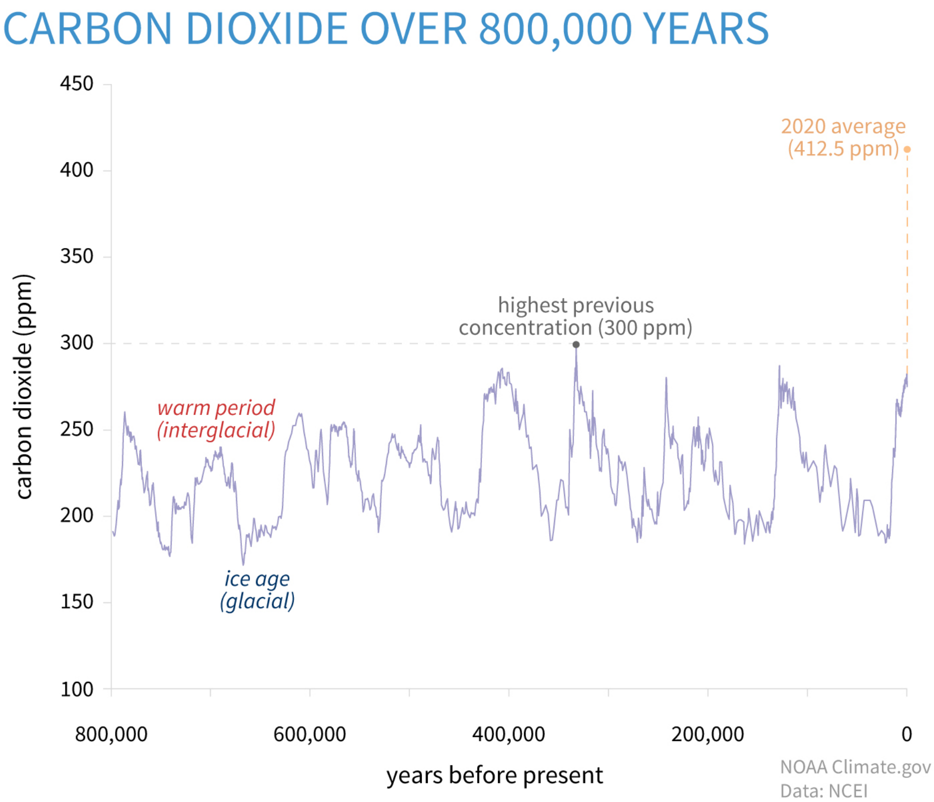

Figure 3.2: Carbon dioxide over 800,000 years

Source: NOAA Climate.gov based on data from Lüthi et al. (2008), via NOAA NCEI Paleoclimatology Program.

It is possible to properly define a pollutant from an environmental economics perspective based on several criteria (Walheer, 2022). Our pollutant is first identified as the excess anthropogenic CO2 emissions, since it is induced by human activities and include all residuals or byproducts of otherwise socially useful activities such as production and consumption. According to a mobility criteria, it is a pollutant from stationary sources, like for example from a fixed site producer of pollution, which is generally a single identifiable source. Considering the spatial scope of the environmental damage, we are referring to global pollution, because it is involving widespread environmental effects with global implications, namely global warming. Pollutants also differ in the ability of the ecosystem to clean them, here we are referring to biodegradability, or how fast a matter can be broken down, safely and relatively quickly, by biological means, into the raw materials of nature and disappear into environment Walheer (2022). Finally, from the evidence found by Peters et al. (2017), we know that we are dealing with a threshold effects or the point at which there is an abrupt change in an ecosystem quality, property or phenomenon. The definition of CO2 as a pollutant in this analysis is summarized in figure 3.3.

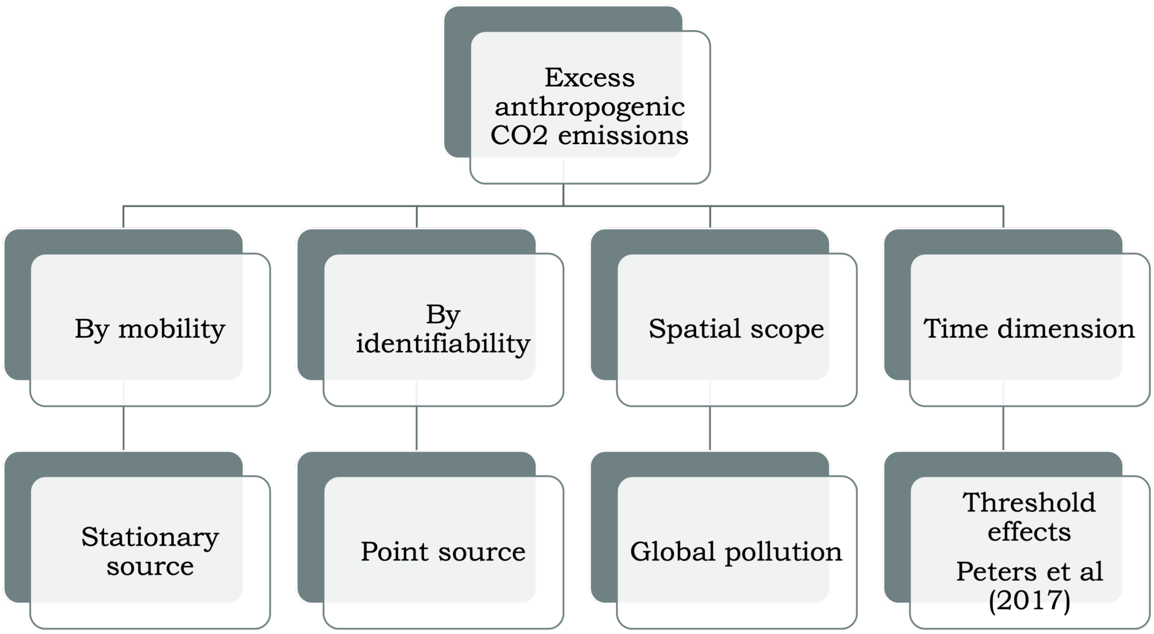

Figure 3.3: The nature of the pollutant

Source: Walheer (2022)

Now that we have defined the environmental issue and the pollutant, it is possible to identify the causal links between pollution sources and effects, as illustrated in figure 3.4. Consequently, fuel combustion from industrial activities generates excess CO2 that are left in the atmosphere, and this along with other greenhouse gases trap heat close to earth's surface, and lead to a rise in the average global temperature. Which in turn, creates serious alterations to the environment and damages to human health. From an environmental economics point of view, this environmental problem arises from the failure of complete information which is a condition for the existence of competitive markets. And the source of this market failure is known as externality, which exists "when the consumption or production choices of an agent enters the utility or production function of another agent, without that entity's permission or compensation" (Walheer, 2022), in this case we are dealing with a negative externality. An attempt to quantify the effects of this environmental problem might be challenged by measurement issues, a topic that we will not develop in this study.

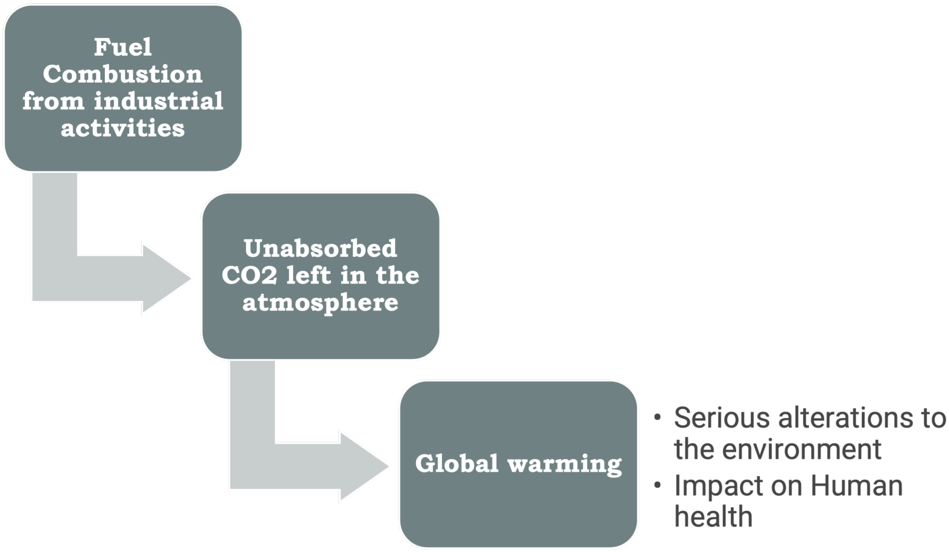

Figure 3.4: Causal link

Source: Author

3.2 The policy instrument: CBAM

3.2.1 Context of introduction

The first global initiative to tackle this global warming issue was the Kyoto Protocol, it required small reductions in the emissions of industrialized countries for a short period of time, about a 5% decrease according to Barrett (2008). In line with its commitment to the protocol and due to lack of global treaty on the matter, the European Union established in 2005 its own Emissions Trading System, subjecting regulated firms to a cap-and-trade mechanism of CO2 emission certificates. Are subject to this, power generators and energy-intensive industries, aviation sector, as well as further sectors and gases (Commission, 2021b). The emission certificates are distributed to polluting firms either freely or through auctioning. For instance, the industry of electricity generation has shifted to a full auctioning system since 2013. But until 2019, 94% of the certificates was still distributed under free allocation system. The iron and steel sector realized about 16 billion profit from this system (Zhongming et al., 2021).

Nine years after the protocol and a year after EU ETS has been put in place, Stiglitz (2011) argued about the importance of dealing with non cooperating countries in this fight against common environmental problems. As a matter of fact, unilateral climate policies have always raised concerns about emission leakage and competitive disadvantage, see for instance Hoel (1991) but also Felder and Rutherford (1993), particularly with respect to energy-intensive and trade-exposed (EITE) industries. On one hand, carbon leakage refers to businesses that were to transfer production to other countries with laxer emission constraints, and Caron (2012) said that this issue has been underestimated since. Leakage can occur through any of at least two distinct channels, firstly through the relocation of existing economic activity to countries with lower costs of environmental regulation, either through domestic firms losing market share to firms with lower costs of regulatory compliance or simply through plant relocation, secondly through the diversion of new investment from the regulating country to countries with lower costs of regulation (Cosbey et al., 2012). On the other hand, competitive disadvantage stems from the idea that regulated firms incur additional production cost under EU ETS, hence they suffer from competitive disadvantage vis a vis imported products. This is concerned about the loss of profits, market share, production, investment and related jobs (Cosbey et al., 2012). For Kuik and Hofkes (2010), sectoral competitiveness justifies the expansion of EU carbon price to foreign competitors products. That is why, not long after ETS implementation, discussions arose in the scientific literature about policy options to be coupled with domestic carbon taxation. There were attempts to deal with these issues with domestic measures, such as free allocation, but this mutes the carbon price, as well as the uptake of mitigation options in the sectors receiving allowances according to the growing evidences in the literature.

In December 2019, the Commission presented for the first time the European Green Deal, whose aim is to transform the EU into a modern, resource-efficient, competitive and zero net emission economy by 2050 (Commission, 2019). In fact, the European Union is well-known for being at forefront of international effort to combat climate change. The president of the commission stated that "The European Green Deal provides a roadmap with actions to boost the efficient use of resources by moving to a clean and circular economy, to stop climate change, revert biodiversity loss and cut pollution. It outlines investments needed and financing tools available, and explains how to ensure a just and inclusive transition" (Commission, 2019). The Green Deal is broken down into several objectives and one of them has been translated into what has been entitled the "Fit for 55" package. With this package, the European Union aims to reduce its emissions by 55% by 2030 compared 1990 level, and to become a climate-neutral continent by 2050. As a part of this effort, along with reforms of the EU ETS, a Carbon Border Adjustment Mechanism (CBAM) was presented on July 14, 2021.

3.2.2 CBAM in the litterature

The literature on CBAM started to emerge around the period when EU ETS was put in place. It is mainly made of results simulation and theoretical predictions, however this always enhances understanding of the mechanism and shed lights on potential effectiveness and possible implications of a CBAM for the implementing country, but also for the partner countries and globally. "A border carbon adjustment is a measure applied to traded products that seeks to make their prices in destination markets reflect the costs they would have incurred had they been regulated under the destination markets greenhouse gas emission regime" (Cosbey et al., 2012). Since the

EU Commission actually announced the introduction of a CBAM within the European Green Deal, debates have intensified on its effectiveness for climate action, on it adhering to WTO regulations, and the potential trade wars with main trade partners like China and the US.

A comprehensive analysis of CBAM by Mehling et al. (2019) expects it to have two central functions which are to level the playing field among competing producers, and to create political leverage for more ambitious climate action across countries, both in order to address leakage problem. Indeed, using a simple political game theory model, Helm et al. (2012) shows concrete stronger progress in emissions reduction could be achieved from the threat of unilateral trade policies, such as CBAM. Given the failure to agree on a common course of action, and each country fully aware of the impacts of their actions, the game is designed to allow each party to move unilaterally and sequentially. The paper concludes that properly crafted CBAM could help limit the competiveness effects, reduce trade distortions, and help build a broader coalition for more global actions against common environmental problems. Similarly, applying a game theory approach to a reciprocal-market model, and solving the three-stage game by backward induction under two alternative scenarios, Anouliés (2015) suggests that if well-designed, a border tax adjustment could achieve the first-best market equilibrium by mitigating competitiveness losses of domestic industries and carbon leakage. Additionally, Böhringer et al. (2012) found evidences that CBAM can mitigate adverse consequences on EITE industries of the country taking unilaterally the initiative to abate pollution and effectively reduce leakage. According to their results, a CBAM will substantially shift the economic burden of emission reduction to non-abating countries through implicit changes in international prices. However, they conclude that the global efficiency gains from a CBAM are modest. Therefore, given this limited scope for efficiency gains and the burden shifting potential, CBAM must be handled with care.

With a CGE model, (Mattoo et al., 2009) find that strong CBAM imposed by United States would depress India and China manufacturing exports between 16% and 21%. However, it must be remembered that China will in all likelihood consume domestically more than 98% of its steel production and 99% of its cement production, the effects of CBAM on Chinese production would then be very small. Subsequently, Mattoo et al. (2013) found that the effects on countries highly depend on how a CBAM would be implemented. A key factor affecting this impact could be for example the basis for the calculation of carbon content of import. The estimates from their analysis suggest that a calculation based on the carbon content of imports themselves when applied to all merchandise imports would address competitiveness and environmental concerns in high-income countries but with serious consequences for trading partners. The findings of this paper have shown that China's manufacturing exports would decline by one-fifth. Moreover, the corresponding declines in real income would be 3.7 and 2.4 %. On the contrary, a CBAM based on the carbon content of domestic production would broadly address the competitiveness concerns of producers in high-income countries and less adversely affect developing country trade. In fact, special attention has been given to possible impacts of a CBAM on China, since this country is a huge exporter to the European Union. And above all, China is the world's top energy consumer and CO2 emitter, accounting for 30% of global emissions (Shan et al., 2018). Therefore, Tang et al. (2015) also examines the impacts of a CBAM on China's trade, based on a multi-sector dynamic computable general equilibrium (CGE) model including 7 energy sectors and 30 non-energy sectors and running up to the year 2030, that allows to examine the effects of re-routing trade flows. The results suggest that CBAM would have a negative impact on China's trade, it will directly decrease China's exports. Moreover, CBAM will affect China's total imports and sectoral import in an indirect but more complex way. However, the simulation results indicates that improving energy technology efficiency and enhancing China's power in world price determination will effectively help the country to mitigate the adverse consequences caused by CBAM on its economy. Likewise, assessing the effect of carbon tariffs on international trade and emission reduction of China's industrial products, Chen and Guo (2017) argues that a CBAM will cause a decrease in exports for high-carbon industries. Additionally, they found that a CBAM will generate an increase in exports for low-carbon industries and cause a greater reduction on imports for low-carbon industries than that for high-carbon industries. Moreover, a CBAM will also lead to a considerable increase in output for light industry and a decrease in output for heavy industry. The authors conclude that a CBAM has an obviously positive effect on emission reduction for China's industrial sector, which bears the most responsibility of emission reduction.

As we can see, there are numerous studies about EU CBAM effects on rich economies. Nevertheless, Eicke et al. (2021) argue that the implications of the EU CBAM, especially in the Global South, have been underrepresented so far. Hence, they conducted a study that evaluates countries relative risk levels based on two different scenarios, firstly CBAM addresses only emissions-intensive sectors, secondly CBAM targets the whole economy. Using a risk index encompassing the export structure of countries, their emissions intensity, emissions reduction targets, and institutional capacities to monitor and report product-based emissions, the authors map countries relative risks in these two scenarios. Thus they found that the range of impacted nations varies between the two analysed scenarios but more importantly, the impacts of CBAM are distributed unevenly across the globe. But in both scenarios, most countries at relatively higher risk are located in Africa. This kind of analysis sheds light on different patterns of country vulnerability to be handled with care when choosing among policy options.

