STOCKHOLM SCHOOL OF ECONOMICS
Department of Economics
5350 Master's Thesis in Economics
Academic Year 2021-2022

Can EU Emissions Trading System Affect Other Countries?

A Panel Study of EU's Trade Partners

Bolun Cong (41656)

Abstract

European Union commenced the EU Emissions Trading System in 2005. EU ETS has proven efficiency in reducing EU-wide greenhouse gas emissions and remains the largest emission trading scheme in the world after one decade of development. Existing literature regarding ETS's external impact mainly focuses on examining carbon leakage while leaving other impacts unexplored. In this thesis I use 2000-2014 sector level panel data from the World Input-Output Database to examine the impact of EU ETS on the emission, export and output of EU's trade partners. I firstly use a diff-in-diff model and find out that the first three stages of EU ETS did not significantly affect any of these aspects. There is neither any sign of carbon leakage nor evidence of technological innovation. Next I conduct a heterogeneity test and confirm that the emission impact is not statistically different for developing and developed countries.

Keywords: EU ETS, Environmental Policy, Emission, International Trade

JEL: F18, Q27, Q56, Q58

Supervisor: Pamela Campa
Date Submitted: 06 December 2021
Date Examined: 17 December 2021
Discussant: Elena Giulia Clemente
Examiner: Magnus Johannesson

Table of Contents

1 Introduction **3**

2 EU ETS: A Market-Based Scheme **5**

3 Literature Review **9**

3.1 External Emission Impact of Domestic Environmental Policy 9

3.2 Emission Impact of International Trade 11

3.3 Evaluation of the EU Emissions Trading System 12

4 Data and Methodology **14**

4.1 Data Source and Description 14

4.1.1 Outcome Variables 14

4.1.2 Explanatory variable 15

4.2 Empirical Model 15

4.3 Internal Validity 18

5 Results **22**

5.1 Emission Impact 22

5.2 Output Impact 22

5.3 Export Impact 24

5.4 Robustness Check: ETS Placebo Effect Test 27

6 Conclusion **29**

A Appendix: Trade partners, Sector Classification and ETS coverage **35**

List of Tables

1 Descriptive Statistics 16
2 Parallel trend test 19
3 Main Results—Emission Impact 24
4 Main Results—Output Impact 25
5 Main Results—Export Impact 27
6 Placebo Effect Test 28

List of Figures

1 Relative CO2 Emission 1970-2020 6
2 ETS Allowance Price 6
3 Free-Allowance Issued v.s. Actual Emission 7
4 CO2 Emission Level by Group 20
5 Sector Output by Group 20
6 Export Partner Share by Group 21
7 CO2 Emission Level by Group 21
8 Event Study—CO2 Emission, Sector Level Treatment 23
9 Event Study—CO2 Emission, Country-Sector Level Treatment 23
10 Event Study—Output, Sector Level Treatment 26
11 Event Study—Export Partner Share, Sector Level Treatment 26

1 Introduction

Climate change caused by greenhouse gas (GHG) emissions is a global issue. However, efforts to control emissions are mainly regional[1]. In a simple setting, environmental policies reduce emissions by putting emission level [2] into firm's production function. When policies are regional and firms could choose their location of production, desired outcome might not be delivered. Developing countries tend to adopt less strict regulations than developed countries due to the fact that their products are more carbon-intense (Walter and Ugelow, 1979). Such policy asymmetry gives rise to two opposing imports. The environmentally harmful impact is carbon leakage, the situation that environmental policy shifts the pollution-intensive manufacturing from regulated countries to less regulated countries and the products are imported back to regulated countries; The beneficial impact of policy asymmetry relates to several spillovers. For example, it contributes to advancement in environmental technology and increases environmental awareness among firms. It also encourages other governments to act towards emission reduction by providing policy precedents.

Given the theoretical foundation, it is not surprising that European Union[3] Emissions Trading System (EU ETS), the world's first and remaining largest multinational emissions control scheme, has affected emissions of not only EU but also other countries, especially the countries that have close link with EU. Yet, the studies to date appear to be one-sided: the majority of existing literature about external impact has put primary emphasis on exploring carbon leakage while there is insufficient discussion and empirical evidence about the positive effect or the net effect.

This thesis aims to shed some light on evaluating the overall impact of EU ETS on the emission, output and export trajectory of EU's major trade partners. Using a comprehensive database that contains sector emission, output and export data, the analyses in this paper are accomplished by treating EU ETS as a quasi-natural experiment and comparing the sector emission, output and export patterns in EU's developing and developed trade partners pre- and post- ETS. Corresponding to previous studies by Lilliestam et al. (2021), van den Bergh and Savin (2021) and Naegele and Zaklan (2019), this thesis confirms that the first three phases of EU ETS have not caused carbon leakage or

[1]The emission reduction goals proposed by Kyoto Protocol and Paris Agreement are, despite international, not compulsory for member countries.

[2]In terms of tax, subsidy, etc.

[3]The term "European Union" or "EU" used in this thesis refers to EU-28, the 28 EU countries included in EU ETS since phase II. United Kingdom was in EU ETS during the studied period.

technological innovation in non-EU countries. Moreover, the empirical results suggest the impact on all three aspects: foreign emission, output and export is not significant.

The outcome of this paper would provide useful insight for forecasting the international impact of other large-scale climate policies. Some countries have already carried out or will carry out their own green house gas ETS scheme, for example, Switzerland, Japan and China. These national ETS cover a large amount of CO_2 emission and are possible to affect other countries through various channels. Studying the similarities and differences between these ETS and EU ETS could provide some insights about how to prevent carbon leakage or encourage innovation.

The remainder of this thesis is structured as follows. Section 2 provides background information about EU ETS. Section 3 summarises a number of previous research about the relationship among international trade, environmental policy, and emissions; an emphasis is given to the evaluation of EU ETS. Section 4 describes the data and identification strategy that are employed in this thesis. Section 5 presents the main results and the interpretations. Robustness check is conducted in section 5 to support the validity of the main results. Finally, Section 6 summarises the whole thesis, giving an overview of the paper's contribution to current literature, discussing the economic significance of the results, listing some limitations of this paper, and pointing out several directions for future studies.

2 EU ETS: A Market-Based Scheme

Aiming at fighting climate change and fulfilling the emissions reduction goal characterized by Kyoto Protocol, European Union, the second largest economy and third largest CO_2 emitter (after China and USA (IMF, 2017)) in the world, launched EU ETS in 2005. EU ETS was the first and remains the largest multi-national GHG cap-and-trade scheme in the world. Under the scheme, a firm must acquire permits to cover every unit of its GHG emission. A maximum amount of emission permits is set each year and a market that trades the emission permits is built. A firm obtains the emission permit either from the market or from government allocation (more common in the early stage of the policy), it can also choose to sell its excess permits.