3.2.3 The EU's CBAM

In the literature, the CBAM is assimilated to a tariff on import, or a border tax, however, to avoid being blocked in negotiations, and by European legislation, but also to ensure compatibility with the WTO, another way to put the CBAM into place has been opted by the Commission. The idea is to make CBAM as an appendix of the ETS, within the reform of this latter. Chase and Pinkert (2021) summarizes the implementation of EU CBAM, therefore the CBAM,

- is tied exclusively to the EU ETS as said previously, rather than attempting to reflect the broader costs the Fit for 55 package as a whole will impose on the EU economy;
- avoids double protection of EU industry by phasing in the CBAM in parallel with the phasing out of ETS free allowances in the covered sectors, simply because the two of them coexisting

would be a double protection for European industry, which is against international trade rules;

- is designed to ensure that "imported products are subject to a carbon price equivalent to the one they would have paid under the EU ETS, if they had been produced in Europe" (Chase and Pinkert, 2021);
- mandates that importers pay the carbon price through the purchase of emissions certificates based on the carbon content of the product rather than as a duty charged at the border or an excise tax, with no limit on the number of import certificates that can be purchased;
- ties the price of the import certificates to the weekly average market price of EU ETS emission certificates;
- allows the price to be offset by carbon prices paid in the origin country, the burden of proof being on the importer;
- applies initially only to five sectors, iron and steel, cement, fertilizers, aluminum and power generation, that are also covered by the ETS. The sectors account for a large proportion of emissions, face high levels of imports, and produce easily identifiable basic materials and products for which reference values of carbon content can be determined. These four sectors can also be qualified as EITE sectors;
- applies to products from all countries, regardless of their level of development, on the premise that "neither the EU nor any of the trading partners would have an interest in fostering the growth of carbon-intensive industries in these countries" (Cosbey et al., 2020);
- targets products from individual facilities rather than countries, allowing the latter to demonstrate actual carbon content levels, while providing an alternative default value based on European production site average emissions. This system incentivizes technology upgrading and allows foreign suppliers with lower carbon intensity production processes to receive credit for that, while letting others have recourse to a default based on European production technologies, that provides relatively generous reference values;
- allows for a three-year adjustment period in which emissions certificates for imported products are provided for free as importers prepare for gathering information about actual embedded emission levels from their foreign suppliers;

In sum, the European Union recently emitted its decision to adopt a Carbon Border Adjustment Mechanism (CBAM), an accompanying measure of EU ETS as this one will be reformed in the "Fit for 55" package. Its objective is to tax the difference between carbon content of import coming into the EU and the certificates submitted by the importer (Lim et al., 2021). Thus, the carbon content of imported products and the certificates submitted by the importers will be compared, while the deficit will have to be filled, the profit margins can be returned if the importer is able to prove that a carbon price has already been paid prior to CBAM, in the origin country for instance.This mechanism simply mirrors the European carbon market, as it establishes a carbon price equivalent to the rate of ETS certificates for imported products. The objective of the EU through the CBAM is actually to protect European industry but also to encourage its partner countries to adopt new and more ambitious environmental objectives. Regarding the timing, it will be introduced in 2023, a three-year transitory period is planned, and then full imposition will take place from 2026 (Commission, 2021a). The CBAM targets all countries that are not part of the European Union, except the members of the European Free Trade Area (EFTA). The sectors that will be initially covered by the CBAM are, cement, iron and steel, aluminium, power generation, and fertilizers. Nevertheless, the range of sector is to be expanded after 2026. According to the "Réseau Action Climat France", the countries that will be mostly impacted by this measure are Turkey, Russia, China, and Ukraine (RAC, 2022).

Regarding the legislative train of CBAM (Parliament, 2022), it has first undergone a public consultation between July 22, 2020 and October 28, 2020. On September 16, 2020, Commission President Ursula von der Leyen announced a legislative proposal on CBAM among the key new initiatives for 2021. On March 10, 2021, Parliament adopted the resolution on a WTO-compatible CBAM with 444 votes for, 70 against and 181 abstentions. On July 14, 2021, the Commission adopted its proposal for a CBAM, which would equalise the price of carbon between domestic products and imports in selected sectors. The adopted act was open for feedback until November 17, 2021. Since the adoption, several institutions published draft reports containing suggestions about sectors to be covered, type of emissions to be included, but also the timing of introduction. For example, the European Economic and Social Committee (EESC), adopted its opinion on the proposal on December 8, 2021. The EESC welcomes the proposal and also calls for the extension of the impact assessment to export activities within the covered sectors. Furthermore, EESC's opinion is in favour of supporting the industrial transition of the affected sectors through directly allocating revenue from CBAM to that purpose. The EESC also expects the Commission to address the possible effects of CBAM through the value chain by means of an impact study.

3.2.4 Type of policy instrument

Even though the commission claims that the CBAM is not a policy instrument, for an analysis purpose, we consider the CBAM as an environmental policy instrument throughout this study, since it is very similar to some categories of instrument if not one. First of all, a policy instrument is defined as any public intervention on the operations of markets. They can also be defined as the techniques used by the governing authorities to promote certain policies to achieve a predefined set of goals (Policy Design, 2022). In environmental economics, we distinguish three types of policy instrument depending on the goal of this one (Walheer, 2022), price instrument, quantity instrument and quality instrument. Price instruments aim to influence prices that the economic agents face through taxes, subsidies, fees, or effluent charges. We refer to this category for the case of CBAM and leave the two others aside because CBAM sets a carbon price for imports (Chase and Pinkert, 2021), thus it aims to influence the price of imported products. In other words, price instruments are policy instruments that influence the final price of a good or service.

In environmental contexts, the objective of a price instrument is usually to align marginal private costs (MPC) or the change in the producer's total cost brought about by the production of an additional unit of a good or service, and marginal private benefits (MPB) or the additional satisfaction that a consumer receives when the additional good or service is purchased, with marginal social costs (MSC) or the change in the cost that society pays as a result of the production of additional unit or utilization of a good or service, and marginal social benefits (MSB) or the change in satisfaction obtained by the society as a whole when an additional unit of a good or service is purchased (Walheer, 2022). Ultimately, the purpose is to get the price signal right. To do so, public authority can act on either the product market by imposing fees or production decisions by simply imposing effluent charges. A distinction is sometimes also made between instruments that apply directly to the pollution, output-based instrument or on the inputs, input-based instrument, the CBAM applies directly to the products embedded emissions, hence it is an output-based instrument. In addition, a price instrument can also be either a command-and-control instrument which impose a technology or a conduct or also a market-based instrument which encourage change in behavior through market signals, which is the case of CBAM. As a conclusion, the CBAM is a price instrument that acts on production decision by setting an effluent charge, which is a fee imposed directly on CO2 pollution discharge, thus output-based. Finally, it is a market-based instrument since it induces behavioral change through price signals. The categorization of CBAM as a policy instrument is summarized by figure 3.5.

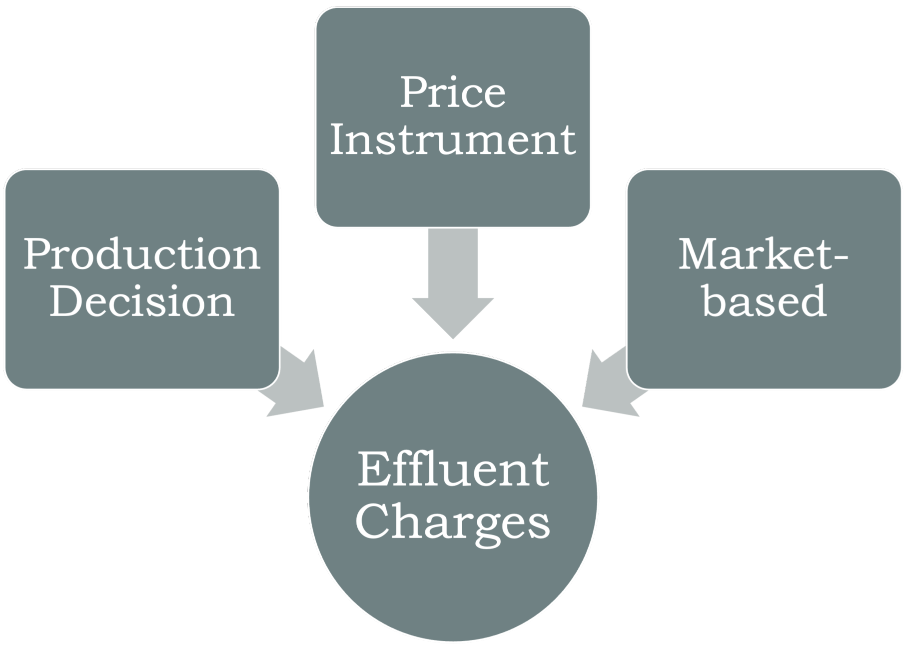

Figure 3.5: The type of policy instrument

Source: Walheer (2022)

Turning to price instrument theory to have a better apprehension of the policy instrument of interest in this study, suppose that we have two inputs, and there is a change in the cost of input 1 due to effluent charge imposed on it. This will ultimately lead to a change in input mix, more precisely there will be more use of input 2 for a given quantity produced Q. The reason behind this is that the objective of the producer is to minimize the following cost function,

$$C(Q) = Min_{i_1,i_2}\{i_1(w_1 + t) + i_2w_2\}$$

Which is subject to,

$$f(i_1, i_2) \geqslant Q$$

With,

- $C(Q)$, the total cost as a function of the quantity produced Q;
- i_j, the quantity of input j, $j = 1, 2$;
- w_j, the price of input j, $j = 1, 2$;
- t the effluent charge;
- $f(.)$ the production function;

An important assumption in this model is, substitution is possible between inputs, this involves more flexibility than what is often possible in the reality.

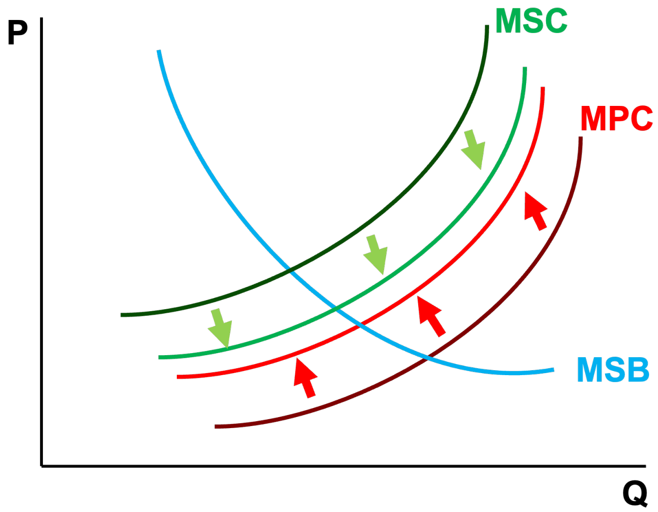

Figure 3.6: Indirect effects

Source: Walheer (2022)

On one side for every unit of Q, the total cost is now higher, and MPC increases, on the other side MSC decreases due to lower use of polluting input for every Q, as shown in figure 3.6. In this case, product tax and effluent charges are not equivalent when the product tax does not adjust to the pollution content of the product. The effluent charge proves to yield higher output than in the case of a product tax. Hence, the consumers and producers gain from clearer signals for production choices under the effluent tax. But the scope is also quite different, effluent taxes, by definition, cover the pollution generated during production. While product taxes go further since they can also cover external costs of the end product such as toxicity of batteries. In a nutshell, price based mechanisms bring the competitive equilibrium closer to the social optimum. If the charge equals to the external cost of the polluting input, the competitive equilibrium coincides with the social optimum.

In the next section, we perform a complete policy evaluation, because analyzing a policy is not only a matter of economic efficiency, there are a lot more dimensions of a policy that must be considered in order to conclude about its quality and effectiveness. Since, the EU CBAM has not yet been implemented, we fully rely on the predictions and simulation results in the scientific literature to conduct our complete policy evaluation.

3.3 A complete policy evaluation

3.3.1 Economic efficiency

Economic analysis of CBAM finds its essence in the effects of climate policy on competitiveness (Fischer and Fox, 2012), a term that accounts for changes in trade flows, terms of trade, carbon leakage, and domestic economic indicators like production, employment, or market share. Bao et al. (2013) argue that CBAM is very effective to protect competitiveness but it shifts a part of the mitigation burden to developing countries. In fact, different CBAM options have been explored individually by economists, many of whom use similar multicountry, multisector static general equilibrium models. For example, Babiker and Rutherford (2005) compare a reference case of Kyoto-style emissions targets without CBAM to adjustment measures including import tariffs, export rebates, exemption of energy-intensive industries, and voluntary export restraints on the part of non coalition countries. They focus on the impacts by country rather than by sector and find that adjustment measure taking the form of exemptions produce the least leakage overall but are associated with higher carbon prices, while from a welfare perspective, most countries prefer adjustment through tariffs. Peterson and Schleich (2007) investigate CBAM options for the EU ETS, concentrating on the calculation of the carbon content of imports, which mainly affects the stringency of CBAM as we have seen in the previous sections. They found that for most energy-intensive sectors in the EU15, implementing a CBAM will neutralize the increased import competition and more than neutralize the loss in export sales. But also, CBAM is not effective for the petroleum and coal product sector because the majority of EU-15 trade is with regions that are not subject to the CBAM. Finally, export sales of energy intensive products from the EU-15 are enhanced under a CBAM because the export subsidy offsets the increase in EU-15 production costs. Thus, by offsetting the price-cost increase in the EU-15, the CBAM enhances the export competitiveness of the energy-intensive sectors rather than just eliminating any loss of competitiveness. Demailly and Quirion (2006) use a detailed spatial model of the cement industry to compare two combinations of a CO2 tax with border adjustment. In the first case, the border adjustment is based on actual emissions intensities, both for export rebates and for import taxes. In the second scenario, the border adjustment corresponds to the CBAM, with rebates given according to the least CO2-intensive technology available at a large scale, and imports are taxed to the same level. They find that carbon leakage decreases in both cases, and foreign emissions even decrease in the first case. However, border adjustment also causes the cement price in the regulated countries to increase, further affecting the consumers.

3.3.2 Equity

CBAM faces potential conflicts with Common but differentiated responsibility, since it can be perceived as attempting to achieve similar regulatory burdens for firms from both exporting and implementing countries, qualified as a levelling of the playing field. Common but differentiated responsibility is a principle that is essential in many multilateral environmental agreements, including the UNFCCC, Article 3 of which says that: "parties should protect the climate system for the benefit of future and present generations of human kind on the basis of equity and in accordance with their common but differentiated responsibility and respective capabilities" (Protocol, 1997). Common but differentiated responsibility affirms that addressing environmental issues such as climate change is a common responsibility of all nations since the impact is global. However, some should take stronger actions than others. There are two justifications for differentiated responsibilities on climate change, first, those that have most heavily contributed to and mainly benefited from the accumulation of atmospheric greenhouse gas emissions have a greater burden of responsibility, second, those that have greater capability to address climate change, by means of greater wealth, greater access to technology, and so on, should contribute more to pollution abatement.

One of the reasons multilateral agreements such as the UNFCCC are preferable to unilateral action such as CBAM is that the former can find international consensus on a distribution of different national burdens in addressing climate change, as in the Kyoto Protocol. Common but differentiated responsibility in the UNFCCC defines the rights and responsibilities of the parties. While, CBAM as currently contemplated involves a unilateral determination. Consequently, any CBAM that aims to bring about equivalent national policies will probably violate Common but differentiated responsibility principle. The story is different for CBAM focused on the practices of individual producers, to which the UNFCCC confers no legal rights. But there is no clear distinction on which we have consensus, it can be argued that if regulations applied to exporting country producers make the exporting country worse off, the result is still a violation of Common but differentiated responsibility (Muller, 2012). There are elements of any CBAM regime that might move it in the direction of respect for Common but differentiated responsibility principle. These include national exemptions and provisions for revenue refunds, based on historic responsibility and on national capability (Cosbey et al., 2012).

Furthermore, Eicke et al. (2021) have also shown that economic risks related to an EU CBAM are distributed unequally across the globe. The relative risks for countries differ depending on whether a CBAM is applied to only EITE sector goods, or all goods. Kazakhstan, for example, is among the countries with the highest relative risk levels in the first scenario but is at lower risk in the second. In contrast, Zimbabwe and Bhutan rank among the countries with the highest relative risk levels in the second scenario but would be at low risk in the first one. Several countries including Turkey, North Macedonia, Sao Tome and Principe, and Saint Lucia are relatively in high-risk in both scenarios. They additionally conducted comparative case studies of three relatively high-risk countries to understand the different patterns of vulnerability. These case studies evaluate countries exposure based on their trade relations with the EU, and vulnerability based on their trade diversification, carbon intensity, energy and climate policies, and the institutional capacities for measurement, reporting and verification. The selected countries cover different world regions and highlight specific drivers of vulnerability. The result of the case study can be summarized as follow, Mozambique's risk level is driven by a low statistical capacity to prove emissions, Morocco's relatively high risk is strongly influenced by carbon lock-in, and Bosnia and Herzegovina's low diversification of trading partners and goods decreases their adaptive capacity.

3.3.3 Political feasibility

For WTO purposes, any measure that applies only to imports is suspect, as it can be presumed to be protectionist. That explains the straightforward prohibitions in GATT Article II (tariffs above a particular ceiling are prohibited) (Koul, 2018) and GATT Article XI (quantitative restrictions on imports are generally prohibited) (Zedalis, 2002). In contrast, a measure that applies to both imports and domestic products is fully accepted as long as it does not discriminate against imports or against imports from particular countries (the obligation of "most-favored-nation treatment"). Indeed, discriminating by country conflicts with GATT's MFN provisions, though there is a chance that it might be justified by GATT's Article XX exceptions, since it can be argued to be environmentally based and non-arbitrary (Cosbey et al., 2012). Can the WTO provisions on border tax adjustment be used to offset such cap-and-trade system like the EU ETS? Border tax adjustment for a cap-and-trade system is deemed to be more complicated (Pauwelyn, 2007).

A way to evaluate the political feasibility of a policy instrument such as CBAM is to look at previous dispute cases. Traditionally, it was held that the General Agreement on Tariffs and Trade (GATT) of 1947 rules forbids distinctions made on the basis of the way in which goods are produced, this is the so-called non-product-related production and process methods. The World Trade Organization (WTO) Appellate Body in its Shrimp–Turtle judgement overturned the absolute ban in earlier jurisprudence of the two Tuna–Dolphin cases where the GATT panels had decided that the US could not apply import restrictions on tuna conditional on the way they had been caught. In the later Shrimp–Turtle case, the WTO Appellate Body, while condemning the actual measures applied by the US as discriminatory between countries, nevertheless concluded that there might be grounds to allow regulations that distinguish between products on the basis of the impact on the environment of their method of production (Holmes et al., 2011). Thus the Shrimp–Turtle judgement did not explicitly comply with non-product-related production and process methods but allowed that they could, in certain circumstances, be justified under the GATT's Article XX exception provisions (Wolfrum et al., 2010).