Traditional emission reduction practice, such as command-and-control, emission tax and subsidies, requires government to possess certain information to achieve desired level of reduction. Government needs to know the numeric relationship between emission and tax/subsidy to determine the optimal rate. Similarly, government needs to gather detailed information about production cost of each firm or industry to set the emission limit. In contrast, the cap-and-trade scheme delivers the same amount of emissions reduction with less effort. Government is more certain with the amount of emission since the cap itself can be considered as the overall emission. Yet, cap-and-trade is not perfect due to its market-based nature. Certainty over emission amount is at the cost of certainty over price; If firms can exert their market power or if the cap is set too high/too low, the allowance market would fail and cannot lead to optimal outcome[4].

[4]However, all variations of environmental policy are able to deliver the same and optimal outcome as long as the following conditions are met: Governments have perfect information and firms behave as price takers in the allowance market.

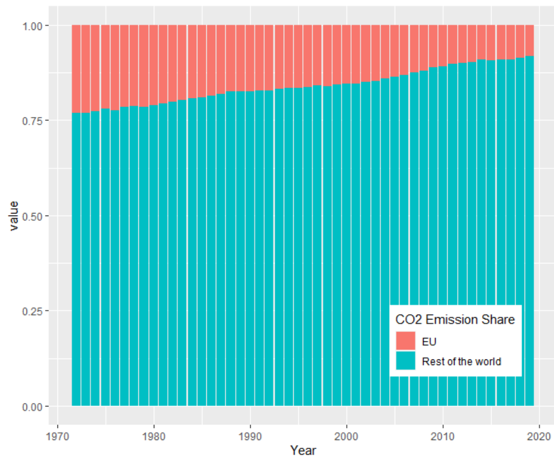

Figure 1: Relative CO2 Emission 1970-2020

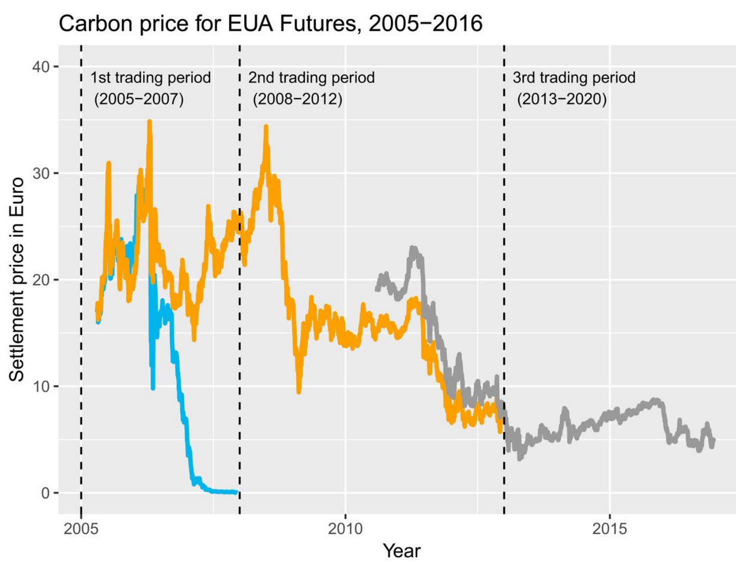

Figure 2: ETS Allowance Price

Note: Phase I(Blue); Phase II(Orange); Phase III(Grey)

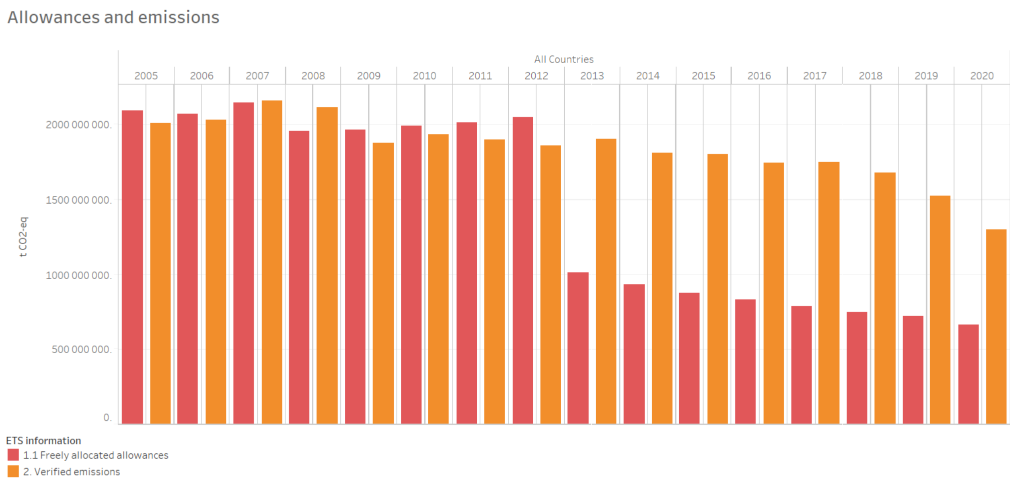

Figure 3: Free-Allowance Issued v.s. Actual Emission

The scale of sector coverage and policy stringency of EU ETS improves over time. The first phase (2005-2007) was a learning-by-doing stage where caps are at national level and free permits were assigned[5] to firms in emission intensive industries by the government of each member countries. The phase I allowance price (Marked by the blue line in Figure 2) went down to nearly zero after European Commission announced that the issued permits exceeded the actual emission. The second phase (2008-2012) was also the first commitment period of the Kyoto Protocol where there were solid emission reduction goals to achieve for each EU countries. Moreover, aviation sector[6] was included in the scheme in late phase II. Despite the allowance price was much higher than the former phase, 2008 financial crisis and the aftermath caused large amount of allowance surplus. In phase III (2013-2020), emphasis has been put on improving allowance market efficiency and addressing surplus. Important changes have been made such as discontinuing free allocation in most industries unless there is risk of carbon leakage. From this phase onwards, the annual emission cap is set at EU level and the cap decays at a rate of 1.74%; Furthermore, EU ETS has just entered its forth phase (2021-2030) [7] which is expected to be the most efficient and the most stringent phase. The cap decaying rate will be raised to 2.2% per year. Improving the allocating mechanism of emission permits will be one of the phase IV targets[8].

[5]The amount of emission permit assigned to each firm is based on several criteria, for example, past emission and size of the firm. The quotas cannot be transferred to next phase, hence would expire at the end of 2007.

[6]International flights are not included hence aviation sector is not considered as in the treatment group

[7]Due to data availability, phase IV is not covered in the empirical study.