This opened up the possibility for imports made in environmentally unfriendly ways to be treated differently from "greener" products, or products that are more respectable of the environment. The judgement left the exact legal position unclear but countries seeking to impose trade restrictions on carbon-related grounds may be able to claim a legal justification, at least on a first impression, as long as the restrictions are applied in a non-discriminatory manner. Indeed, Pascal Lamy, General director of the WTO, appears to maintain that the WTO can accommodate any policy measures that might affect trade, but may be necessary to facilitate a climate change agreement, whether by flexible interpretation of Article XX about general exceptions or by additional modifications to the WTO texts. Even if certain trade practices are deemed not to be in compliance with any new global carbon regime and there is an agreement on what measures might be taken, there is still considerable room for dispute about whether a national policy is truly non-compliant and whether any trade response is legitimate (Holmes et al., 2011).

Several other papers took a legal view of the CBAM, see for instance Brewer et al. (2010), Magnusson (2004), and Sampson (2001).

3.3.4 Accountability

The EU understands that addressing climate change requires tough measures. In its Fit for 55 package, the European Commission has proposed instruments to mitigate the increasing costs of fighting climate change, hoping to build and retain the political support that will be needed to take these steps (Commission, 2019). The CBAM is one of these, meant to assure European firms and workers that their sacrifice will not simply be lost to imports (Commission, 2021a). It has been carefully crafted, in part to ensure its legitimacy and acceptance under international trade law. But it seems that there will be always a triangular dilemma, as domestic politics, trade law, and climate objectives will remain in tension with one another (Chase and Pinkert, 2021).

CBAM's effect on international negotiations is unclear, it could be used as a "strategic stick" to force other countries to join the abating coalition according to Lessmann et al. (2009), but it could also trigger a trade war because of "green protectionism" suspicions. For example, China strongly opposes CBAM and claims that exports from EITE sectors are already taxed (Voituriez and Wang, 2011). Nevertheless, Weitzel et al. (2012) demonstrate that climate coalition countries have an incentive to deviate from the optimal carbon tariff rate to change their terms of trade. And even with good-quality data, there is room for judgement discretion in carbon content estimation and hence a disguised protectionism (Holmes et al., 2011).

Monjon and Quirion (2011) compare border adjustments and allocation options for cement, steel, and aluminum in the European Union, and conclude that the most efficient way to tackle leakage is auctioning with border adjustment, which generally induces a negative leakage, a spillover effect. This holds even if the border adjustment does not include indirect emissions, if it is based on EU rather than foreign specific emissions, or for some values of the parameters if it covers only imports. Similarly, Böhringer et al. (2012) argue that border adjustments are effective to reduce leakage through the competitiveness channel, in model simulations, the leakage rate decreases by about 10 percentage points on average.

3.3.5 Fiscal sustainability

There are a number of options for the use of the revenues collected by means of adjustment applied to imports. Cosbey et al. (2012) has identified the following, they include directing the collected funds to general revenues in the implementing country, refunding any adjustments collected to the exporting country, either directly or by subsidizing clean technology transfer, contributing adjustments collected to internationally administered funds for climate change mitigation and adaptation, designating funds collected to be disbursed by the implementing country in ways that benefit developing countries, like for instance financing for mitigation and adaptation projects. The first option is not recommended by Cosbey et al. (2012) because it creates incentives to use CBAM to enhance domestic welfare by manipulating the terms of the adjustment. The remaining three options move the regime as a whole toward better respect for the principles of Common but Differentiated Responsibility. For such measures to be meaningful, it would be important to ensure that the earmarked contributions are additional to those already required by international agreements, or pledged under existing programs of support. In other words, they should not simply replace funds from existing commitments.

As an illustration, Springmann (2013) provides a comprehensive analysis of coupling carbon tariffs to clean development financing using an energy-economic model of the global economy. He found that Recycling the revenues from carbon tariffs back to the exporting country distributed those revenues in proportion to their exports emissions intensities. Thus in the paper's main scenario, China and the other Asian economies together received about 60% of clean development financing, about $2.9 billion each approximately. Within Asia, about 70% of the $2.9 billion went to Indonesia and the Asian Tiger Economies, 24% to India, and 33% to other Asian countries. Central and South America, Africa, and the Middle East received about $1 billion each. In Central and South America, the funds were almost equally divided between Brazil, Mexico, Venezuela, and other countries in the region. In Africa, however, 70% of clean development financing flowed to South Africa.

3.3.6 Administrative realism

Any CBAM system will involve possibly very substantial administrative burdens that the empirical literature is not accounting for. These come in various forms and depend on the design of the CBAM regime. Since no CBAM has been put in place in any country, direct empirical evidence on such costs is not available. In the complete CBAM regime firms would have to reveal the carbon content of their products and the information provided by them would have to be verified by authorities. The more complex a good is, the harder it is to assess the true carbon content of it. This would require tracking and verifying the entire production chain, both domestically and abroad. We take as benchmark some of the empirical evidence on the bureaucratic costs associated to the so-called rules of origin required in preferential trade agreements. These rules define under which conditions a good exported from some country is seen to actually originate from that country. For example, EU producers wishing to export duty free to Korea have to satisfy the rules of origin laid down in the EU-Korea free trade agreement. Satisfying and documenting those rules of origin is costly; often so much that firms prefer to incur tariffs rather than to document the rules of origin. Anson et al. (2005), Carrère and De Melo (2004), and Estevadeordal and Suominen (2006) have attempted to quantify these costs and found that they can amount to several percent of the export value. Hence, substantial red tape exists in other trade policy areas as well. Consequently, it would be advisable to concentrate a CBAM system on industries which are most heavily affected by carbon leakage and where the unavoidable red tape compares favorably with the benefits of achieving a level playing field. The bureaucratic burden is probably highest with the complete CBAM regime in which firms would have to reveal the carbon content of their products and the information provided by them would have to be verified by authorities. Alternative regimes could save on administrative costs but fare less well in terms of effectiveness and efficiency. The EU will have to strike a delicate balance between administrative costs and effectiveness.

The purpose is to calculate an accurate carbon footprint for imported products covered under CBAM. Meeting this objective becomes more difficult if the product can be manufactured using more than one process with widely different emissions profiles, but also if the manufacturing process simultaneously manufactures multiple products. Cosbey et al. (2012) found that using the average emission intensity in the exporting country as a benchmark would be somewhat effective at preventing leakage. But taking an average has the disadvantage that any producers with above-average carbon intensities are assessed at the average level, meaning that there are no incentives for those poor performers to improve to the average level. In contrast, there is no reward or incentive for performing better than average unless the regime features an option for submitting actual data. Using exporting country data as a basis could be problematic where such data are not readily available or verifiable, and gathering such data across a variety of exporting countries would be onerous.

EU ETS effects on competitiveness

4.1 A review of the empirical literature

The term competitiveness has been used in numerous studies, reports, and articles and underlies economic policies. However, this concept is difficult to define and susceptible to ambiguities. At a firm or sectoral level, competitiveness can refer to "ability to sell" or "ability to earn" (Berger, 2008). Competitiveness as "ability to sell" is the capacity to increase market share, and can be measured through indicators involving exports, imports, and domestic sales. Competitiveness as "ability to earn" is the capacity to increase margins of profitability, and can be measured with indicators involving some measures of profit or stock values. Distinguishing these two notions is useful since the same climate policy can have different impacts on both. For instance, distributing free emission allowances based on historic data only, as is the case in the US SO2 ETS, increases the ability to earn but not the ability to sell, since an operator can close a plant and continue to receive the same amount of allowances (Grubb and Neuhoff, 2006). Hence, only competitiveness as ability to sell may generate leakage. The notion of competitiveness at the national level is controversial, and is considered meaningless by some economists, like Paul Krugman (Krugman, 1994). The main indicator is the balance of trade, that is, the difference between the monetary value of exports and imports, but an increase in the balance of trade may result from many factors like a contraction in domestic demand, which are completely unrelated to the competitiveness of domestic firms. Whether climate policies have to protect competitiveness at a national level or at a sectoral level is a legitimate question. EU ETS sectors contribute around 40% of EU emissions, but less than 5% of its gross domestic product (GDP) and an even smaller share of its jobs. The sectors at risk of carbon leakage account for slightly more than 1% of GDP in the UK and 2% in Germany. However, they account for a much higher share of greenhouse gas (GHG) emissions therefore protecting their competitiveness in order to limit leakage cannot be discarded at first sight (Branger and Quirion, 2014).

The international community remains skeptical about this CBAM project. Chase and Pinkert (2021) expects countries like the UK, Russia, Ukraine, Turkey and China, but also Mozambique, Morocco and Senegal to be unhappy about this measure as the EU represents a significant part of their total export. There are also legal concerns with regards to international trade law and World Trade Organization agreements. Much ink has been spilled on whether, and under which conditions, CBAM could be compatible with WTO law. Mehling et al. (2019) puts an emphasis on one point that has been underappreciated, the legal validity of any border tax adjustment depends on its specific design features and the modalities of its application and implementation.

All these doubts around the CBAM deserve that we investigate on whether this measure is well-grounded and well-justified. Verde (2020) has conducted a rigorous survey on econometric literature about the two arguments behind CBAM and concluded that there are no evidence of the EU ETS having had widespread negative or positive effects on the competitiveness of regulated firms, nor is there evidence of significant carbon leakage. Estimating the effect of domestic carbon taxation on leakage is a complex task due to the type of data that would be required and several proxies that have to be thought of. However, the literature is dense regarding how the EU ETS has impacted regulated firms competitiveness since its implementation.

Here is a detailed empirical review of the impact of carbon pricing on firms competitiveness. We can distinguish various measure of competitiveness, different samples covering either single sector or multiple sectors, and single country or multiple countries. But also, diverse approaches, notably Difference-in-differences (DiD), Panel data and Time series. They differ with respect to the ETS period they study as well, but it has been noticed that very few included the third phase of ETS, and still just the beginning of it. Therefore, we are going to present the results of the papers from the shortest period of ETS covered to the longest one.

Based on an analysis on 1000 Swedish firms operating in the energy sector using DiD, Yu (2013) found no significance impact of ETS on these firms profit margins in 2005, but then negative significant impact on the following year. The author concludes that the latter was due to an increase in the investment in abatement technology. Considering the entire ETS phase I, Demailly and Quirion (2008) address two dimensions of competitiveness, production and profitability, for the iron and steel industry and include updating allocation options. Based on their findings, emissions in the iron and steel sector covered by the EU ETS drop by 12%, of which only 9% is due to the decrease in production and 91% to the drop in emissions intensity. Therefore, they conclude that production losses are weak, and thus they find little competitiveness effect from the EU ETS, which is in line with even prior studies like Obernhofer et al. (2006).

The three following papers cover the first phase of EU ETS. Commins et al. (2011) studied the impact of carbon taxes on four different measure of competitiveness, employment, investment in intangible fixed assets, total factor productivity (TFP) and return on capital (ROC) using a cross-sector and cross-country firm level panel data. They found that the effect was positive on employment, and the estimates were all significant only at 10% level. However, they suspect some measurement error and effect of sectoral shocks, because the participation to ETS is defined by sector and not by firm. Using a cross-country aluminium sector time series data, Reinaud (2008) analyses the impact of carbon taxes on net imports. She concludes that the effect was indirect, through electricity prices but this was not statistically significant. The reason behind this might be that electricity contract are long-term contracts and this study covers only the first two years of EU ETS. Costantini and Mazzanti (2012) applied the reputed international trade gravity model to bilateral trade data from 15 EU countries to 145 importing countries covering multiple sectors.

Taking exports as a measure of competitiveness, they found that EU ETS increased exports of medium-low technology sectors, but these roughly correspond to total sectors subject to ETS. The authors qualify this finding as being far from conclusive, because more detailed sectoral data and longer time series are needed to infer the real impact of the EU ETS on the competitiveness of regulated firms.

Considering data up to 2008, Abrell et al. (2011) applied DiD approach and has not found significant effect of EU ETS on variables that are a measure of firms competitiveness, except a modest negative effect on employment, a positive one on the profit margin of energy sector and negative on non-metallic mineral product. But this study suffers from the following limitations, heterogeneity in estimated average effects due to widely defined sector subsamples, also firms in control and treated groups operated in different sectors. Finally, there are potential indirect effects of ETS on firms in control group through electricity prices that are ignored. Besides, Lundgren et al. (2015) studies the impact of ETS and Swedish energy and carbon taxes on TFP growth of 100 firms in the pulp-and-paper sector. They first compute two indicators namely efficiency change and technological development and thus found positive effect on the former but negative on the latter. Additionnally, (Zhao, 2011) examined the impact of carbon tax on energy-intensive industries in short and long-term from an international trade perspective using the gravity model of international trade. Analyzing data of 21 OECD countries and 9 sample energy- intensive industries, he found that when only the importing countries have carbon tax, this exerts negative influence on the international competitiveness of the energy-intensive industries of the exporting countries during 1992-2000 and 2000- 2008, and this effect increased with the time. But when only the exporting countries have carbon tax, the carbon tax policy exerts positive influence on the international competitiveness of the energy-intensive industries of the exporting countries during 1992-2000 and 2000-2008; this impact during 1992-2000 is much larger than that 0f 2000-2008.

Chan et al. (2013) investigates the period until 2009 for electricity, cement, iron and steel sector. This is similar to Abrell et al. (2011) but firms in control and treated groups belong to the same sector, which reduces the risk of estimation bias. They take unit material cost, employment and turnover as measures of competitiveness and found statistically significant effect in electricity sector manifested by an increase in unit material cost and turnover. The authors relate the results to compliance cost and cost pass-through to output prices.

Gathering data up to 2010, Jaraité and Di Maria (2016) analyses the case of around 5000 Lithuanian firms from multiple sectors considering investment and profitability as measures of competitiveness. They found that regulated firms invested less than non regulated firms up to 2009, but conversely in 2010 they invested more. They also obtained negative effects on profitability, but which is statistically significant only at the 10% level in 2009 and 2010. An explanation to this according to the authors is much tighter allowance allocation in phase II for Lithuanian firms than in phase I. Similarly but for German firms, Petrick and Wagner (2014) found no significant effect of EU ETS on employment, but positive effects on the value of sales and exports for the first 3 years of phase 2. However, the authors warn that the positive effects are clearly non-robust, moreover they become statistically insignificant in most of the alternative estimations performed.

Considering a time series on cross-country aluminium sector up to 2011, Sartor (2012) has found indirect effect through electricity prices on net imports, because aluminium sector came under ETS in 2013 only. However this indirect effect is not statistically significant. This is quite similar to Reinaud (2008), but it controlled for both additional variables and co-integration. The author concludes that there are other factors much more important than carbon prices in determining the competitiveness of primary aluminium sector.

Moving now to paper that investigated the entire first and second phase of ETS, more precisely from 2005 to 2012, Branger et al. (2016) used monthly time series until the year 2012 for the steel and cement sectors of multiple countries to analyse the effect of EU ETS on net imports. But they found that the estimates were not statistically significant. Lutz (2016) used a large database of 15000 german firms operating in different sectors to see the effect of EU ETS on TFP. The effects turned out to be positive but the results are heterogenous across sectors. They found a positive one for basic metals in phase I, while no statistically significant effects are found for the food, paper and chemical industries. The author suggests that the results may at least in part reflect pass-through of regulation costs. On the other side, Marin et al. (2018) considered a larger number of variables as a measure of competitiveness, thus applying DiD approach to cross-country and cross-sector data, they have got the following results. Positive statistically significant effects are found in the first two trading periods, for markup (1.5% and 3.2% in Phases I and II, respectively) and investment intensity (1.2% and 1.5%), and only in Phase II, for turnover (6.6%) and labour productivity (5.1%). For employment, a negative effect is found (2.1%), but only in Phase I. This lead the authors to conclude that firms appear to have reacted to the EU ETS, on one hand by passing-through carbon costs and, on the other hand, by investing more, thereby improving labour productivity. Another study, Löschel et al. (2019) assesses the impact of EU ETS on production efficiency, which is measured as the firm-level distance to the estimated sector-specific production frontier. This is also about German firms and is similar to Lutz (2016). According to the findings, there is no evidence found on negative effects of EU ETS on production efficiency, however positive impact for firms in the paper sector and more generally on regulated firms during the first year of phase I only. The last study that considers the period up to 2012 is Dechezleprêtre et al. (2018) and it presents the advantages that the cross-country and cross-sector firms in the sample are similar in all observed characteristics prior to the introduction of the policy. They found an increase in regulated firms revenues and fixed assets due to EU ETS. This for them is due to carbon cost pass-through and investments in emissions abatement.

Nevertheless, very few studies have looked at the third phase of ETS as we mentioned. On one hand, Klemetsen et al. (2016) accounted for the first year of phase III, and it collected data on plant level in Norway. Using DiD approach, they found very large positive effects of EU ETS on value added and labour productivity but only for phase 2. However, they suggest that this was due to non-stringent allowance allocations and pass-through to output prices. On the other hand, Boutabba and Lardic (2017) included two additional years of phase III, hence until 2015. It is close to Branger et al. (2016) but they use longer data series of cement and steel sectors, updated with more recent information, also they account for multiple structural changes. Therefore, they have found positive and statistically significant effects of EU ETS on net imports for some sub periods. They arrived at the conclusion that modest operational leakage took place, and that it was more evident in steel than in cement sector.