[8]For more information about the development of EU ETS, visit https://ec.europa.eu/clima/sites/default/files/factsheet_ets_en.pdf

Despite the early inefficiency, EU's efforts against climate change lead to significant outcome: Overall, EU-wide GHG emission in 2019 is 24% lower than 1990 level. During the same period, the economy has expanded by 60%. Emission reduction effect is much more significant in the directly regulated sectors. A 9.1% decline in these sectors is observed between 2018 and 2019. Moreover, comparing to the emissions trajectory of other major economies, EU emissions are declining at a relatively faster pace. Both EU's share of CO_2 emission and per capita CO_2 emission have dropped sharply. EU accounts for 13.7% global emission in 2005 and 9.1% in 2016. EU's per capita CO_2 emission fell from 8.1 ton in 2000 to 7.0 ton in 2016. Upon efficient implementation of ETS, EU expects the 2030 GHG emissions to be 40% less than 1990 level.

3 Literature Review

Although the relationship between environmental policy and domestic emissions has been amply studied, there are few literature explored the potential spillover on foreign countries other than the pollution haven/carbon leakage effect. It is possible that changes induced by a policy can be passed onto another country. The exact policy impact depends on the characteristics of the policy itself and the involved countries.

This section is divided into three parts. In the first part, existing discussions about the channels through which environmental policy affects other countries are included. The second part covers the previous studies about the effect of international trade on environment. The last part presents the analyses and evaluations of EU ETS by current literature.

3.1 External Emission Impact of Domestic Environmental Policy

There is a limited number of studies that directly examined this causality. Most findings are about the negative impact, namely "leakage" or "pollution haven" effect. Other findings related to this topic are usually a by-product of exploring the relationship between environment and trade. Based on a model of two-trading-economy, Markusen (1975) was the first that pointed out domestic environmental policy (taxation) has an external pollution impact. Later studies (Markusen, 1975; Krugman, 1980; Markusen et al., 1993; Felder and Rutherford, 1993; Koźluk and Timiliotis, 2016; Annicchiarico et al., 2018; Shapiro, 2020) have identified the following channels through which regional environmental regulation affects other countries.

(1) Commodity Market: Stringent environmental policy lowers the production of emission-intensive goods domestically, price of the goods rises and causes other countries (whose regulation is laxer) produce more. Foreign emission increases.

(2) Factor Market: Strict regulation leads to capital outflow. Price of energy inputs drops as a response of less production. Foreign production and emission rise.

(3) Market Structure: Environmental regulation changes the number of profitable firms in one country. Amount and variety of final goods available is affected accordingly. Consumer behavior and mark-up are then affected. These effects finally convert to changes in number of firms in foreign countries. Foreign emission is ambiguously affected.

There are other channels that are less trade-relevant but would also generate significant impact on foreign emissions (Eaton and Kortum, 2002; Rauch and Trindade, 2003; Dechezleprêtre et al., 2014; Shapiro, 2016; Battaglini and Harstad, 2016; Kuroishi, 2020; Lilliestam et al., 2021; van den Bergh and Savin, 2021).

(4) Technological Innovation: Strict environmental policy induces R&D and innovation in energy, transportation and other relevant sectors globally, nevertheless, this channel remains controversial.

(5) Policy/Institutional Innovation: Successful regional environmental policy leads to more international cooperation, increasing the probability of new policy in another country.

(6) Environmental Awareness of Citizen: Environmental beliefs can be spread to other countries; Environmental outcome achieved by policy improves the environmental awareness among citizens in another country.

Existing literature primarily focus on channel (1) - (2) to estimate the leakage effect (Levinson and Taylor, 2008) while do not sufficiently cover channel (3) - (6) which could deliver beneficial impact. In practice, the mechanism of these effects is complex due to latent interactions with politics and geography (Marchiori et al., 2017). In general, the authors of the pollution haven literature agree that pollution haven effect exists in some countries but they disagree over the magnitude of the effects. Ben Kheder and Zugravu (2012) studied the emission impact of French FDI outflow after France strengthened environmental regulation. The results revealed significant evidence of pollution haven effect, despite that some countries still attracted more FDI even though they had more stringent environmental policy than France; Tang (2015) analysed the trade flow of US chemical industry and claimed that pollution haven effect has been observed in less developed countries, after US strengthened its environmental policy; Aichele and Felbermayr (2015) claimed there is evidence that Kyoto Protocol caused carbon leakage.

In contrast, Elliott and Shimamoto (2008) used Japan data and argued that pollution haven effect was not observed in Southeast Asian countries. Contrary to expectation, Japan's FDI to Philippines dropped after Japan imposed stricter policy. There have also been some critiques over the validity of pollution haven effect. For example, the empirical specification in many relevant studies uses measurement of economic activities in polluted industry as dependent variable (such as trade, emission, and output) and uses policy stringency as independent variable (Al-mulali and Foon Tang, 2013). The problem is that policy stringency is difficult to quantify. Despite FDI was widely employed as a proxy in previous studies, the indicator itself is an outcome measurement resulting in capturing excess policy-irrelevant factors (Botta and Koźluk, 2014). Nevertheless, stricter environmental policy does not always lead to detrimental effect on other countries. According to OECD (2005), increased policy strength encourages the evolution of markets of environmental goods through trade. The level of environmental technology R&D in exporting countries also positively responds to the environmental policy in importing countries. These aspects have potential positive impact on the environment in the long run.

Preliminary conclusions can be drawn from the literature that regional environmental policy can have both negative and positive impact on other countries, moreover, it could also affect trade flows. The negative(in terms of environment) impact is usually carbon leakage or pollution haven effect; the positive impact is considerable but less quantifiable, such as institutional change, improved technology or increased environmental awareness. The sign of the overall impact depends on both the characteristics of the policy and the trading countries.

3.2 Emission Impact of International Trade

The overall environmental effect of international trade could be either positive or negative. A majority of existing literature uses decomposition method developed by Antweiler et al. (2001) to study the environmental impact of international trade. The impact of trade is divided into three parts: scale effect, technique effect and composition effect. The first effect refers to the case that the size of economic growth induced by trade will affect environment. The scale effect is ambiguous because increased trade volume leads to economic development, and thus higher demand for energy, and more pollution. But economic development in turn enhances the capability of handling environmental problems (Tobey, 1993; Copeland and Taylor, 1994).

The second effect is the technique effect. It refers to the situation that international trade introduces technology exchange and advancement (Cole and Elliott, 2003). Better production and transportation technologies will result in less emission. Therefore, technique effect is expected to reduce emission. Depending on the variables selected, the scale effect and tech effect might not be separated from each other.

The third effect is the composition effect. It is related to a country's comparative advantage in the international trade. Exposure to international trade shifts the production pattern of products. In most cases, developing countries have comparative advantage in the production of pollution-intensive goods(Levinson, 2009). Thus, the composition effect from trade tends to increase emission in developing countries and reduce emission in developed countries. Cole and Elliott (2003) further argued changes introduced by environmental regulation are absorbed in the composition effect.