In sum, the existing literature has found no significant evidence of regulated firms suffering from competitive disadvantage due to domestic carbon taxation. Most surprisingly, the effects are sometimes positive on variables like employment, value added, markup, turnover and exports. But recall that only ETS periods up to 2015 were considered in these scrutinized literature. However the third phase was the one introducing more stringent measures such as a single EU-wide cap on emissions instead of the national caps. It is also characterized by the power generation sector moving to a system of full auctioning for the emission permits. This leads us to the next section, which fills this gap in the literature, by answering the following question, What is the effect of EU ETS on competitiveness when complete three first phases are considered?

4.2 The dataset

4.2.1 International trade data

In general, our data comes from the CEPII's website, which has already combined data from differents sources into a single file. Founded in 1978, the CEPII is the leading French center for research and expertise on the world economy. It contributes to the policy making process through its in-depth analyses on international trade, migrations, macroeconomics and finance. Therefore, the CEPII produces databases and one of them is the Gravity database. The Gravity database aims at gathering in a single place a set of variables that could be useful to understand the determinants of international trade. Each observation corresponds to a combination of exporter-importer-year, or more precisely origin-destination-year, for which trade flows, as well as geographic, cultural, trade facilitation and macroeconomic variables are provided (Head and Mayer, 2013).

Data spans from 1948 to 2019, and includes 252 countries, some of which only exist for a shorter period of time. Variables included in Gravity database may correspond to unilateral characteristics, or country characteristics such as GDP, population, and so on, or to bilateral characteristics or country-pair characteristics such as distances, trade flows, relation trade agreements, and so on. When we refer to unilateral variables, the variable name ends with "$\_o$" when the information belongs to the origin country, and with "$\_d$" when it belongs to the destination country. For instance, $iso3$ the variable identifying each country or territory with the ISO3 alphabetic code becomes $iso3\_o$ when referring to the origin and $iso3\_d$ when referring to the destination (Head and Mayer, 2013).

The variables that we are likely to use in our empirical analysis, depending on the model specification, are listed in table 4.1, we provide information on its content, its level, unilateral or bilateral, and finally on its source.

Table 4.1: List of variables from GRAVITY database

Variable Name	**Content**	**Level**	**Source**
iso3	ISO3 alphabetic code	unilateral	CEPIIs GeoDist dataset and World Banks WITS
country_exists	1 if the country actually exists	unilateral	CEPIIs GeoDist dataset and World Banks WITS
contig	1 if countries are contiguous	bilateral	CEPIIs GeoDist database
dist	Distance between most populated city of each country (km)	bilateral	CEPIIs GeoDist database
distcap	Distance between capitals (km)	bilateral	CEPIIs GeoDist database
comlang_off	1 if countries share common official or primary language	bilateral	CEPIIs GeoDist dataset
comleg_posttrans	1 if countries share common legal origins after 1991	bilateral	La Porta et al. (1999) and La Porta et al. (2008)
col_dep_ever	1 if pair ever was in colonial or dependency relationship (including before 1948)	bilateral	Head and Mayer (2010)
pop	Population (in thousands)	unilateral	World Banks Development Indicators (WDI)
gdp	GDP (current thousands US$)	unilateral	World Banks Development Indicators (WDI)
gatt	1 if country currently is a GATT member	unilateral	WTO
wto	1 if country currently is a WTO member	unilateral	WTO
rta	1 if the pair currently has a RTA	bilateral	WTOs(2020) "Regional Trade Agreements Information System (RTA-IS)"

entry_cost	Cost of business start-up procedures (% of GNI per capita)	unilateral	World Banks Development Indicators (WDI)
entry_tp	Days required to start a business + number of procedures to start a business	unilateral	World Banks Development Indicators (WDI)
tradeflow_comtrade_o	Trade flow as reported by the exporter (in thousands current US$)	bilateral	UN Statistics Division Comtrade data

Nevertheless, the Gravity database does not provide all the information required for us to answer the research question. Data goes up to 2019 only, and we need data until 2020 for our analysis, thus the database had to be filled with 2020 values on trade flow as well as macroeconomic characteristics such as GDP and population mainly. The 2020 data on bilateral trade values comes from the World Integrated Trade Solution (WITS) website developed by the World Bank, in collaboration with the United Nations Conference on Trade and Development (UNCTAD) and in consultation with organizations such as International Trade Center, United Nations Statistical Division (UNSD) and the World Trade Organization (WTO) (WITS, 2022). This software allows users to access and retrieve information on trade and tariffs. The data we require is compiled by the UNSD Commodity Trade (UN, 2022) database, which contains merchandise trade exports and imports by detailed commodity and partner country data. Values are recorded in US dollars and the database includes information on more than 170 countries reported to the United Nations since 1962. As for the macroeconomic data, they come from the World Development Indicators of the World Bank. The World Development Indicators is a compilation of relevant, high-quality, and internationally comparable statistics about global development and the fight against poverty. The database contains 1,400 time series indicators for 217 economies, with data for many indicators going back more than 50 years (WDI, 2022). For the qualitative information on unilateral and bilateral characteristics represented by several dummy variables in the Gravity database, we are ready to make the assumption that value for 2020 is same as the previous year, 2019.

4.2.2 Variable ETS

The world's first international emissions trading system, EU ETS or European Union Emissions Trading System was launched in 2005. At the origin of this initiative, the 1997 Kyoto Protocol set for the first time legally-binding emissions reduction targets, or caps, for 37 industrialised countries. This led to the need for policy instruments to meet these targets. Therefore, in March 2000, the European Commission presented a green paper with some first ideas on the design of the EU ETS, and the directive was adopted in 2003 (Commission, 2022). Regarding the development of ETS, we had a first phase which was a three-year (2005–2007) program of "learning by doing" to prepare for phase two, when the EU ETS would need to function effectively to help the union meet its Kyoto targets. Phase one covered only CO2 emissions from power generation and energy-intensive industries. Almost all emission certificates were given to businesses for free and the penalty for non-compliance was set €40 per tonne. This first step succeeded to establish a price for carbon, develop free trade in emission certificates across the EU, put in place the infrastructure needed to monitor, report and verify emissions from the businesses covered. The cap on emissions was set at national level through national allocation plans. However, in the absence of reliable emissions data, phase one caps were set on the basis of estimates. As a result, the total amount of allowances issued exceeded emissions and, with supply significantly exceeding demand, in 2007 the price of allowances fell to zero, knowing that phase one allowances could not be banked for use in phase two(Commission, 2022). In phase 1, trading volumes rose from 321 million allowances in 2005 to 1.1 billion in 2006 and 2.1 billion in 2007, according to the World Banks annual Carbon Market Reports.

Phase two went from 2008 up to 2012, and it coincided with the first commitment period of the Kyoto Protocol, according to which the countries in the EU ETS had concrete emissions reduction targets to meet. The second phase of ETS was characterized by lower cap on allowances, some 6.5% lower compared to 2005 (Commission, 2022), and three new countries joining the european integrated market, Iceland, Liechtenstein and Norway. In phase two, the proportion of free allocation fell slightly to around 90%, since several countries held auctions. The penalty for non-compliance was increased to €100 per tonne, and businesses were allowed to buy international credits totalling around 1.4 billion tonnes of CO2 equivalent (Commission, 2022). The aviation sector was brought into the EU ETS on January 1, 2012, but application for flights to and from non-European countries was not yet effective for 2012. Since verified annual emissions data from the pilot phase was now available, the cap on allowances was reduced in phase two, based on actual emissions data. However, the 2008 economic crisis led to emissions reductions that were greater than expected. This led again to a large surplus of allowances and credits, which weighed heavily on the carbon price throughout phase 2 (Commission, 2022). Nevertheless, the market in emission allowances developed strongly from the start, trading volumes jumped from 3.1 billion in 2008 to 6.3 billion in 2009. In 2012, 7.9 billion allowances, worth 56 billion, were traded. The evolution of the European carbon market up to the end of phase two is shown in figure 4.1.

The reform of the ETS framework for phase 3, which goes from 2013 to 2020 changed the system considerably compared to the two previous phases. The main changes included a single, EU-wide cap on emissions instead of the previous system of national caps, auctioning is now the default method for allocating emission certificates, in place of free allocation. Additionally, more sectors and gases are now covered by the system. Also, there were 300 million allowances set aside in the New Entrants Reserve to fund the deployment of innovative, renewable energy technologies and carbon capture and storage through the New Entrants Reserve 300 programme (Commission, 2022). The drastic changes lead us to expect the third phase to have different impacts on regulated firms as compared to the two previous phases, which is why it is relevant to update the results in the scientific literature by considering the entire phase three in the analysis of the impact of EU

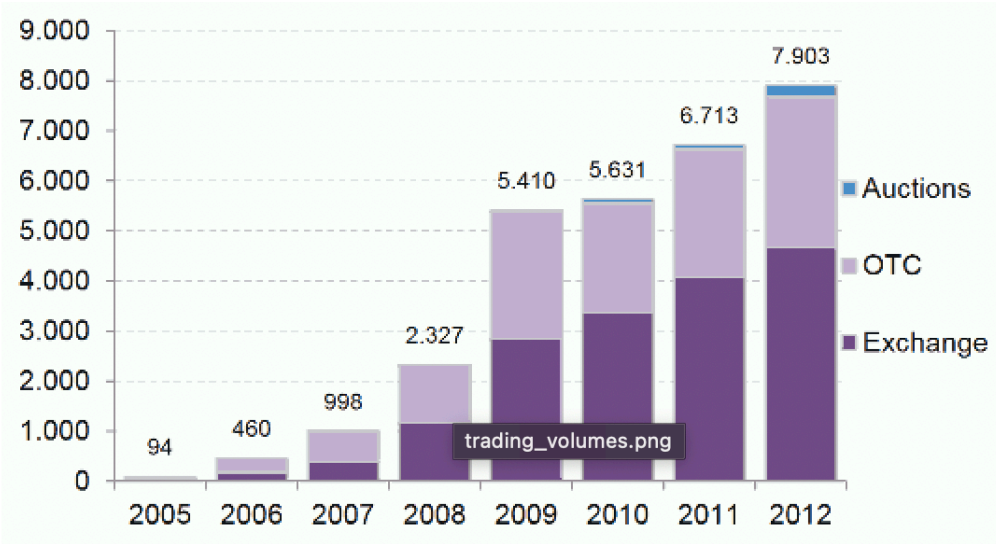

Figure 4.1: Evolution of the European carbon market, 2005–2012

Source: Bloomberg New Energy Finance. Figures taken from Bloomberg, ICE, Bluenext, EEX, GreenX, Climex, CCX, Greenmarket, Nordpool

ETS on firms competitiveness.

Therefore, we construct a dummy variable in our database which will account for this environmental policy known as Emissions Trading System. Therefore, the variable takes the value 0 or 1, it is equal to 1 during the ETS period, which means from 2005 to 2020 included, and 0 otherwise. We name the variable "eu_ets" in our dataset.

4.2.3 Preliminary analysis

It is essential to first understand the pattern of the data we are dealing with before to proceed with regression analysis, this will help us better specify our model later in this paper . Graph 4.2 exhibits the evolution of export from EU-15 countries between 1996 and 2020. We may say that trade flow displayed an increasing trend during that period, and even a boom after 2000. At that time, in terms of globalization process, multinational corporations become more pervasive, and anti-globalization protests occur frequently during meetings of International Monetary Fund and World Trade Organization, especially in the early 2000s. Additionally, the Euro becomes legal tender in twelve European Union countries in 2002, it is the largest monetary union in history and it eases trade in the Eurozone. Hence, all these might explain this jump in average trade flow value. However we can spot consequences of great economic crisis on the graph, such as the financial crisis which occured between 2007 and 2009. This Global Financial Crisis was a severe worldwide economic crisis, it was the most serious financial crisis since the Great Depression of the 30s. Moreover, it was also followed by the European debt crisis, which began with a deficit in Greece in late 2009. Putting aside the European sovereign debt crisis experienced exceptionally by Portugal and Greece, economic shocks in the trading partners that might have impacted their ability to import might also explain the second temporary decline in trade flow value. Finally, we can see the impacts of COVID-19 recession as well on the graph, it is an economic recession that happened across the world economy in 2020 due to the COVID-19 pandemic. Global stock markets experienced their worst crash since 1987, and in the first three months of 2020 the G20 economies fell 3.4% year-on-year (OECD, 2020).

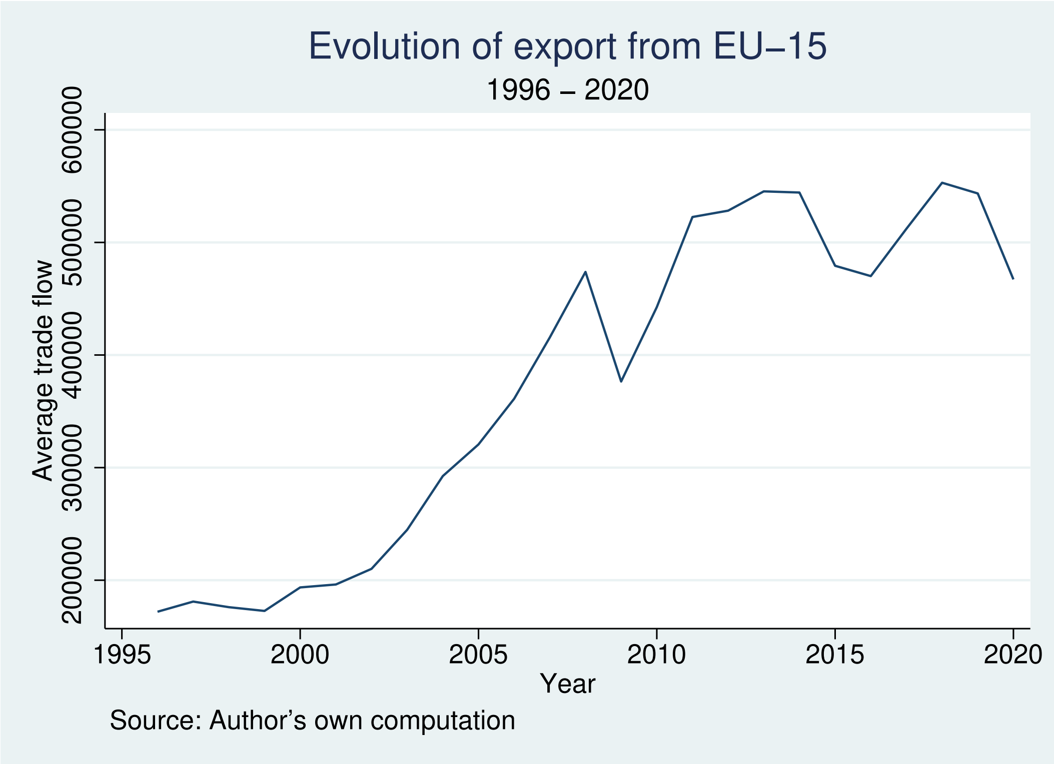

Figure 4.2: Evolution of average trade flow

Before moving forward in our empirical analysis, some descriptive statistics may be useful to describe or summarize the characteristics of our sample. Looking at the data on trade flow value, on average the trade flow value is about $455 405 900 between the period 1996 and 2020. But this value is not very representative of our sample because when we look at percentiles, more than 75% of the observation have values less than $108 960 100, even excluding zero trade observations, and 5% of observations have values more than $1 694 979 000. Indeed, when we look at the measure of skewness, which is a measure of symmetry, or more precisely, the lack of symmetry, we have a value which equals to 22.71308, this indicates that data are skewed right, it means that the right tail is long relative to the left tail. Similarly, the kurtosis is very high, 704.7924, this means that data tend to have heavy tails, or outliers.

Finally, we look at the correlation between some variables, in fact correlation coefficients are statistical measures that provide information about the strength and the direction of relationship between two variables. Table 4.2 summarizes the correlation between trade flow value, GDP and population of origin and destination countries. We do not report the values that do not have appealing interpretation such as correlation between gdp_o and pop_d for instance. Consequently, we can see that gdp_d is the macroeconomic indicator that has the strongest relationship with average trade flow value. The intuition behind this is that, the richer the destination country, the more it has the ability to import, this represents the demand. Apart from that, there is a strong positive relationship between gdp_o and pop_o, and from this we suspect potential multicollinearity between the two variables.

Table 4.2: Correlation coefficients

	$tradeflow\_o$	gdp_o	gdp_d	pop_o	pop_d
$tradeflow\_o$	1.0000				
gdp_o	0.1562	1.000			
gdp_d	0.5813	.	1.0000		
pop_o	0.1368	0.9443	.	1.0000	
pop_d	0.2584	.	0.4433	.	1.0000

4.3 The gravity model

4.3.1 Theoretical foundation

The gravity equation in international trade is one of the most robust empirical finding in economics (Chaney, 2018). It originated in "law of attraction" in the physics proposed by Newton in 1687, that is, the gravitational force between two objects is proportional to the quality and inversely proportional to the distance. The first key feature of trade data that mirrors the physical gravity equation is that exports rise proportionately with the economic size of the destination and imports rise in proportion to the size of the origin economy. Tinbergen (1962) and Pöyhönen (1963) began to use gravity model in the research of international trade issue. Through empirical research they confirmed that trade flows between the two economies is proportional to their individual economies scale and is inversely proportional to the distance between them.

The initial equation of the gravity model can be written as follow,

$$X_{ij} = \frac{GY_iY_j}{D_{ij}} \tag{4.1}$$

In this equation, G denotes a constant which is usually assimilated to the world GDP in the literature on gravity equation, X_{ij} is the bilateral trade value between regions or countries, Y_i and Y_j are the economic size of two countries or regions, widely used proxy is a country's GDP. D_{ij} is the economic distance between the two countries, generally refers to the distance between two economic centers or major ports. Among this, Y_i represents the potential supply of the exporting country and Y_j measures the potential demand of the importing country, whereas D_{ij} is a proxy for resistance to trade.