Antweiler et al. (2001) used data primarily from developed countries during 1971-1996 and found evidence that international trade is beneficial for the environment. Although the composition effect of trade leads to more SO_2 pollution, scale and technique effects are large enough to offset the damage. 1% increase in trade activity causes 0.3% more SO_2 concentration through composition effect, but the growth in income and output due to trade causes pollution to decrease by 1.4%. Using similar empirical setting but four types of pollutants: SO_2, NO_x, CO_2 and Biochemical Oxygen Demand (BOD measures water pollution), Cole and Elliott (2003) argued the relationship between pollution and trade is more complicated and depend on pollutant type. Trade tends to reduce per capita BOD emission, but increase per capita NO_x and CO_2. Furthermore, the relationship between trade and SO_2 is unclear due to offsetting scale-tech and composition effects; Managi et al. (2009) explored potential difference between OECD and non-OECD countries. Significant inter-group contrast has been observed. Short-run and long-run difference is also large. International trade only reduces emissions of pollutants in OECD countries in both short-run and long-run whereas it causes more SO_2 and CO_2 emission in non-OECD countries in the short-run and even more in the long-run.

In addition to decomposition, there are some papers employed different research methods to explore the overall effect of trade on the environment. For example, Levitt et al. (2019) separated CO_2 emission into production-emission and consumption-emission, and tested the effect of importing from China on the emission level of China's trade partners. The paper found importing from China leads to a net-increase in trade partner's emission level. The increased consumption emission is not offset by falling production emission. This work, in combination of Managi et al. (2009)'s paper, provides a theoretical support that trade with specific partner has unique environmental outcomes, comparable advantage/disadvantage.

3.3 Evaluation of the EU Emissions Trading System

Considerable amount of literature has assessed EU ETS throughout its development. At the beginning of the program, carbon price was unstable. It went up to 30 euro per ton but within two years plummeted to nearly 0 after European Commission announced that the issued pollution permits were higher than actual emission level. Various sources concluded that ETS was inefficient in phase I. Montagnoli and de Vries (2010) tested the Efficient Market Hypothesis (EMH) on ETS carbon market and stated the market was initially inefficient. Similarly, Hintermann (2010) explained that ETS was a relatively new concept, unexpected actual emission and lack of information were the major causes to the sudden price collapse. He also argued the inefficiency was adequately corrected after the price adjustment. Lundgren et al. (2015) analysed how Swedish pulp and paper industry reacted to EU ETS and found that low carbon price did not create sufficient incentive for firms to reduce emission.

Phase II carbon price experienced similar pattern but was less volatile. Policy effectiveness restored to some extend and carbon price started at around 25 euro per ton, gradually reduced to 8 euro per ton at the end of phase II. de Perthuis and Trotignon (2014) identified three causes of phase II price drop, which are the unexpected 2008 financial crisis, large use of carbon offsets, and interaction between ETS and other environmental policy at the same time. Dechezleprêtre et al. (2018) estimated phase II achieved a 10% emission reduction in regulated firms.

In phase III, carbon price stayed at 4 - 8 euros interval for nearly 5 years and raised to more than 20 euros per ton in 2020. Bayer and Aklin (2020) argued ETS is still efficient in reducing emission despite EUA price was low. They found that actual EU-wide emission level was 3.6% lower, comparing to the counterfactual without the presence of EU ETS constructed by synthetic control method. The number is much higher in regulated sector.

Other literature relevant to phase III mainly focused on the prediction of carbon price trend and analysis of ETS outcome, few have mentioned policy inefficiency in phase III. Salant (2016) claimed the major price driver in phase III is expectation. In the final years of phase III, beliefs about tougher phase IV ETS measures might explain the carbon price increase. In addition, some attempt to identify the connection between ETS and carbon leakage (Healy et al., 2018; Naegele and Zaklan, 2019) did not end up finding plausible evidence.

4 Data and Methodology

4.1 Data Source and Description

The data I use come from the World Input-Output Database (Timmer et al., 2015), which has three components, namely "Input-Output Tables", "Environmental Accounts" and "Socio-Economic Accounts". One advantage of using this database is that the sectors in WIOD are harmonized using the International Standard Industrial Classification revision 4 (ISIC Rev. 4). Hence the definition of sectors is the same across all variables (emission, export indicators and control variables). This eliminates bias from translating variables under different standards. Secondly, the database covers data of 43 major economies (28 from EU and 15 non-EU) at sector level[9] from 2000 to 2014. Since EU ETS only regulates specific sectors, observing the data at this level allows us to consider the significant difference among sectors within a country and also control for potential fixed effect at country-sector level. The third advantage of WIOD is that the emission data are calculated using plant-level energy consumption and are expected to be more accurate reflecting sector production emission, comparing to other databases of which emission levels are inferred from satellite images.

The original data entries in the "Input-Output Tables" describe a sector-to-sector relationship. Each record in table contains information about the amount of sector export from one country to sectors in other countries in a certain year. Several transformations are performed in the early stage in order to obtain the variables of interest at sector-to-EU level.

4.1.1 Outcome Variables

Measures of emission, export and output (CO_2 emission level, export partner share and total sector output [10]) are the dependent variables used in the empirical strategy of this thesis. CO_2 is the major green house gas that EU ETS and the affiliating carbon market try to control. It would be useful to determine whether EU ETS has delivered the same or opposite impact to other countries as compared to EU through the previously discussed channels.

EPS measures the importance of EU as a trade partner, defined as the export volume (EV) to EU divided by total export in a sector of a country and in a certain year. The consequence of EU ETS on international trade is expected to be reflected by export to EU instead of import from EU

[9] More details can be found in the Appendix

[10] Accordingly, they are referred to as CO_2, EPS and TOT.

because EU ETS is a EU supply shock that drives up production cost instead of a demand shock. Hence import (import from EU to other countries) is not employed in the empirical study because changes in import pattern does not help us understand carbon leakage or technological innovation.

EPS is determined using the following formula:

$$EPS_{ist} = \frac{EV_{ist}^{ToEU}}{EV_{ist}^{Total}}$$

TOT is the sector output, it serves as a indicator of technological innovation. Observing the changes in emission pattern might give us a first impression on how are the other countries being affected, however, solid conclusion cannot be made without observing the impact on export or output at the same time. An increase in sector emission accompanied by increase in sector export volume indicates carbon leakage exists in EU side. Moreover, a drop in sector emission cannot be viewed as an improvement in production technology or in environmental legislation if the drop comes with a sharply decreased sector output.

4.1.2 Explanatory variable

The end of EU ETS phase I (2007) is the major explanatory variable in the empirical study. Although EU ETS has already started in 2005, the consensus among various sources shows that EU ETS failed to deliver a substantial impact on EU emission until it entered phase II. It is reasonable to believe that other countries will not be affected without EU countries being firstly affected. In one of the robustness tests, phase I starting date(2005) is employed as a fake treatment to see whether there is a placebo effect. Next, export partner share (EPS) also serves as an explanatory variable for classification purpose. When this happens, the effect of ETS on EPS is not tested to avoid endogeneity. More detailed description about the classification is presented in the next section.

Certain variables in the "Socio-Economic Table" are selected as control variables to improve the internal validity by reducing the influence of confounding factors. Including control variables does not change the significance level of estimators. Summary statistics are provided in table 1. More details of WIOD are provided in Appendix.

4.2 Empirical Model

My empirical strategy exploits two features. The first one is that the implementation of EU ETS can be considered as a quasi-natural experiment as it is an event that permanently drove up the cost

Variable	Unit	Mean	Std.Err	Min	Median	Max	Obs.
CO2 Emission	log kton	7.22	2.43	-0.88	7.29	14.74	9664
Export Partner Share	(%)	0.03	0.07	0.00	0.01	0.74	9664
Total Output	log mUS$	10.00	1.64	1.46	10.00	15.01	9664
Treatment_s	-	0.28	-	-	-	-	-
Treatment_{is}	-	0.20	-	-	-	-	-
Working Hours	log mhours	5.82	1.92	-2.66	5.87	12.22	9664
Intermediate Inputs	log mUS$	11.93	3.08	0.24	11.22	21.41	9664
Number of Workers	log k	5.45	1.93	-3.147	5.41	12.45	9664

Table 1: Descriptive Statistics

of production of firms located within EU in the regulated sectors. The policy is exogenous for non-EU countries and sectors. Second, ETS has substantially changed the EU emission and production pattern. The scale of the change is unprecedented. It is reasonable to assume the causality that EU ETS has also affected non-EU countries through these changes. Utilizing the variations in the outcome variables of interest between the ETS covered and non-covered sectors in a trade partner and between the years before and after the implementation of EU ETS allows us to understand the external impact of EU ETS.

Based on the empirical strategy, I firstly estimate a baseline difference-in-difference (DiD) specification to exploit the quasi natural experiment. I assume (1) One sector will not be affected as long as its counterpart in EU is not covered by ETS. (2) EU ETS affects the covered sectors in all the countries. The model is then specified as follows:

$$logY_{ist} = \beta_1 Treatment_s + \beta_2 Post_t + \beta_3 Treatment_s \times Post_t + V_{ist}^{'}\theta + \lambda_{is} + \gamma_{it} + \epsilon_{ist} \tag{1}$$

Where Y_{ist} is the outcome variable of interest represents (a) the emission level of carbon dioxide (b) the net export volume (in USD) to EU (c) the export partner share relative to EU and (d) the sectoral output (in USD) in sector s country i in year t. $Treatment_s$ is the group identifier, $Treatment_s$ taking value 1 means sector s is an EU ETS covered sector. The full list of covered sector can be seen in the Appedix. $Post_t$ stands for the ETS treatment, $Post_t$ takes value 1 for years later than or equal to 2007 as discussed earlier. $V_{ist}^{'}$ is a matrix containing time-varying country-sector control variables as discussed earlier. λ_{is} and γ_{it} are the country-sector and country-year fixed effect. ϵ_{ist} is the regression error term. In this specification, β_3 is the DiD coefficient that measures the treatment of EU ETS phase II on the outcome variables.

Specification (1) assumes that EU ETS affects the covered sectors in all trade partners, however, this assumption could potentially be fragile in situations such that a sector has a sufficiently low export exposure to EU. EU ETS is very unlikely to affect either the trade condition or the emission level of sector that has 0 export exposure to EU. An opposite example to consider is the sectors in Swiss. EU is the largest trade partner of Swiss and if EU ETS does have a significant foreign supply impact, it is almost certainly that Swiss absorbed some of the shock. Hence, country characteristics could also be taken into consideration when assign control and treatment effect. To proceed, I group the country-sectors according to their export partner share in 2006, a sector s in country i is in the treatment group if and only if it is an ETS covered sector and its export partner share is above the median export partner share of the sector. This also makes the difference between treatment and control groups more distinct.

Specially,

$$Treatment_{is} = [Covered_s] \ \& \ [EPS_{is} > Median(EPS_s)]$$

I estimate specification (2) to accommodate this change, the treatment effect is now specific to country-sector instead at mere sector level.

$$logY'_{ist} = \beta_1 Treatment_{is} + \beta_2 Post_t + \beta_3 Treatment_{is} \times Post_t + V'_{ist}\theta + \lambda_{is} + \gamma_{it} + \epsilon_{ist} \tag{2}$$

β_3 is still the interested effect whereas the outcome variable Y'_{ist} now contains only (a) the emission level of carbon dioxide. Using median EPS in 2006 as the group classifier introducing risk of endogeneity to the estimation of post-2007 EPS and TOT.

The model can be further expanded. The emission impact of EU ETS on foreign countries might be different regarding certain country characteristics, such as the stage of development or comparative advantage in international trade. In terms of emission, developing countries are more likely to become the destination of carbon leakage other than developed countries, due to the relatively lower production cost and more relaxed environmental policy. In terms of policy induced technology advancements, the mechanism can be more complicated. On one hand, developing countries can approach existing advanced technology more easily if they have lag in technology. On the other hand, developed countries are more advantageous in making breakthroughs as they invest more in R & D. To conduct heterogeneity test, I add $Developed_i$ to the equation as an additional difference to examine the differential outcomes among EU's trade partners. β_7 is estimator of interest that measures the difference of treatment effect between control and treatment group, between developed and developing countries and in pre- and post- treatment years. The model is specified as the following:

$$\begin{aligned} logY'_{ist} = \beta_1 Treatment_i s + \beta_2 Post_t + \beta_3 Developed_i + \beta_4 Treatment_{is} \times Post_t + \\ \beta_5 Post_t \times Developed_i + \beta_6 Treatment_{is} \times Developed_i + \\ \beta_7 Treatment_{is} \times Post_t \times Developed_i + V'_{ist}\theta + \lambda_{is} + \gamma_{it} + \epsilon_{ist} \end{aligned} \tag{3}$$

4.3 Internal Validity

DiD models rely on several assumptions to be valid. The first and most crucial one is the parallel trend assumption. It requires the difference between the control and treatment group is constant over time in absence of EU ETS, in other words, there must not be any treatment effects or pre-treatment trends in either group in pre-treatment years. To test the parallel trend assumption in DiD, the observations before 2007 are used to construct a sample and an event study is perform on the sample for each of the outcome variables. For the heterogeneity test, I conduct the same analysis as in DiD but for developed and developing sub-samples. Furthermore, passing parallel trend test requires none of estimators near 2007 are significant. The estimator $Treatment \times Year$ reported in table 2 measures the difference between control and treatment groups in a specific year. All the estimators are not statistically significant at given threshold, indicating all specifications with different outcome variables do not violate the parallel trend assumption.