This model has been successfully verified by many scholars empirical studies and it is a powerful tool for analyzing bilateral trade flows. Compared with various trade theories, the trade gravity model quantified the bilateral trade between two countries or regions, opening up a space for econometric analysis in international trade. For the extending use of the gravity model of international trade, economists mainly modify original model through the introduction of new explanatory variables, which could be divided into two categories, one of them is exogenous variables affecting trade, such as GDP, population, per capita GDP, per capita income, and so on, the other is dummy variables, representing qualitative information such as existence of preferential trade agreements, integration organizations, common language, and so on.

Early theoretical contributions attempted to derive the gravity equation from a model that assumed product differentiation (Anderson, 1979), monopolistic competition (Bergstrand, 1985) and product differentiation with increasing returns to scale (Helpman, 1987). Linnemann (1966) applied the gravity model to measure the trade flows between the two countries by introducing two new explanatory variables, which are an endogenous variable, population and a dummy variable, trade policies, such as preferential trade agreements. Later, Anderson and Van Wincoop (2003) derived an operational gravity model based on the manipulation of the Constant Elasticity of Substitution (CES) system that deals with the issue of Multilateral Resistance Terms. According to Baldwin and Taglioni (2006) and Baier and Bergstrand (2007), by including specific country-pairs time-variant effects, the Multilateral Resistance Terms can also be represented appropriately for a panel dataset where country effects may be interpreted as the effect of different price structures over trade dynamics. This last information will be very useful in our model specification.

In the study of trade and environmental issue, Van Beers and Van Den Bergh (1997) added environmental regulation variable to the gravity model, analyzing three kinds of bilateral trade flows of 21 OECD countries in 1992. After that, Harris et al. (2002) analyzed three types of bilateral trade flows in 24 OECD countries during the period 1990–1996 on the basis of an improved model. Afterwards, World Bank report 2008 on "International Trade and Climate Change" introduced carbon tax policy variable to gravity model for the first time, to analyze the impact of the carbon tax on international competitiveness of industries.

The reasons of choosing gravity model as an analytical tool are based on two considerations,

- Firstly, a carbon tax policy involves complex factors such as tax rate, object taxed, tax relief and so on, which are difficult to be quantified, but in the gravity model we can introduce a dummy variable which represents whether or not to levy carbon tax into the gravity model in our research;

- Secondly, the advantage of discussing bilateral trade flows through gravity mode instead of multilateral trade flows model is that the sum of multilateral trade volume may offset the impact of different carbon tax policies on trade flows between countries. Hence, the bilateral trade flow data will reveal the impact of different carbon tax policies more clearly;

- Thirdly, it is relevant to use "export" as a measure of competitiveness in this analysis, because CBAM covers trade exposed industries, and the issues that CBAM attempts to deal with are due to EU's openness to trade, which are known as carbon leakage and competitive disadvantage vis a vis imported products.

4.3.2 Empirical approach

When used in empirical tests, gravity equations are usually taken into logarithmic form, in that way we obtain an equation which is linear in the parameters. As a result, the variables like X_{ij}, Y_i, Y_j and D_{ij} will appear in their logarithmic form. We take the logarithmic form for variables that only takes on positive values, thus the model using log as the dependent variable often satisfies the Classical Linear Model assumptions more closely than models using the level. But also, taking the log of the variables often reduces its variation and can make OLS estimates less sensitive to extreme values. Finally, log functional forms lead to coefficients with appealing interpretations. Similar to Helpman et al. (2008), we are ready to assume that missing trade data corresponds to zero trade. However, this has an important incidence on our sample, since taking the log implies that observations with zero values are automatically dropped from the sample.

Consequently, we initially have 81 015 observations, and end up with effectively 66 857 observations after taking log of bilateral trade values. Our sample goes from 1996 up to 2005, because countries suffered from a recession between 1991 and 1995, a period during which saving and investment were unusually low. Subsequently, we have data on 231 countries, among which 15 are exporters, and 216 are importers, forming 3 240 country-pairs ultimately. The exporters in our sample are the EU-15 countries covered by the ETS, which are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom, because this latter was still a member of the EU at that time. EU-15 has been chosen because these fifteen EU member countries together account for almost 85.5% of EU's exports in 2019 (Workman, 2020). As for the importing countries, the choice was conditional on data availability, they are NON-EU countries, an exception is made for EFTA member countries, which are , Iceland, Liechtenstein, Norway and Switzerland, because the latter has its own ETS linked with EU ETS, and the three others are covered by EU ETS.

After a logarithmic transformation, our gravity equation can be written as follow,

$$lnX_{ij} = lnG + lnY_i + lnY_j + lnD_{ij} \tag{4.2}$$

Now let us consider each variable separately and see how we can proxy each one of them, depending on data availability. X_{ij} in the original equation is the bilateral trade value between countries. From the Gravity dataset, we choose the variable $tradeflow\_comtrade\_o$ to proxy for

X_{ij}, and then take its log $ltradeflow\_comtrade\_o$ for the empirical analysis. The reason is that Comtrade data is more complete compared with other sources. It has a reporter-partner structure, meaning that each reporting country indicates how much it trades with each of its partner countries, both as exports and as imports. Data was reshaped to fit the origin-destination structure of the Gravity dataset. For instance, a trade flow reported by Belgium as exports towards its partner Madagascar will become a flow from Belgium to Madagascar, as reported by the origin. Note that trade flows reported by the exporter are FOB (Free on Board).

Y_i and Y_j as we said in the theoretical development of the model, represent the economic size of the countries. For that purpose, macroeconomic indicators such as GDP and number of population are available, where income and population dimensions are proxies of demand and supply of the importer and the exporter. For GDP and population data, WDI is the main source. When WDI data is available, we use it to create the variables gdp and pop, also used in their log form, which gives $lgdp$ and $lpop$.

The term D_{ij} is a proxy for resistance to trade. It is the economic distance between the two countries, and generally refers to the distance between two economic centers or major ports. From our dataset, we choose $distcap$, which is the distance between countries capitals, measured in kilometers (km), and it is a bilateral variable. They are also usually taken logarithmic into linear form in the empirical test, thus we use $ldistcap$ in our analysis.

We develop an extension of the model based on previous literature, and add a set of dummy variables that introduces qualitative information in our model, about factors that influence bilateral trade, they either encourage or restrict trade. We have geographic variables such as, $contig$ which is equal to 1 if countries are contiguous, or in other words sharing a common border. The dataset contains also cultural and historical variables, such as $comlang\_off$ equal to 1 if countries share common official or primary language. But also, $comleg\_posttrans$ which is equal to 1 if countries share common legal origins after transition of some countries from the Socialist legal system following the fall of the Soviet Union. Finally, we have information on colonial relationship from, col_dep_ever equal to 1 if country pair was ever in colonial relationship. This variable also takes into account colonial relationships before 1948.

Gravity database also provides trade facilitation variables, like for instance $gatt$ equal to 1 if country is a GATT member in a given year, wto equal to 1 if country is a WTO member in a given year. These two are unilateral variables, for later use, we construct a country-pair version of them that we labeled $gatt\_both$ and wto_both, which are equal to 1 if the trading countries are both members of GATT or WTO, respectively, in a given year. Data on GATT and WTO membership is taken directly from the WTO database, without additional modifications. GATT and WTO membership are kept distinct to maintain the ability to identify those few cases in which countries are part of GATT but not of WTO. These cases are Lebanon and Syria for countries that currently still exist. Other trade facilitation variables are, rta equal to 1 if origin and destination country are engaged in a regional trade agreement of any type within the given year. The WTO distinguishes 4 types of RTAs, Partial Scope Agreements (PSA), Free Trade Agreements (FTA), Customs Union (CU) and Economic Integration Agreements (EIA). First, PSAs typically involve the elimination of import tariffs in only a few sectors. Then, FTAs entail the elimination of import tariffs in most sectors but FTA members retain independent trade policies. Next, Customs unions build on FTAs by requiring participants to harmonize their external trade policy, including establishing a common external tariff. And finally, EIAs involve the liberalization of trade in services. These types may be combined, for instance a pair of countries can be both in a customs union and in trade agreement liberalizing services. This is why the categorical variable that describes the type of RTA may take more than one value. Finally, we have information on business start-up procedure like, $entry\_cost$ the cost of business start-up procedures as a percentage of Gross National Income per Capita, that we keep in the model at level, and $entry\_tp$ the number of days required to start a business plus number of procedures to start a business, that we include with its quadratic form to capture potentially decreasing or increasing marginal effects of the variable. For these last two variables, we consider only data on destination country, since we are interested in export variation.

Therefore, we construct our econometric model as follow, including all the exogenous and dummy variables explained previously,

$$\begin{aligned} ltradeflow\_comtrade\_o_{ijt} =& \beta_0 + \beta_1 lgdp\_o_{it} + \beta_2 lgdp\_d_{jt} + \beta_3 lpop\_o_{it} + \beta_4 lpop\_d_{jt} \\ &+ \beta_5 ldistcap_{ij} + \beta_6 entry\_cost\_d_{jt} + \beta_7 entry\_tp\_d_{jt} \\ &+ \beta_8 entry\_tp\_d2_{jt} + \delta_1 eu\_ets_t + \delta_2 contig_{ij} + \delta_3 comlang\_off_{ij} \\ &+ \delta_4 comleg\_posttrans_{ij} + \delta_5 col\_dep\_ever_{ij} + \delta_6 gatt\_both_{ijt} \\ &+ \delta_7 wto\_both_{ijt} + \delta_8 rta_{ijt} + u_{ijt} \end{aligned} \tag{4.3}$$

We already described each variable previously. The β_k's and the δ_k's are the parameters to be estimated ($k = 1, 2, ...$), the different notation is used to distinguish between coefficients on exogenous variables and on dummy variables, respectively. We use the subscript i and j, when referring to the exporter and the importer, respectively. Finally, the subscript t is added for variables that are time-variant. u_{ijt} is the error term, and contains all unobserved factors that influence bilateral trade values, but that we cannot control for in our model.

Our parameter of interest is δ_1, since we are mainly interested on the effect of EU ETS on exports from EU-15. We expect the coefficient on dummy variable eu_ets to have a negative sign, since we expect the third phase to have made a difference with more stringent reforms. Regarding the other parameters to be estimated, we make the following hypothesis on the sign of estimates based on the gravity model empirical literature. A coefficient will be negative if it restricts trade, and positive otherwise. In this model, GDP measures the potential supply or demand of the exporting or importing country, therefore, the corresponding slope parameters β_1 and β_2 are expected to be positive. The number of population is used to capture the effects of economies of scale in the exporting and importing countries, since countries with large populations tend to be more self-reliant, one might expect β_3 and β_4 to be negative. However, the expansion of the scale of productive capacity causes long-run average costs to fall, giving more populous countries a competitive edge in exporting, so that the estimates could also be positive (Costantini and Mazzanti, 2012). Subsequently, we expect β_5 to be negative, β_6, β_7 to be negative as well and β_8 to be positive. Indeed, we expect the number of days plus number of procedure to have an increasing marginal effect, in other words, higher number of days and procedures impacts trade less negatively. Nevertheless, we expect δ_2, δ_3, δ_4, δ_5, δ_6, δ_7, and δ_8 to all be positive, since they are coefficients on trade facilitation variables.

In the model specification, we have to be careful with three type of mistakes commonly made in the empirical literature on gravity equations according to Baldwin and Taglioni (2006), who estimated the size of the biases due to these errors. First there is the bronze medal error, which is the inappropriate deflation of nominal trade values by the aggregate price index. Since there are global trends in inflation rates, inclusion of this term probably creates biases via spurious correlations. Rose (2000) and other papers offset this error by including time dummies in the gravity equation. Since every bilateral trade flow is divided by the same price index, a time dummy corrects the mistaken deflation procedure, thus we do the same in our final model specification. Then, the silver medal error refers to averaging the reciprocal trade flows. The theoretically founded gravity model suggests that trade should preferably be treated separately each way. Most gravity models, however, are not estimated on unidirectional trade, rather, they work with the average of the two-way exports. This can create a serious bias, which is even more severe in panel data analysis (Baldwin and Taglioni, 2006). However, we do not encounter this error in our analysis, because our dependent variable is the unidirectional trade flow as reported by the exporter. Finally, the gold medal error goes to the omission of what Anderson and Van Wincoop (2003) call the "multilateral trade resistance" term, or "remoteness" for other researchers. The important contribution of Anderson (1979)'s paper has been to highlight that bilateral trade is determined by relative trade costs. Multilateral trade resistance are not observable, if omitted, they are are correlated with trade cost term, and creates the problem of omitted variable bias. One way to take care of this, based on practices in the empirical literature on gravity model estimation is to include country-specific fixed effects in the model specification. They control for unobserved characteristics of a country, that is to say, any country characteristic that affect its propensity to trade. They are also used to proxy each country's remoteness, but they do not control for unobserved characteristics of pair of countries Anderson and Van Wincoop (2003). Since country effects for exporters and importers approximating multilateral trade resistance often catch differences in structural dimensions, estimated parameters for unilateral variables that do not vary over time often lose statistical robustness (Costantini and Mazzanti, 2012) and thus are dropped from the model to eliminate potential multicollinearity between explanatory variables.

Note that estimating gravity equations with fixed effects for the importer and exporter, as is now common practice and recommended by major empirical trade economists, does not involve strong structural assumptions on the underlying model. As long as the precise modeling structure yields an equation in multiplicative form such as in equation 4.1, using fixed effects will yield consistent estimates. However, most gravity estimations employ dataset that span many years. In such cases the exporter and importer fixed effects should be time-varying as well. For panel data with a large number of years, the estimation might run into computational feasibility issues due to the very large number of resulting dummies to be estimated as we have encountered in our analysis. Consequently, we give up on the possibility to include time-varying country-specific fixed effects in the estimation of our gravity equation.

Consequently, we turn to a pooled cross-sectional analysis with fixed effects. And we are left with two possibilities, the first one is to include time dummies as well as country-specific fixed effects. Whereas the second one involves adding time dummies as well as country-pair fixed effects. In both cases, our main variable of interest eu_ets can be kept in the model since it does vary over time. The two final econometric models can be written as follow, recall that equation 4.4 includes nation dummies, and equation 4.5 includes pair dummies,

$$\begin{aligned} ltradeflow\_comtrade\_o_{ijt} =& \beta_0 + \beta_1 lgdp\_o_{it} + \beta_2 lgdp\_d_{jt} + \beta_3 lpop\_o_{it} + \beta_4 lpop\_d_{jt} \\ &+ \beta_5 ldistcap_{ij} + \beta_6 entry\_cost\_d_{jt} + \beta_7 entry\_tp\_d_{jt} \\ &+ \beta_8 entry\_tp\_d2_{jt} + \delta_1 eu\_ets_t + \delta_2 contig_{ij} + \delta_3 comlang\_off_{ij} \\ &+ \delta_4 comleg\_posttrans_{ij} + \delta_5 col\_dep\_ever_{ij} + \delta_6 gatt\_both_{ijt} \\ &+ \delta_7 wto\_both_{ijt} + \delta_8 rta_{ijt} + F_i\alpha_1 + F_j\alpha_2 + t\alpha_3 + u_{ijt} \end{aligned} \tag{4.4}$$

$$\begin{aligned} ltradeflow\_comtrade\_o_{ijt} =& \beta_0 + \beta_1 lgdp\_o_{it} + \beta_2 lgdp\_d_{jt} + \beta_3 lpop\_o_{it} + \beta_4 lpop\_d_{jt} \\ &+ \beta_5 ldistcap_{ij} + \beta_6 entry\_cost\_d_{jt} + \beta_7 entry\_tp\_d_{jt} \\ &+ \beta_8 entry\_tp\_d2_{jt} + \delta_1 eu\_ets_t + \delta_2 contig_{ij} + \delta_3 comlang\_off_{ij} \\ &+ \delta_4 comleg\_posttrans_{ij} + \delta_5 col\_dep\_ever_{ij} + \delta_6 gatt\_both_{ijt} \\ &+ \delta_7 wto\_both_{ijt} + \delta_8 rta_{ijt} + P_{ij}\alpha_1 + t\alpha_2 + u_{ijt} \end{aligned} \tag{4.5}$$

4.4 Results

Due to the presence of time-constant unobserved effects, cross sectional analysis without controlling for fixed effects yields biased estimator. Nevertheless, we present the results from Pooled OLS without fixed effects to use it as a reference or benchmark for our results.

A gravity equation deals with observations that may be heterogeneous in a variety of ways. We run the Breuch-Pagan Lagrange Multiplier test version to test for heteroskedasticity. Indeed, we would like to verify if our unobserved error term has a constant variance. In other words, does the variation in the error term depend on the explanatory variables. In fact, we obtain a $p - value = 0.000$, therefore we can reject the null hypothesis, and this means that we do not have a constant variance for the error term. Consequently, the usual standard errors are not valid, we have to make our results robust to heteroskedasticity for them to be valid and useful in our analysis. Another problem associated with using country-pair observations is that the errors may be correlated across country-pairs, which means that country-pair observations are not independent. To address this problem, one should correct for cluster errors using a bilateral variable which is time-invariant such as $distance$ for example. Consequently, we correct for cluster errors in our regression analysis and robust standard errors are systematically used.

As presented in the previous section, we have two options in our model specification, the first one controls for individual country specific fixed effects and the other one controls for country-pair fixed effects. However, every time we include time dummies to eliminate potential errors due to incorrect deflation, or simply to explain variation in our dependent variable which is simply due to the passage of time. Therefore, we display the results from the two models with the benchmark model. Let us now interpret the estimates from our regressions.

Table 4.3: Regression results

	(1) (Without FE)	(2) (Nation and Time)	(3) (Pair and Time)
lgdp_o	1.600***	0.184*	0.185*
	(0.0850)	(0.102)	(0.0983)
lgdp_d	1.031***	0.700***	0.701***
	(0.0177)	(0.0297)	(0.0300)
lpop_o	-0.370***	-1.650***	-1.618***
	(0.0749)	(0.368)	(0.376)
lpop_d	-0.0342*	-0.147*	-0.125
	(0.0186)	(0.0768)	(0.0766)
ldistcap	-1.011***	-1.745***	-3.358***
	(0.0421)	(0.109)	(0.198)
entry_cost_d	0.000331**	0.0000706	0.0000724
	(0.000162)	(0.0000824)	(0.0000850)
entry_tp_d	-0.00333***	-0.000931***	-0.000933***
	(0.000675)	(0.000353)	(0.000361)
entry_tp_d2	0.00000531***	0.000000897*	0.000000845
	(0.00000110)	(0.000000540)	(0.000000550)
eu_ets	-1.187***	0.244***	0.224***

	(0.0510)	(0.0844)	(0.0815)
contig	1.430**	1.448**	-10.07***
	(0.575)	(0.679)	(0.828)
comlang_off	0.823***	0.785***	5.999***
	(0.108)	(0.0857)	(0.425)
comleg_posttrans	0.125**	0.120**	-1.135***
	(0.0552)	(0.0500)	(0.140)
col_dep_ever	0.429***	0.847***	-0.646***
	(0.143)	(0.105)	(0.0935)
gatt_both	0.100	1.008**	2.641***
	(0.0646)	(0.485)	(0.174)
wto_both	0.280***	-0.0490	-0.0326
	(0.0658)	(0.0386)	(0.0385)
rta	0.0397	-0.0448	-0.0155
	(0.0465)	(0.0292)	(0.0292)
_cons	-26.40***	23.95***	38.22***
	(1.080)	(2.859)	(2.668)
Time dummies	No	Yes	Yes
Exporter dummies	No	Yes	No
Importer dummies	No	Yes	No
Pair dummies	No	No	Yes
N	55128	55128	55128
adj. R^2	0.782	0.870	0.926

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We start with our parameter of interest, the coefficient on the variable eu_ets, which will tell us what is the impact of ETS on export, which is considered as a measure of competitiveness in this case. Since eu_ets is a dummy variable and the dependent variable is in logarithmic form in the model, δ_1 is interpreted as the absolute effect that ETS has on the trade flow value. In the benchmark model, δ_1 is negative and has a large magnitude, which means that it has a very negative effect on export. The coefficient has the sign that we expected, however the results from this model are biased as we explained previously, it is preferable to look at the two other models. Surprisingly, when we control for fixed effects, in the two scenarios, δ_1 is positive, and it has the same magnitude in the two model estimation. But the second model provides estimate on δ_1 with lower standard errors. The estimate is statistically significant even at 1% level of significance, in all alternative estimations we performed. Thus, the estimated coefficient on eu_ets tells us that, when there is eu_ets, $tradeflow\_comtrade\_o$ increases by 24.4%. This means that, when EU ETS is in place, export from EU-15 countries are 24.4% higher. In other words, EU ETS does not lead to competitive disadvantage of regulated firms, if we take $export$ as an indicator of competitiveness. On the contrary, it increases competitiveness of European firms, which is in line with the findings of Costantini and Mazzanti (2012), Petrick and Wagner (2014) and Zhao (2011). The latter even precised that "when only the exporting countries have carbon tax, the carbon tax policy exerts positive influence on the international competitiveness of the energy-intensive industries of the exporting countries". As it was the case when only earlier ETS periods were considered in empirical analysis, this result could be explained by the ability of firms to pass-through the cost of EU ETS to output prices. Additionally, allowance allocation might not have been stringent enough to have negative impact on competitiveness. Subsequently, carbon price has not been that high during the entire three ETS phases, compared with carbon prices that we witness today. In February 2022, it has reached €90 the ton, while before 2021, the highest price was €32.72 in December 2020, and at some point in the first phase it was even zero (Trading, 2022). We run an one-sample student test, to test against the hypothesis that our estimate $\delta_1 \leqslant 0$, and we obtain a $p-value = 0$, thus we can reject the null hypothesis, and state with confidence that δ_1 is strictly positive. We will comment further on this impact of EU ETS on competitiveness in the discussion section.

Regarding the traditional variables that explains bilateral trade value, let us make the interpretation of the estimates by category of variable. Looking first at macroeconomic variables, GDP has a positive impact on trade in the benchmark and the two alternative estimations, coefficients have the expected sign. The estimates are statistically significant at least at 10% level, but coefficients on GDP of destination country is more significant. Therefore, if we consider the third column, a 1% change in gdp_o leads to a 0.184% change in $tradeflow\_comtrade\_o$, and a 1% change in gdp_d yields a 0.700% change in $tradeflow\_comtrade\_o$. However, the coefficients on population are negative in all regressions, and the estimates are statistically significant at 10% level, except for $lpop\_d$ in the third column (3). Population has the expected negative impact. Indeed, if we look at GDP per capita, if the population grows, all other things remaining equal, GDP per capita decreases, thus reducing international trade. Thus, if we look at estimates in column (2), a 1% change in pop_o yields a -1.650% change in $tradeflow\_comtrade\_o$, and when pop_d increases by 1%, $tradeflow\_comtrade\_o$ decreases by 0.147%. We run a test of joint significance for the macroeconomic variables, to test if at least one of the estimates is equal to 0, and we obtain a $p-value = 0$, thus we can reject the null hypothesis and conclude that our variables are jointly significant.

With regard to the geographic variables, the estimates on $ldistcap$ are statistically significant even at 1% level. They have the expected sign, thus when distance between capitals increases by 1%, trade flow decreases by 3.358% in column (3). However, the sign on $contig$ is ambiguous, we expected it to be positive, since sharing common borders should ease trade. However, this result might be explained by the fact that only 0.22% of our country-pairs have a common frontier, since we study trade between EU and NON-EU countries. This means that $contig$ should not influence much of the variation in bilateral trade that we attempt to explain in this study. We run a test of joint significance for the geographic variables, to test if at least one of the estimates is equal to 0, and we obtain a $p - value = 0$, thus we can reject the null hypothesis and conclude that our variables are jointly significant.

Moving to historical and cultural variables, $comlang\_off$ is statistically significant even at 1% level, it has the positive sign that we expected. The estimate from column (2) tells us for example that when the two trading partners share common official or primary language, $tradeflow\_comtrade\_o$ are 78.5% higher. Common language actually eases communication and documentation which are most of the time arduous in international trade. As for $comleg\_posttrans$, it also has the positive sign we expected in the benchmark model and the column (2), however estimate in column (3) is negative. Estimates are statistically significant at least at 5% level of significance. From column (2), we may say that if countries share common legal origins after 1991, trade flow is 12% higher. In addition, if country-pair ever was in colonial or dependency relationship (including before 1948), export increases by 84.7% in the second estimation (2). The estimates are highly significant, but the sign is ambiguous since column (3) does not give the positive sign that we expected. We run a test of joint significance for the cultural variables, to test if at least one of the estimates is equal to 0, and we obtain a $p - value = 0$, thus we can reject the null hypothesis and conclude that our variables are jointly significant.

Turning to trade facilitation variables at last, $gatt\_both$ is not significant in the benchmark estimation but as we move to alternative model specification it becomes significant. It has the positive sign that we expected, and if we look at estimates in column (3), when the two countries are currently GATT members, bilateral trade flow is 264.1% higher, which means that exports have more than tripled under GATT. Which can make sense, because The General Agreement on Tariffs and Trade (GATT) is a legal agreement between many countries, whose overall purpose was to promote international trade by reducing or eliminating trade barriers such as tariffs or quotas. Regarding wto_both, the sign of the estimate is as expected only in the benchmark model, it has a negative sign as we move to other model specifications. The estimates are neither statistically nor economically significant, in column (2) and (3), therefore we do not attempt to interpret them. The reason behind this is that there might be some multicollinearity between $gatt\_both$ and wto_both. The variable rta is not statistically significant, even at 10% level, in none of the three estimation we performed. In our model we also included variables about entry cost in the destination country, but $entry\_cost\_d$ is not statistically significant in column (2) and (3) and the estimates do not have the negative sign that we expected. Finally, $entry\_tp\_d$ has been included in the model with its quadratic form, estimates are statistically significant at level and has the negative sign that we expected. However, the estimate on the quadratic form of the variable loses significance as we improve model specification, the effect is also very small in magnitude but it has the positive sign that we expected. Consequently, because the coefficient on $entry\_tp\_d$ is negative and the coefficient on $entry\_tp\_d2$ is positive, this literally implies that, at low values of number of days plus number of procedures to start business in destination country, an additional day or procedure has a negative effect on $ltradeflow\_comtrade\_o$. At some point, the effect becomes positive, and the quadratic shape means that the semi-elasticity of trade flow with respect to $entry\_tp\_d$ is increasing as $entry\_tp\_d$ increases. We run a test of joint significance for the trade facilitation variables, to test if at least one of the estimates is equal to 0, and we obtain a $p - value = 0.95$, which is lower than 5%, thus we can reject the null hypothesis and conclude that our variables are jointly significant.

Overall, when we look at the adjusted R^2, the model with country-pair and time dummies explains better the variation in $ltradeflow\_comtrade\_o$ than the model with individual country and time dummies, the former has an adjusted R^2 value of 0.926, which is actually really good in the empirical literature. Baldwin and Taglioni (2006) argues that combination of pair and time dummies are superior to nation and time dummies in panel data analysis, and this may lead us to opt for the third column. Nevertheless, many of the estimates in column (3) do not have the sign we expected them to have, based on literature. If we try to explain this, we may say that the pair dummies control for all bilateral characteristics, thus some bilateral variables lose statistical robustness in our estimation. Since these are time-invariant such as our pair fixed effects. The case is different for unilateral variables in column (2), because there is no reason for GDP and population to not vary over time, therefore it is not accounted for in the country-specific fixed effects which are time-invariant in this model. Fortunately, we did not encounter such issues with the coefficients on the variable eu_ets, since the two models give approximately the same results, potential specification problem in either of the two model does not impede on our interpretation and the purpose of this study.

4.5 Discussion

Thus, according to our results, EU ETS still does not have significant negative impact on competitiveness, even when we consider longer periods and more recent data. Not only that but the positive estimates are statistically significant event at 1% level. The magnitude of the coefficient cannot be underestimated as well, a 24.4% increase remains important in empirical studies. This already gives an overview of what could be the answer of our research question in the next section. But much more important factors determine competitiveness, other than carbon price (Reinaud, 2008). Therefore, let us not stop there, our results might suffer from serious limitations, but it will allow us to raise some relevant questions and draw some recommendations in this section.

Now that we have considered EU ETS up to the end of phase 3, the idea is to look beyond that and it could be useful to have information about the forthcoming changes with EU ETS revision.

On 14 July 2021, the European Commission adopted a series of legislative proposals setting out how it intends to achieve climate neutrality in the EU by 2050, including the intermediate target of an at least 55% net reduction in greenhouse gas emissions by 2030. The package proposes to revise several pieces of EU climate legislation, including the EU ETS. Today, the EU ETS operates in 31 countries and covers 11.000 installations, which account for about 45% of the European emissions. The ETS is designed to reduce covered emissions in a cost-effective way by providing a price signal for carbon to the market. The revised EU ETS Directive, which will apply for the period 2021-2030 (phase 4), will enable the reduction of GHG emissions through a mix of measures that aims to strengthen the EU ETS for the next decade. The EU wants to speed up the pace of emissions cuts, the overall number of emission allowances will decline at an annual rate of 2.2% from 2021 onwards, compared to 1.74% in 2020. For less exposed sectors, free allocation is foreseen to be phased out after 2026 from a maximum of 30% to 0 at the end of phase 4 (2030). In fact, free allocation does not send correct price signals to economic agents, for them to actually reduce their CO2 emissions. More exposed sectors such as the iron and steel sector are very skeptical about this measure, even though The system of free allocation will be prolonged for another decade and has been revised to focus on sectors at the highest risk of relocating their production outside of the EU (Commission, 2021c). Additionally, the carbon price that we have witnessed mainly in the beginning of 2022 raises concerns, as it almost reached €90 (Trading, 2022).

From these, we may understand that CBAM might not be motivated by past experiences with the European carbon market. Indeed, CBAM is the product of anticipation, as EU ETS phase 4 will be even more stringent than phase 3. Thus, it is important for the EU to prevent carbon leakage and competitive disadvantage from actually becoming a real issue for its economy. If free allocation is meant to be phased out gradually, this should be done simultaneously with the progressive introduction of CBAM, to protect somehow European industries. Hence, CBAM as foreseen by the EU may present the following advantages. It is an extension of EU ETS and allows the elimination of free allocation. It will send the correct price signal to market participants and increase global climate ambition. With EU CBAM, countries will be on the same level playing field with the extension of carbon pricing to imports. Therefore, CBAM might induce other countries to take responsibility in emissions reduction, but also encourage innovation in abatement technologies, investment in new and green technology, and ultimately change in behaviour. And above all things, it will help reduce CO2 emissions from human activities, and solve global warming and climate change issues.

However, many technical points are to be considered for the implementation of a CBAM (Monjon and Quirion, 2010; Cosbey et al., 2012), which are not only technical details without consequences, but would determine the viability of this policy option under international laws. The first aspect to be properly determined is the range of covered sectors, there is a general consensus in the literature that only sectors at risk should be covered by this type of scheme, however, the classification of sectors being at risk or not may be controversial, such as we encountered for the third phase of EU ETS (Clò, 2010; Martin et al., 2012). Then, the list of covered countries is also substantial. Exceptions might be required, for example, for poor and Least Developed Countries

(LDC) for equity purposes, or for countries that have taken comparable action on climate policies, as in the Waxman-Markey bill (Sheppard, 2009). However, climate policies are so diverse that comparing different climate policies is not an easy task, whether it is a mix of carbon pricing, subsidies or regulation. We can distinguish two principles on which comparison can be performed "comparability in effectiveness" as in the WTO Shrimp–Turtle dispute (Davey, 2005) or "comparability of efforts" as in the Common but Differentiated Responsibilities principle (Rajamani, 2000). The method of quantifying the carbon content of a product is also crucial. Four options could be considered according to the literature on CBAM, which are respectively home country's average emissions, exporter's average emissions, self-declaration and best available technology (BAT) based on benchmarks. Because of information asymmetry and administrative costs, a reliable knowledge of the carbon content of every foreign product seems out of range. The estimations should be rather conservative to avoid a WTO challenge because of discrimination, thus one will tend to favor BAT benchmarking, or a choice between home country's average emissions and self-declaration (Ismer and Neuhoff, 2007). Another important question is the inclusion or not of indirect emissions. For instance, considering the indirect emissions from electricity consumption can be relevant for industries with high electricity costs, such as aluminum, but it also extremely complicates the calculations. We cannot also forget that the energy mix differs among countries, and calculation of emissions from electricity consumption is likely to cause disagreement, because of differences between average and marginal specific emissions. The legal form of the CBAM raises also significant questions. Indeed, the adjustment could take the form of an obligation to surrender allowances, the origin of which is to be determined or of a tax. There are also concerns about the timing, for example a period of good faith could be offered to third countries before the full implementation of such measures. Clear conditions for phasing out must also be decided, because a well-designed CBAM is meant to disappear. Inclusion of export rebates could also be useful to level the playing field in third countries markets, but their WTO compatibility is not guaranteed according to the literature. A last dimension of CBAM that could influence its good functioning is the use of revenues generated from the CBAM itself. Many have argued that these revenues could be used to finance clean technology transfer or adaptation through a Green Climate Fund (Godard, 2009; Springmann, 2013).

Conclusion

CO_2 emission certificates help internalise effects of fossil fuel consumption on global climate. However, consumption, production and investment decisions do not reach the optimal allocation when the system is only implemented in some countries. Production with inefficient facilities in non-participating countries may even increase (Ismer and Neuhoff, 2007). This is the case when the EU ETS was put in place in 2005, EU firms may experience competitive disadvantage compared with foreign competitors as long as they are the only one incurring additional carbon taxes. Hence the decision to adopt a Carbon Border Adjustment Mechanism in July 2021, as part of the EU Green Deal. The system mirrors the European carbon market for foreign products coming into the EU, and thus set a carbon price for import based on the weekly average price of EU ETS allowance. Nevertheless, this decision is very controversial within international community, and even among selected sectors, because the counterpart for EU sectors will be the gradual elimination of free allocation of emission certificates. Consequently, we found it essential to deepen our understanding of CBAM, and came to know that being an extension of ETS, it aims to solve global warming problem through reduction of CO_2 emissions. It is a price instrument according to environmental economics theory, and from a complete policy evaluation point of view, its design is crucial for it to be successfully implemented for the first time in the EU. Afterwards, we were further interested into looking thoroughly at the motivations for a CBAM, and found that in the existing literature considering EU ETS period up to 2015, EU ETS does not have a significance impact on firms competitiveness, and when it does, the effect is even positive, see for instance Commins et al. (2011), Abrell et al. (2011), Lutz (2016), Marin et al. (2018), and Klemetsen et al. (2016).

The research objective was therefore to update the results in the scientific literature about EU ETS impact on competitiveness. To do so, we collected data until 2020, the end of Phase 3, and applied a gravity model approach to our sample data covering 15 EU exporters and 216 NON-EU importers. This means that the measure of competitiveness is $export$ and the variable ETS has been introduced in the model as a dummy variable, taking the value 1 during ETS, and 0 otherwise. Ultimately, we would like to know if competitive disadvantage due to EU ETS justifies the introduction of CBAM. Our results then indicate that EU ETS had a positive impact on $export$ and the estimates are statistically significant, no matter how the model is specified. When the EU ETS is in place, exports from EU-15 to NON-EU countries, except EFTA member countries, are 24.4% higher. From this, we may answer our research question and state that EU ETS does not have detrimental effects on competitiveness, therefore competitive disadvantage cannot be an argument for a Carbon Border Adjustment Mechanism in this case.