The second assumption is the Stable Unit Treatment Value Assumption(SUTVA), SUTVA requires the composition of control and treatment groups is stable overtime. One concern related to this is the potential endogeneity problem discussed previously that ETS could affect the export exposure of one country through carbon leakage. Therefore, using median EPS in 2006 as the threshold for separating groups ensures ETS treatment does not affect the grouping based on this. Nevertheless, median export volume is not a good group classifier because export volume varies largely across years and pre-trend cannot be eliminated, countries with export volume near median level tend to be different each year. Given the justifications in this section, I argue that the specifications in the empirical part are able to separate and investigate the impact of interest.

Pre-treatment Years:	2002	2003	2004	2005	2006
Outcome Variable					
DiD (1)					
logCO2	0.0065	-0.0012	-0.0298	-0.0349	-0.0055
	(0.0190)	(0.0225)	(0.0217)	(0.0290)	(0.0322)
logTOT	-0.0025	0.0020	0.0091	0.0086	0.0127
	(0.0044)	(0.0052)	(0.0056)	(0.0067)	(0.0073)
EPS	0.0013	0.0008	0.0016	0.0000	0.0020
	(0.0018)	(0.0018)	(0.0020)	(0.0021)	(0.0021)
DiD (2)					
logCO2	0.0042	0.0078	-0.0291	-0.0490	-0.0201
	(0.019)	(0.024)	(0.022)	(0.031)	(0.034)
Heterogeneity Test (3)					
logCO2	0.0155	0.0132	-0.0293	-0.0693	-0.0580
(Developed)	(0.0265)	(0.0352)	(0.0292)	(0.0417)	(0.0434)
logCO2	-0.0137	0.0026	-0.0204	-0.0023	0.0574
(Developing)	(0.0252)	(0.0306)	(0.0332)	(0.0478)	(0.0546)

Note: Reported are the coefficient on $Treatment \times Year$ in event study in pre-treatment sample i.e. the difference in outcome variable between treatment and control group in pre-treatment years. 2007 is the actual year of treatment. Specification (1) is when the treatment is on all ETS covered sectors. Specification (2) is when the treatment effect is assigned to only ETS covered sectors with high EPS. Same control variables are used as in the main regression. Specification (3) is the heterogeneity test. Standard errors are clustered at country-sector level and are reported in parenthesis. None of the coefficients are significant at specified significance level, this holds for all outcome variables, indicating there are no pre-treatment trends in these variable.

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 2: Parallel trend test

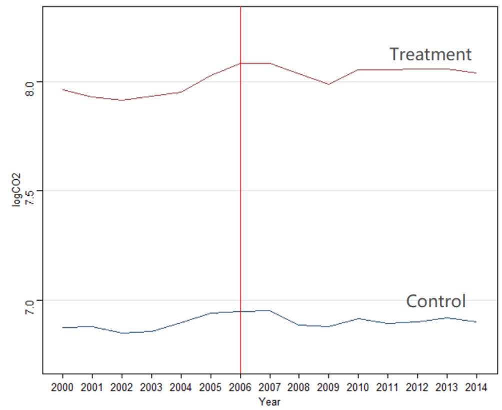

Figure 4: CO2 Emission Level by Group

Note: Treatment Group: Sectors covered by EU ETS in non-EU countries.

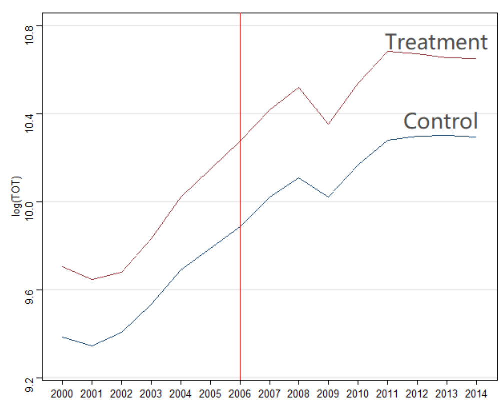

Figure 5: Sector Output by Group

Note: Treatment Group: Sectors covered by EU ETS in non-EU countries.

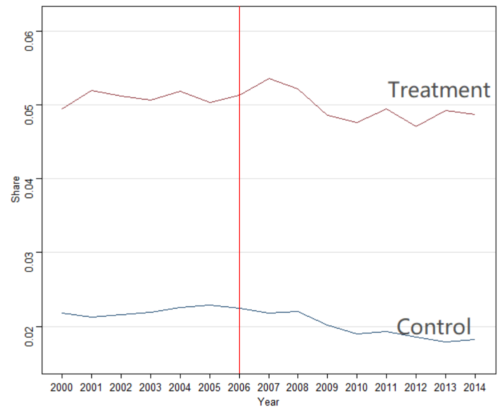

Figure 6: Export Partner Share by Group

Note: Treatment Group: Sectors covered by EU ETS in non-EU countries.

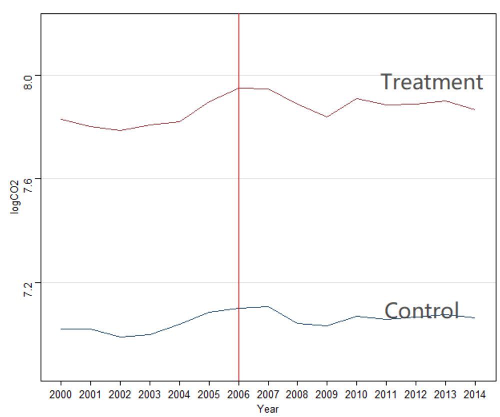

Figure 7: CO2 Emission Level by Group

Note: Treatment Group: Sectors covered by EU ETS and have high export exposure in 2006 in non-EU countries.

5 Results

My analysis focuses on the link between EU ETS and sectors in EU's trade partners. The DiD estimator is the major explanatory variable. I study the impact of EU ETS on sector CO_2 emission, output and export.

5.1 Emission Impact

The magnitude and standard error of the effect that ETS imposed on sector emission level is reported in table 3. Column (1) shows the the treatment effect from model 1 (when the treatment applies to covered sectors in all countries). Column (2) presents the treatment effect from model 2 (when the treatment is limited to sectors with high export exposure to EU in 2006). The regression result suggests both coefficients are insignificant. The heterogeneity test is reported in the 3rd column, and it is not significant either. Preliminary conclusion can thus be drawn from the table that EU ETS does not create a significant emission impact on sectors in other countries, this also holds for the sectors with high export exposure to EU. Moreover, the insignificant impact is not due to the effect on developing and developed countries are significant but opposite, as confirmed by coefficient in the third column that ETS has the same (insignificant) impact on both type of countries.