However, our results could be far from being conclusive, despite a very high R^2. The empirical analysis that we have conducted suffer from various limitations. Firstly, it is a multisectoral analysis, the motivation behind this was that ultimately, the range of sector being subject to CBAM will be increased after 2026. But sectors are highly heterogenous, impact of EU ETS on one sector to another might vary differently, and we could not control for this heterogeneity in our model. Secondly, we were not able to conduct a panel data analysis due to the very large number of dummy variables to be estimated, we actually encountered computational feasibility issues during the process. As a result, we surely have serial correlation across the error terms, and this impact the efficiency of our estimates. Thereafter, we made the assumption that missing trade data corresponded to zero trade values. The existence of many zero in trade values induces a potential bias (Silva and Tenreyro, 2006). Finally, we could have controlled for other variables such as the exchange rate, but we were unfortunately constrained by data availability.

Though we did not get a negative estimate on the coefficient of eu_ets, and could not justify a CBAM with competitive disadvantage, this does not mean that a CBAM will not be required. As we have seen in the previous section, CBAM might not be motivated by past experience due to EU ETS. Indeed, thanks to free allocation under the three first phases, its effect has been offset. In fact, CBAM is more motivated by anticipation of forthcoming changes due to increased climate ambition and current EU ETS reforms. This means that CBAM will be required soon as the fear we had about consequences of ETS in the past on carbon leakage and competitive disadvantage might really be justified in a near future, as a result of Phase 4 presented previously. Moreover, CBAM has also the advantage to induce other countries to take responsibility in the fight against global warming, and ultimately climate change. A CBAM might achieve a second best optimum, compared with EU ETS, but since we are facing a situation with multiple equilibria, the first best optimum might be one in which we would have a world integrated carbon market.

While pondering this research master thesis, we could actually observe that unilateral environmental policy cannot be fully effective because of free trade, but also efforts toward more sustainable economies weaken the World Trade Organisation's sovereignty in governing trade between nations. Hence, future research could inspect the possibility to reconcile trade and environment. More interestingly, our current international trade system might be a potential template for developing more integrated environmental policies. To begin with, it will be important to analyse how trade impacts the environment. Thereafter, in the case of unilateral environmental policy as we have witnessed until today, effectiveness of border adjustment implementation has to be examined. Finally, we could assess whether international trade should be restricted to meet the commitments in the Paris Agreement, or how could we possibly reconcile these two. Climate change is the biggest challenge of our times, and it is an opportunity to build a new economic model.

Appendices

Greenhouse gases heating influence

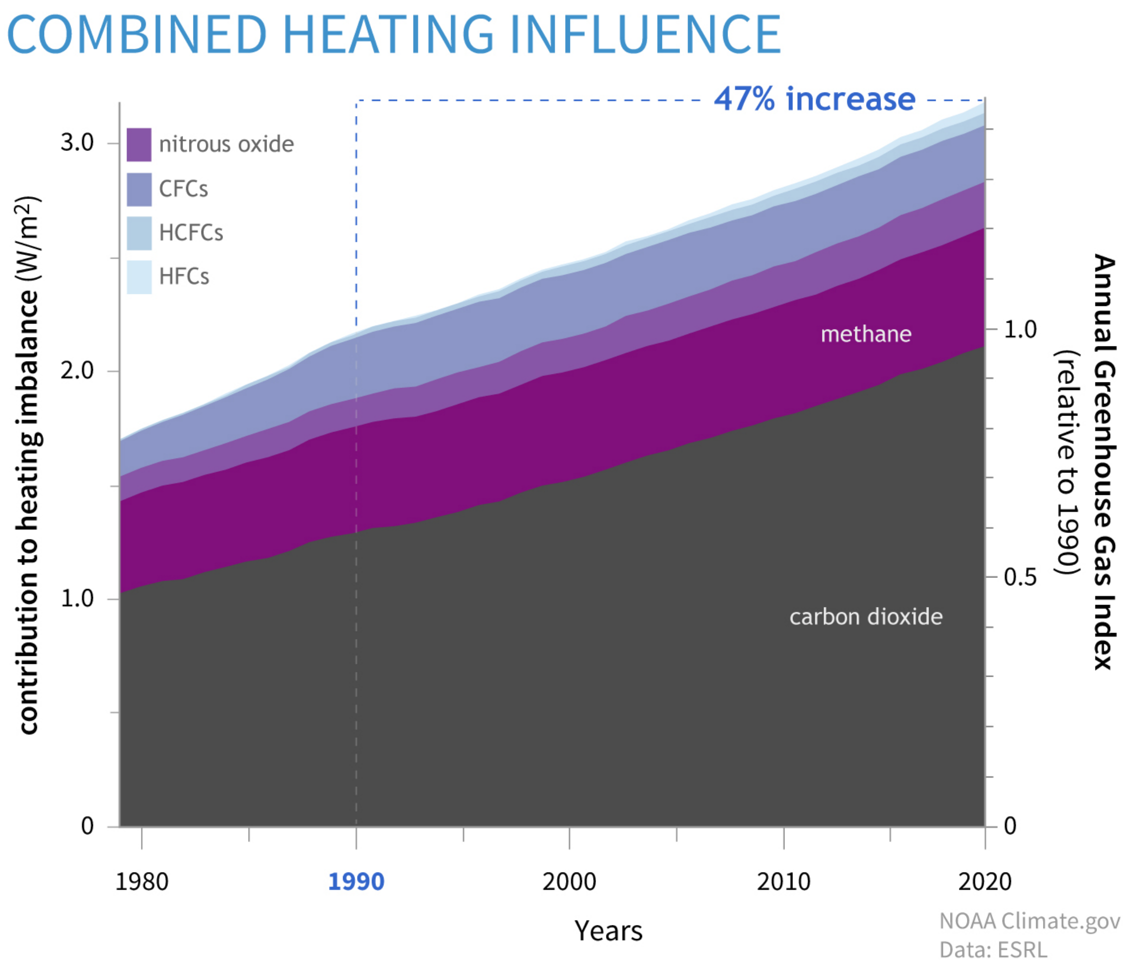

Figure 6.1: Heating imbalance caused by the major human-produced greenhouse gases

Source: NOAA Climate.gov based on data from NOAA ESRL

CBAM sector coverage

Sector/Materials or Material Products	Imports, million euros	Imports, thousands of tons
Cement		
Clinker	111	2,166
Portland cement	130	2,314
Iron & Steel		
Iron & steel primary forms	4,208	9,485
Hot rolled & further steps	350	530
Coated hot rolled & further	3,945	5,291
Forged, extruded and wire	1,269	2,350
Aluminum		
Aluminum unwrought	4,919	2,790
Aluminum unwrought alloyed	5,956	3,110
Aluminum products	2,490	903
Alloyed aluminum products	3,977	1,310
Fertilizers		
Ammonia	799	3,283
Urea	1,029	4,117
Nitric acid	17	124
Ammonium Nitrate	67	336

Figure 6.2: Initial Shortlist of Products for CBAM; Volume and Value of Total Imports of EU-27 in 2019

Source: Derived from CBAM Impact Assessment, Section 5, Table 1 and Figure 4, pp. 23-24. (DG TAXUD, 2020)

Stata Do File

```
*********************************************
*********************************************
**                                        **
** Voahary ANDRIAMAROMANANA               **
** Master in Economic Analysis and Policy   **
** HEC Management School                  **
** Academic Year 2021 - 2022              **
**                                        **
*********************************************
*********************************************


                    // RESEARCH THESIS STATA COMMAND //


******************************************************************

//CLEANING GRAVITY DATABASE

keep if iso3_o=="AUT"|iso3_o=="BEL"|iso3_o=="DEU"|iso3_o=="DNK"|
iso3_o=="FIN"|iso3_o=="FRA"|iso3_o=="GRC"|iso3_o=="ITA"|iso3_o==
"ESP"|iso3_o=="PRT"|iso3_o=="SWE"|iso3_o=="GBR"|iso3_o=="LUX"|
iso3_o=="IRL"|iso3_o=="NLD"

drop if eu_d==1

drop if iso3_d=="CHE"|iso3_d=="ISL"|iso3_d=="LIE"|iso3_d=="NOR"

drop if year<1996

******************************************************************

//MISSING VALUES 2020

browse

foreach var of varlist country_exists_o country_exists_d
gmt_offset_2020_o gmt_offset_2020_d contig dist distw distcap
distwces dist_source comlang_off comlang_ethno comcol comrelig
col45 comleg_pretrans comleg_posttrans legal_old_o legal_old_d
legal_new_o legal_new_d comleg_pretrans comleg_posttrans
transition_legalchange heg_o heg_d col_dep_ever col_dep
col_dep_end_year col_dep_end_conflict empire sibling_ever sibling
sever_year sib_conflict gatt_o gatt_d wto_o wto_d eu_o eu_d rta
rta_coverage rta_type entry_cost_o entry_cost_d entry_proc_o
entry_proc_d entry_time_o entry_time_d entry_tp_o entry_tp_d{
    replace `var'=`var'[_n-1] if missing(`var')
}
```

```

********************************************************************

// CREATE VAR THAT LIST COUNTRIES WITH NUMERICAL CODES

egen exp=group(iso3_o)
egen imp=group(iso3_d)

egen pairid=group(exp imp)

********************************************************************

// CREATE ALL POSSIBLE COUNTRY-PAIR YEAR OBSERVATION

fillin exp imp year

// ASSUMPTION THAT MISSING TRADE DATA CORRESPONDS TO ZERO TRADE

replace tradeflow_comtrade_o=0 if tradeflow_comtrade_o==.

********************************************************************

// DUMMY VARIABLES

// ETS

gen eu_ets=.
replace eu_ets=1 if year>2004
replace eu_ets=0 if year<2005

// UNILATERAL TO BILATERAL VARIABLES

gen gatt_both=.
replace gatt_both=1 if gatt_o==1 & gatt_d==1
replace gatt_both=0 if gatt_d==0 //same for wto_both

********************************************************************

// DESCRIPTIVE STAT

sum tradeflow_comtrade_o if tradeflow_comtrade_o!=0, detail

// GRAPH

bysort year: egen mtradeflow_comtrade_o = mean(tradeflow_comtrade_o)

twoway (line mtradeflow_comtrade_o year) if ltradeflow_comtrade_o
!=0, ytitle(Average trade flow) xtitle(Year) title(Evolution of
```

```
export from EU-15) subtitle(1996 - 2020) caption(Source: Author's own computation) name(trade_graph, replace)

graph export trade_graph.eps, as(eps) preview(off) replace

*******************************************************************

// FUNCTIONAL FORM

gen ltradeflow_comtrade_o=log(tradeflow_comtrade_o)
gen lgdp_o=log(gdp_o) //and so on

gen entry_tp_d2=entry_tp_d^2

*******************************************************************

// REGRESSION

*******************************************************************

// CROSS SECTION

*** TEST FOR HETEROSKEDASTICITY ***

regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap entry_cost_d entry_tp_d entry_tp_d2 eu_ets contig comlang_off comleg_posttrans col_dep_ever gatt_both wto_both rta

estat hettest, fstat rhs //BP F-test or
estat hettest, iid rhs //BP-LM

*** Cross-sectional analysis without FE ***

regress ltradeflow_comtrade_o lgdp_o lgdp_d ldistcap contig eu_ets, robust cluster(distcap) //Geographic variables

regress ltradeflow_comtrade_o lgdp_o lgdp_d ldistcap eu_ets contig comlang_off comleg_posttrans col_dep_ever, robust cluster(distcap) //Add Cultural variables

regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap eu_ets contig comlang_off comleg_posttrans col_dep_ever, robust cluster(distcap) //Add more Macroeconomic variables

regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap eu_ets contig comlang_off comleg_posttrans col_dep_ever gatt_both wto_both rta, robust cluster(distcap) //Add trade facilitation variables
```

```
regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap
entry_cost_d entry_tp_d entry_tp_d2 eu_ets contig comlang_off
comleg_posttrans col_dep_ever gatt_both wto_both rta, robust
cluster(distcap) //Add more trade facilitation variables

*** Cross-sectional analysis with FE ***

regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap
entry_cost_d entry_tp_d entry_tp_d2 eu_ets contig comlang_off
comleg_posttrans col_dep_ever gatt_both wto_both rta i.exp i.imp i.
year, robust cluster(distcap) //nation and time dummies

regress ltradeflow_comtrade_o lgdp_o lgdp_d lpop_o lpop_d ldistcap
entry_cost_d entry_tp_d entry_tp_d2 eu_ets contig comlang_off
comleg_posttrans col_dep_ever gatt_both wto_both rta i.pairid i.
year, robust cluster(distcap) //pair and time dummies

********************************************************************

// PANEL DATA (Trial)

// DEFINE DATA AS PANEL DATABASE

xtset pairid year

// DESCRIBE THE PATTERN OF PANEL DATA

xtdescribe // ==> STRONGLY BALANCED

// Time-variant FIXED EFFECTS

tab (year), gen (year_)
tab (exp_year), gen (expyear__)
tab (imp_year), gen (impyear__)

// PANEL REGRESSION

xtreg ltradeflow_comtrade_o ldistcap eu_ets contig comlang_off
comleg_posttrans col_dep_ever gatt_both wto_both rta i.exp_year i.
imp_year i.year, robust fe //Only time-varying bilateral variables
and exporter/importer/year FE

xtreg ltradeflow_comtrade_o ldistcap eu_ets contig comlang_off
comleg_posttrans col_dep_ever gatt_both wto_both rta expyear_*
impyear_* year_*, robust fe //Only time-varying bilateral
variables and exporter/importer/year FE
```

```
************************************************************************

// IMPORT TABLES

eststo without

esttab without using reg1modified.tex, se star(* 0.1 ** 0.05 *** 0.01) ar2 title(Without FE) nodepvars numbers mtitles("(1)" "(2)") booktabs long
import // Same for two other regression

************************************************************************

// TEST

// F TEST

test lgdp_o lgdp_d lpop_o lpop_d

// T TEST

ttest

************************************************************************
```

Bibliography

Abrell, J., Ndoye Faye, A., and Zachmann, G. (2011). Assessing the impact of the EU ETS using firm level data. Working Paper 2011/08, Bruegel Working Paper.

Anderson, J. E. (1979). A theoretical foundation for the gravity equation. The American economic review, 69(1):106–116.

Anderson, J. E. and Van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. American economic review, 93(1):170–192.

Anouliés, L. (2015). The strategic and effective dimensions of the border tax adjustment. Journal of Public Economic Theory, 17(6):824–847.

Anson, J., Cadot, O., Estevadeordal, A., Melo, J. d., Suwa-Eisenmann, A., and Tumurchudur, B. (2005). Rules of origin in north–south preferential trading arrangements with an application to nafta. Review of International Economics, 13(3):501–517.

Babiker, M. H. and Rutherford, T. F. (2005). The economic effects of border measures in subglobal climate agreements. The Energy Journal, 26(4).

Baier, S. L. and Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? Journal of international Economics, 71(1):72–95.

Baldwin, R. and Taglioni, D. (2006). Gravity for dummies and dummies for gravity equations. National bureau of economic research Cambridge, Mass., USA.

Bao, Q., Tang, L., Zhang, Z., and Wang, S. (2013). Impacts of border carbon adjustments on china's sectoral emissions: Simulations with a dynamic computable general equilibrium model. China Economic Review, 24:77–94.

Barrett, S. (2008). Climate treaties and the imperative of enforcement. Oxford review of economic policy, 24(2):239–258.

Berger, T. (2008). Concepts of national competitiveness. Journal of international Business and Economy, 9(1):91–111.

Bergstrand, J. H. (1985). The gravity equation in international trade: some microeconomic foundations and empirical evidence. The review of economics and statistics, pages 474–481.

Böhringer, C., Balistreri, E. J., and Rutherford, T. F. (2012). The role of border carbon adjustment in unilateral climate policy: Overview of an energy modeling forum study (emf 29). Energy Economics, 34:S97–S110.

Boutabba, M. A. and Lardic, S. (2017). EU Emissions Trading Scheme, competitiveness and carbon leakage: new evidence from cement and steel industries. Annals of Operations Research, 255(1):47–61.

Branger, F. and Quirion, P. (2014). Climate policy and the carbon haven effect. Wiley Interdisciplinary Reviews: Climate Change, 5(1):53–71.

Branger, F., Quirion, P., and Chevallier, J. (2016). Carbon Leakage and Competitiveness of Cement and Steel Industries Under the EU ETS: Much Ado About Nothing. Energy Journal, 37(3):109–135. Publisher: International Association for Energy Economics, Inc.

Brewer, T. et al. (2010). Trade policies and climate change policies: a rapidly expanding joint agenda. World Economy, 33(6):799–809.

Caron, J. (2012). Estimating carbon leakage and the efficiency of border adjustments in general equilibrium Does sectoral aggregation matter? Energy economics, 34:S111–S126. Publisher: Elsevier BV.

Carrère, C. and De Melo, J. (2004). Are different rules of origin equally costly? estimates from nafta. Estimates from NAFTA (June 2004).

Chan, H. S. R., Li, S., and Zhang, F. (2013). Firm competitiveness and the European Union emissions trading scheme. Energy Policy, 63:1056–1064.

Chaney, T. (2018). The gravity equation in international trade: An explanation. Journal of Political Economy, 126(1):150–177.

Chase, P. and Pinkert, R. (2021). The eus triangular dilemma on climate and trade. German Marshall Fund, Policy Brief, pages 2021–09.