As a further test, I construct two event study plots based on model (1) and (2). The plots demonstrate that the estimated ETS treatment effect and 95% confidence interval alongside with the actual emission trajectory of EU from 2002-2014. From figure 8 and 9, we can see that all of the 95% CI of post-2006 point estimates overlap 0 (so does 2006 and pre-2006 estimates, this confirms the parallel trend assumption), indicating there is no observable treatment effect in each specific year. Comparing the pattern of the verified EU CO2 emission (characterized by the blue line in the figures) to the point estimates (solid black line), we could spot some correlation as they usually move towords the same direction, but this does not serve as strong evidence of emission reducing effect.

5.2 Output Impact

The impact of EU ETS on sector output is reported in table 4. Similarly, the estimator is not significant at 5% level. This is also supported by the event study graph 10. Sector output is not in model (2) and (3) because of the criteria of classifying control/treatment group. The result suggests that EU ETS does not significantly affect output level of covered sectors in other countries. Possible

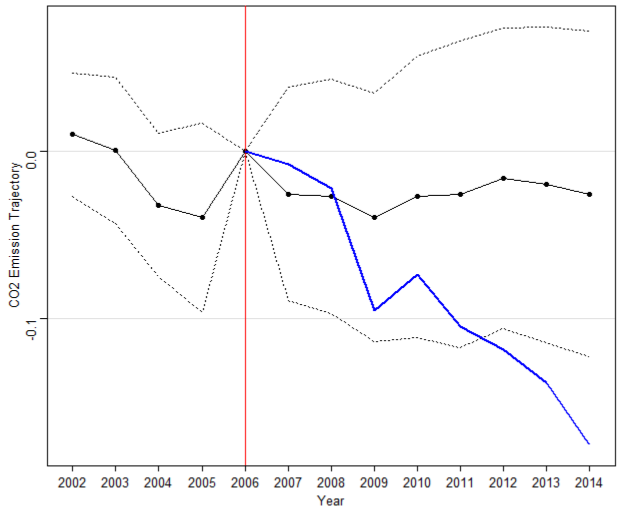

Figure 8: Event Study—CO2 Emission, Sector Level Treatment

Note: Event study graph based on specification (1), where outcome variable is log CO2 emission, treatment is assigned to all ETS covered sectors. The blue line stands for the actual emission pattern of EU. 2006 is the base year and 2007 is the actual year of treatment. 95% CI of all event study estimators overlaps zero.

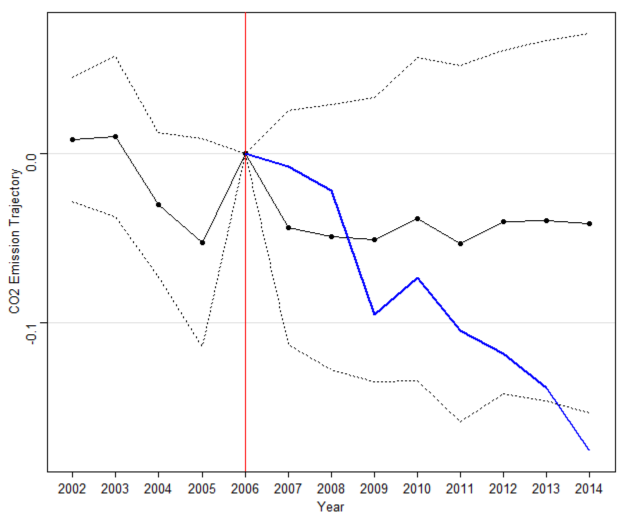

Figure 9: Event Study—CO2 Emission, Country-Sector Level Treatment

Note: Event study graph based on specification (2), where outcome variable is log CO2 emission, treatment is assigned to ETS covered sectors with high export exposure to EU. The blue line stands for the actual emission pattern of EU. 2006 is the base year and 2007 is the actual year of treatment. 95% CI of all event study estimators overlaps zero.

	CO_2 Emission (log kton)		
	(1)	(2)	(3)
Treatment×*Post*	−0.0111	−0.0288	−0.0262
	(0.0310)	(0.0365)	(0.0613)
Treatment×*Post* × *Developed*			−0.0041
			(0.0753)
Country-Sector-Year Control	√	√	√
Treatment Status	Sector	Sector	Country-Sector
Observations:	9664	9664	9664

Note: The table shows the results of the diff-in-diff estimation and heterogeneity test of EU ETS on foreign sector emission. Standard errors are clustered at country-sector level and are reported in parenthesis.

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 3: Main Results—Emission Impact

explanation for this could be the actual external impact of ETS is too small to be observed. Or the reduced production in EU is transferred to smaller countries that are not yet included in WIOD. Furthermore, the WIOD covered countries contributes to more than 70% of EU's import, making the first statement more likely to be the actual situation.

5.3 Export Impact

Lastly, I examine the impact of EU ETS on sector EPS using model (1). The result for this outcome variable is reported in table 5. The event study plot is graph 11. Again, the estimated coefficient is not significant at 5%, indicating the EPS of EU's trade partner is not affected. Given the results from the last section that sector output is not affected, the implication is EU ETS does not change the composition of export of trade partners and does not cause the export to EU relative to total export in one sector to boost or to decrease.

The results, together with previous ones, provide empirical evidence that EU ETS (phase II) does

	Sector Output (log mUS$)
	(1)
Treatment×*Post*	−0.0041
	(0.0063)
Country-Sector-Year Control	√
Treatment Status	Sector
Observations	9664

Note: The table shows the results of the diff-in-diff estimation of EU ETS on foreign sector output. Standard error is clustered at country-sector level and is reported in parenthesis.

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 4: Main Results—Output Impact

not substantially affect covered sectors in EU's trade partners. There is little evidence that EU ETS leads to carbon leakage since emission and export patterns are not affected, this is in line with the findings of Healy et al. (2018) and Naegele and Zaklan (2019). There is also no evidence that EU ETS contributes to innovation in production technology, otherwise, an increase in sector output or a reduction in sector emission is expected in treated sectors. This part of finding corresponds to Lilliestam et al. (2021)'s conclusion. There are several explanations to the findings, the most likely one is that EU ETS really does not influence other countries as this paper and multiple other sources suggest. After all, EU ETS is a regional policy operating only in the EU. It could also be that the impacts occur in EU countries or countries that is not in WIOD.