Chen, W. and Guo, Q. (2017). Assessing the effect of carbon tariffs on international trade and emission reduction of chinas industrial products under the background of global climate governance. Sustainability, 9(6):1028.

Clò, S. (2010). Grandfathering, auctioning and carbon leakage: Assessing the inconsistencies of the new ets directive. Energy Policy, 38(5):2420–2430.

Commins, N., Lyons, S., Schiffbauer, M., and Tol, R. S. (2011). Climate Policy & Corporate Behavior. The Energy Journal, 32(4):51–68. Publisher: International Association for Energy Economics.

Commission, E. (2019). The european green deal. https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6691(accessedJanuary16,2022).

Commission, E. (2021a). Carbon border adjustment mechanism. https://ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en(accessedJanuary16,2022).

Commission, E. (2021b). Eu emissions trading system (eu ets). https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en(accessedJanuary16,2022).

Commission, E. (2021c). Revision for phase 4 (2021-2030). https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/revision-phase-4-2021-2030_en.

Commission, E. (2022). Development of eu ets (2005-2020). Climate Action, https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en.

Cosbey, A., Droege, S., Fischer, C., and Munnings, C. (2020). Developing guidance for implementing border carbon adjustments: lessons, cautions, and research needs from the literature. Review of Environmental Economics and Policy.

Cosbey, A., Droege, S., Fischer, C., Reinaud, J., Stephenson, J., Weischer, L., and Wooders, P. (2012). A guide for the concerned: Guidance on the elaboration and implementation of border carbon adjustment.

Costantini, V. and Mazzanti, M. (2012). On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports. Research Policy, 41(1):132–153.

Davey, W. J. (2005). The wto dispute settlement system: the first ten years. Journal of International Economic Law, 8(1):17–50.

Dechezleprêtre, A., Nachtigall, D., and Venmans, F. (2018). The joint impact of the European Union emissions trading system on carbon emissions and economic performance. Technical report, OECD, Paris.

Demailly, D. and Quirion, P. (2006). Co2 abatement, competitiveness and leakage in the european cement industry under the eu ets: grandfathering versus output-based allocation. Climate Policy, 6(1):93–113.

Demailly, D. and Quirion, P. (2008). European emission trading scheme and competitiveness: A case study on the iron and steel industry. Energy economics, 30(4):2009–2027.

DG TAXUD, U. C. (2020). Inception impact assessment: Carbon border adjustment mechanism (european commission, march 2020). https://www.euractiv.com/wp-content/uploads/sites/2/2020/07/CBAM.pdf.

Eicke, L., Weko, S., Apergi, M., and Marian, A. (2021). Pulling up the carbon ladder? decarbonization, dependence, and third-country risks from the european carbon border adjustment mechanism. Energy Research & Social Science, 80:102240.

Estevadeordal, A. and Suominen, K. (2006). Mapping and measuring rules of origin around the world. The origin of goods: rules of origin in regional trade agreements, pages 69–114.

Felder, S. and Rutherford, T. F. (1993). Unilateral co2 reductions and carbon leakage: The consequences of international trade in oil and basic materials. Journal of Environmental Economics and management, 25(2):162–176.

Fischer, C. and Fox, A. K. (2012). Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates. Journal of Environmental Economics and management, 64(2):199–216.

Godard, O. (2009). L'ajustement aux frontières, manœuvre protectionniste ou pivot d'un nouveau régime international? Regards croisés sur l'économie, (2):214–228.

Grubb, M. and Neuhoff, K. (2006). Allocation and competitiveness in the eu emissions trading scheme: policy overview. Climate Policy, 6(1):7–30.

Harris, M. N., Konya, L., and Matyas, L. (2002). Modelling the impact of environmental regulations on bilateral trade flows: Oecd, 1990–1996. World Economy, 25(3):387–405.

Head, K. and Mayer, T. (2010). The erosion of colonial trade linkages after independence. Journal of International Economics, 81(1):1–14.

Head, K. and Mayer, T. (2013). Gravity equations: Workhorse,toolkit, and cookbook. Working Papers 2013-27, CEPII.

Helm, D., Hepburn, C., and Ruta, G. (2012). Trade, climate change, and the political game theory of border carbon adjustments. Oxford review of economic policy, 28(2):368–394.

Helpman, E. (1987). Imperfect competition and international trade: Evidence from fourteen industrial countries. Journal of the Japanese and international economies, 1(1):62–81.

Helpman, E., Melitz, M., and Rubinstein, Y. (2008). Estimating trade flows: Trading partners and trading volumes. The quarterly journal of economics, 123(2):441–487.

Hoel, M. (1991). Global environmental problems: the effects of unilateral actions taken by one country. Journal of environmental economics and management, 20(1):55–70.

Holmes, P., Reilly, T., and Rollo, J. (2011). Border carbon adjustments and the potential for protectionism. Climate Policy, 11(2):883–900.

Hughes, L. (2000). Biological consequences of global warming: is the signal already apparent? Trends in ecology & evolution, 15(2):56–61.

Ismer, R. and Neuhoff, K. (2007). Border tax adjustment: a feasible way to support stringent emission trading. European Journal of Law and Economics, 24(2):137–164.

Jaraité, J. and Di Maria, C. (2016). Did the EU ETS Make a Difference? An Empirical Assessment Using Lithuanian Firm-Level Data. Energy Journal, 37(1):1–23. Publisher: International Association for Energy Economics, Inc.

Klemetsen, M. E., Rosendahl, K. E., and Jakobsen, A. L. (2016). The impacts of the EU ETS on Norwegian plants' environmental and economic performance. Working Paper 833, Discussion Papers.

Koul, A. K. (2018). Schedules of concessions (article ii). In Guide to the WTO and GATT, pages 105–114. Springer.

Krugman, P. (1994). Competitiveness: a dangerous obsession. Foreign Aff., 73:28.

Kuik, O. and Hofkes, M. (2010). Border adjustment for European emissions trading: Competitiveness and carbon leakage. Energy policy, 38(4):1741–1748. Place: Kidlington Publisher: Elsevier Ltd.

La Porta, R., Lopez-de Silanes, F., and Shleifer, A. (2008). The economic consequences of legal origins. Journal of economic literature, 46(2):285–332.

La Porta, R., Lopez-de Silanes, F., Shleifer, A., and Vishny, R. (1999). The quality of government. The Journal of Law, Economics, and Organization, 15(1):222–279.

Lessmann, K., Marschinski, R., and Edenhofer, O. (2009). The effects of tariffs on coalition formation in a dynamic global warming game. Economic Modelling, 26(3):641–649.

Lim, B., Hong, K., Yoon, J., Chang, J.-I., and Cheong, I. (2021). Pitfalls of the EUs Carbon Border Adjustment Mechanism. Energies, 14(21):7303.

Lindsey, R. (2021). Climate change: Atmospheric carbon dioxide. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

Lindsey, R. and Dahlman, L. (2021). Climate change: Global temperature. National Centers for Environmental Information.

Linnemann, H. (1966). An econometric study of international trade flows. Number 42. Amsterdam, North-Holland.

Lundgren, T., Marklund, P.-O., Samakovlis, E., and Zhou, W. (2015). Carbon prices and incentives for technological development. Journal of Environmental Management, 150:393–403.

Lüthi, D., Le Floch, M., Bereiter, B., Blunier, T., Barnola, J.-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K., et al. (2008). High-resolution carbon dioxide concentration record 650,000–800,000 years before present. nature, 453(7193):379–382.

Lutz, B. J. (2016). Emissions trading and productivity : firm-level evidence from German manufacturing. Working paper, Mannheim. Publication Title: ZEW Discussion Papers Volume: 16-067.

Löschel, A., Lutz, B. J., and Managi, S. (2019). The impacts of the EU ETS on efficiency and economic performance An empirical analyses for German manufacturing firms. Resource and Energy Economics, 56:71–95.

Magnusson, M. (2004). Climate and trade rules: harmony or conflict. Kommerskollegium (Chambre de commerce nationale), Stockholm, Suède.

Marin, G., Marino, M., and Pellegrin, C. (2018). The Impact of the European Emission Trading Scheme on Multiple Measures of Economic Performance. Environmental and Resource Economics, 71(2):551–582.

Martin, R., Muûls, M., de Preux, L. B., and Wagner, U. J. (2012). Cep discussion paper no 1150 june 2012 industry compensation under relocation risk: A firm-level analysis of the eu emissions trading scheme.

Mattoo, A., Subramanian, A., Van Der Mensbrugghe, D., and He, J. (2009). Reconciling climate change and trade policy. Center for Global Development Working Paper, (189).

Mattoo, A., Subramanian, A., van der Mensbrugghe, D., and He, J. (2013). Trade effects of alternative carbon border-tax schemes. Review of World Economics, 149(3):587–609.

Mehling, M. A., Asselt, H. v., Das, K., Droege, S., and Verkuijl, C. (2019). Designing Border Carbon Adjustments for Enhanced Climate Action. American Journal of International Law, 113(3):433–481. Publisher: Cambridge University Press.

Mélières, M.-A. and Maréchal, C. (2015). Climate Change: Past, Present, and Future. John Wiley & Sons.

Monjon, S. and Quirion, P. (2010). How to design a border adjustment for the european union emissions trading system? Energy policy, 38(9):5199–5207.

Monjon, S. and Quirion, P. (2011). Addressing leakage in the eu ets: Border adjustment or output-based allocation? Ecological Economics, 70(11):1957–1971.

Muller, B. (2012). From confrontation to collaboration? cbdr and the eu ets aviation dispute with developing countries. Oxford Energy and Environmental Brief.

NASA (2020 (accessed January 16, 2022)). Overview: Weather, global warming, and climate change. https://climate.nasa.gov/resources/global-warming-vs-climate-change/.

Obernhofer, U., Rennings, K., and Sahin, B. (2006). The impacts of the european emissions trading scheme on competitiveness and employment in europe: a literature review.

OECD (2020). G20 gdp growth - first quarter of 2020. https://www.oecd.org/economy/g20-gdp-growth-first-quarter-2020-oecd.htm.

OED, O. (2022a). Co2, n. Oxford University Press, https://www.oed.com/view/Entry/93783588?redirectedFrom=co2(accessedFebruary25,2022).

OED, O. (2022b). photosynthesis, n. Oxford University Press, https://www.oed.com/view/Entry/142901?redirectedFrom=photosynthesis(accessedFebruary25,2022).

OED, O. (2022c). respiration, n. Oxford University Press, https://www.oed.com/view/Entry/163815?redirectedFrom=respiration(accessedFebruary25,2022).

Parliament (2022 (accessed January 16, 2022)). Carbon border adjustment mechanism as part of the european green deal. https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-carbon-border-adjustment-mechanism.

Pauwelyn, J. (2007). Us federal climate policy and competitiveness concerns: the limits and options of international trade law. Nicholas Institute for Environmental Policy Solutions WP, pages 07–02.

Pearce, W., Holmberg, K., Hellsten, I., and Nerlich, B. (2014). Climate change on twitter: Topics, communities and conversations about the 2013 ipcc working group 1 report. PloS one, 9(4):e94785.

Peters, G. P., Le Quéré, C., Andrew, R. M., Canadell, J. G., Friedlingstein, P., Ilyina, T., Jackson, R. B., Joos, F., Korsbakken, J. I., McKinley, G. A., Sitch, S., and Tans, P. (2017). Towards real-time verification of CO2 emissions. Nature Climate Change, 7(12):848–850.

Peterson, E. B. and Schleich, J. (2007). Economic and environmental effects of border tax adjustments. Technical report, Working Paper Sustainability and Innovation.

Petrick, S. and Wagner, U. J. (2014). The impact of carbon trading on industry: Evidence from German manufacturing firms. Working Paper 1912, Kiel Working Paper.

Policy Design, L. (2013 (accessed January 16, 2022)). Policy instruments and tools. http://policy-design.org/wiki/what-is-policy-design/policy-instruments-and-tools/.PromotingWaste-to-Energy183.

Pöyhönen, P. (1963). A tentative model for the volume of trade between countries. Weltwirtschaftliches Archiv, pages 93–100.

Protocol, K. (1997). United nations framework convention on climate change. Kyoto Protocol, Kyoto, 19(8):1–21.

RAC (2021 (accessed January 16, 2022)). Le mÉcanisme dajustement carbone aux frontiÈres de lunion europÉenne. https://reseauactionclimat.org/wp-content/uploads/2021/07/position-rac-cbam.pdf.

Rajamani, L. (2000). The principle of common but differentiated responsibility and the balance of commitments under the climate regime. Rev. Eur. Comp. & Int'l Envtl. L., 9:120.

Reinaud, J. (2008). Climate Policy and Carbon Leakage Analysis. International Energy Agency, https://www.iea.org/reports/climate-policy-and-carbon-leakage.

Rose, A. K. (2000). One money, one market: the effect of common currencies on trade. Economic policy, 15(30):08–45.

Sampson, G. P. (2001). Wto rules and climate change: the need for policy coherence. Inter-linkages: The Kyoto Protocol and the International Trade and Investment Regimes.

Sartor, O. (2012). Carbon Leakage in the Primary Aluminium Sector.

Shan, Y., Guan, D., Zheng, H., Ou, J., Li, Y., Meng, J., Mi, Z., Liu, Z., and Zhang, Q. (2018). China co2 emission accounts 1997–2015. Scientific data, 5(1):1–14.

Sheppard, K. (2009). Everything you always wanted to know about the waxman-markey energy/-climate billin bullet points. Grist Magazine, Inc.

Silva, J. S. and Tenreyro, S. (2006). The log of gravity. The Review of Economics and statistics, 88(4):641–658.

Springmann, M. (2013). Carbon tariffs for financing clean development. Climate Policy, 13(1):20–42.

Stiglitz, J. E. (2011). 3. A New Agenda for Global Warming. Columbia University Press.

Tang, L., Bao, Q., Zhang, Z., and Wang, S. (2015). Carbon-based border tax adjustments and chinas international trade: analysis based on a dynamic computable general equilibrium model. Environmental Economics and Policy Studies, 17(2):329–360.

Tinbergen, J. (1962). Shaping the world economy; suggestions for an international economic policy.

Trading, E. (2022). Eu carbon permits. https://tradingeconomics.com/commodity/carbon.

UN (2022). Un comtrade. United Nations - UN Trade statistics, https://comtrade.un.org.

Van Beers, C. and Van Den Bergh, J. C. (1997). An empirical multi-country analysis of the impact of environmental regulations on foreign trade flows. Kyklos, 50(1):29–46.

Verde, S. F. (2020). The Impact of the Eu Emissions Trading System on Competitiveness and Carbon Leakage: The Econometric Evidence. Journal of Economic Surveys, 34(2):320–343. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/joes.12356.

Voituriez, T. and Wang, X. (2011). Getting the carbon price right through climate border measures: a chinese perspective. Climate Policy, 11(5):1257–1261.

Walheer, B. (2021-2022). ECON2295-1 Environmental Economics. Course, HEC Management School, University of Liege.

WDI (2022). World development indicators. The World Bank, https://datatopics.worldbank.org/world-development-indicators/.

Weitzel, M., Hübler, M., and Peterson, S. (2012). Fair, optimal or detrimental? environmental vs. strategic use of border carbon adjustment. Energy Economics, 34:S198–S207.

WITS (2022). World integrated trade solution. The World Bank, https://wits.worldbank.org/about_wits.html.

Wolfrum, R., Stoll, P.-T., and Holger, P. (2010). Article xx general exceptions.

Workman, D. (2020). Top eu export countries. https://www.worldstopexports.com/top-european-export-countries/.

Yu, H. (2013). The EU ETS and firm profits: an ex-post analysis for Swedish energy firms. Environmental Economics, 4(3). Publisher: LLC "CPC "Business Perspectives".

Zedalis, R. J. (2002). Gmo food measures as" restrictions" under gatt article xi (1). European Energy and Environmental Law Review, 11(1).

Zhang, Z. and Assunção, L. (2004). Domestic climate policies and the wto. World Economy, 27(3):359–386.

Zhao, Y.-H. (2011). The study of effect of carbon tax on the international competitiveness of energy-intensive industries: an empirical analysis of oecd 21 countries, 1992-2008. Energy Procedia, 5:1291–1302.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., Wei, L., et al. (2021). Additional profits of sectors and firms from the eu ets 2008-2019.

Executive summary

CO_2 concentrations continue to rise significantly, and it is responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise. Fortunately, CO_2 emission certificates, as implemented under EU ETS, help internalise effects of fossil fuel consumption on global climate. But in a world with uneven climate policies, risk of carbon leakage and competitive disadvantage prevent us from reaching optimal allocation of resources. This explains the decision of the Commission to adopt a Carbon Border Adjustment Mechanism (CBAM). However, this unilateral measure that sets a carbon price for imports coming into the EU is highly controversial from an international trade perspective. Therefore, this paper aimed to verify if ETS competitiveness effects on European economy can be an argument for the introduction of CBAM, when considering the complete three first ETS phases (2005 – 2020). The gravity model approach has been applied to trade flow data, from EU-15 to 216 NON-EU countries, collected mainly from the CEPII's Gravity database. Our findings indicate that when the EU ETS is in place, exports from EU-15 countries are 24.4% higher. Thus, EU ETS had a positive impact on export and the estimates are statistically significant even at 1% level, no matter how the model is specified. Consequently, competitive disadvantage cannot be an argument for CBAM in this case, and this is in line with the findings in the literature. In fact, looking further ahead, we may conclude that CBAM is not motivated by past experience, but more by anticipation of forthcoming changes due to increased climate ambition and current EU ETS directives for revision. Hence, some recommendations for the design and implementation of CBAM are discussed, since such mechanism must be handled with care to achieve desired environmental and economic objectives.

(Word count = 20 463)