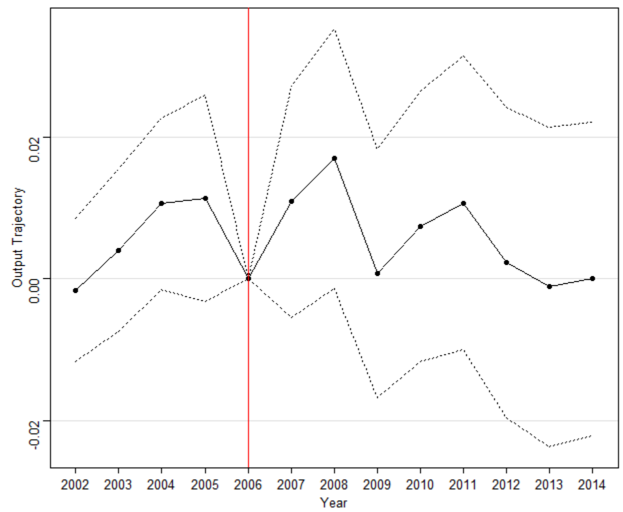

Figure 10: Event Study—Output, Sector Level Treatment

Note: Event study graph based on specification (1), where outcome variable is log sector output, treatment is assigned to all ETS covered sectors. 2006 is the base year and 2007 is the actual year of treatment. 95% CI of all event study estimators overlaps zero.

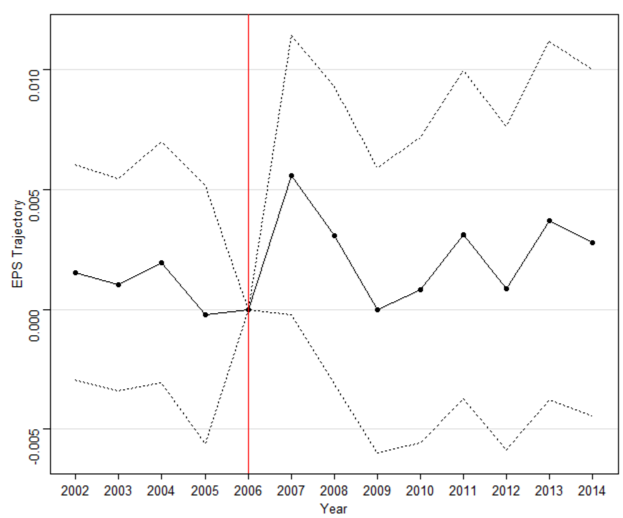

Figure 11: Event Study—Export Partner Share, Sector Level Treatment

Note: Event study graph based on specification (1), where outcome variable is EPS, treatment is assigned to all ETS covered sectors. 2006 is the base year and 2007 is the actual year of treatment. 95% CI of all event study estimators overlaps zero.

	Sector EPS (%)
	(1)
Treatment×*Post*	−0.0013
	(0.0019)
Country-Sector-Year Control	√
Treatment Status	Sector
Observations	9664

Note: The table shows the results of the diff-in-diff estimation of EU ETS on foreign sector EPS. Standard error is clustered at country-sector level and is reported in parenthesis.

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 5: Main Results—Export Impact

5.4 Robustness Check: ETS Placebo Effect Test

Placebo effect test is a necessary step to examine whether the outcome from previous part is due to a spurious relationship, even though previous part does not spot significant results and requirements for parallel trend assumption are always met. To conduct the test, all treated observations are dropped and fake treatments are generated in the remaining sample. A suitable model would not produce significant effect of fake treatment on the sample. To proceed, the five years prior to the actual treatment are considered: 2006, 2005, 2004, 2003 and 2002. It shall be noted here 2005 is the actual starting year of EU ETS.

Table 6 shows the robustness test results of model (1). For all these years, none of the coefficients are significant, thus, placebo effect does not occur in pre-2007 sample.

Fake ETS Start in:	2002	2003	2004	2005	2006
Outcome Variable					
logCO2	-0.0077	-0.0184	-0.0225	-0.0163	-0.0096
	(0.0287)	(0.0287)	(0.0304)	(0.0319)	(0.0312)
logTOT	-0.0048	0.0052	0.0041	0.0013	-0.0001
	(0.0065)	(0.0066)	(0.0066)	(0.0065)	(0.0064)
EPS	0.0005	0.0005	0.0007	0.0008	0.0013
	(0.0018)	(0.0019)	(0.0018)	(0.0019)	(0.0017)
Country-Sector-Year Control	√	√	√	√	√
Treatment Status	Sector	Sector	Sector	Sector	Sector
Observations:	4503	4503	4503	4503	4503

Note: Reported are the coefficient on $Treatment \times Post^{'}$ in diff-in-diff specification (1) in pre-treatment sample i.e. the treatment effect of a fake ETS. In specification (1), ETS treatment effect is assigned to all ETS covered sectors. 2007 is the starting year of real ETS. Standard errors are clustered at country-sector level and are reported in parenthesis. None of the coefficients are significant at specified significance level, this holds for all outcome variables, indicating there are no pre-treatment trends in these variable.

$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 6: Placebo Effect Test

6 Conclusion

This thesis links EU ETS with emission, export and output trajectory of sectors in non-EU countries and aims to give an overview of how these perspectives are affected. This thesis employs a diff-in-diff model that exploits that EU ETS can be treated as a quasi-natural experiment to sectors in non-EU countries. The empirical study is based on a comprehensive database that covers trade, output and emission data from 40 major economics. The major conclusions are the follows: First and most important, although some significant outcomes were expected, EU ETS has insignificant overall-impact on sector output and EPS of EU's trade partner. There could be some minor emission reduction effect but the evidence is weak. Second, the heterogeneity test confirms that at least the emission impact is not statistically different for EU's developing and developed trade partners. The validity of these statements are strengthened by a robustness check. The findings confirm Naegele and Zaklan (2019)'s statement that EU ETS does not trigger carbon leakage even before EU began to prevent carbon leakage in phase III. Whether emission trading contributes to technological innovation remains a controversial topic, nevertheless, this thesis provide some information in favor of Lilliestam et al. (2021)'s and van den Bergh and Savin (2021)'s opinion that emission trading is not an effective factor regarding technological growth. The impacts of EU ETS, not limited to emission, seems to affect EU countries only.

The paper also has several limitations, one is that the presence of trade barrier (such as tariff) is not taken into consideration which could harm the process of identifying the "actual" treatment group. High level of trade barrier prevents technological innovation and reduces carbon leakage regardless of sector export exposure. Secondly, due to data availability some impacts are not examined, EU ETS has insignificant outcome on the studied aspects but it is possible the impact on other indicators is significant, for example, on sector wage level. Given that EU ETS has a insignificant impact, we can only know the positive effects roughly equal to the negative ones (or both zero), the results provide little information about the presence or size of carbon leakage. Lastly, policy stringency of ET ETS is changing over time and different EU countries comply to ETS differently, a simple policy dummy might not be sufficient to capture such variation.

The results of this thesis would provide insights regarding further ETS evaluation. For example, the recent EUA price (in phase IV) is much higher than the price in the studied period of this thesis. High allowance price is a powerful driver of relocating. Another future focus could be evaluating the external impact of new ETS schemes in the world. For instance, China, Japan and South Korea have separately carried out their ETS schemes years after the EU ETS. These countries are substantially different from EU hence the overall impact of their ETS might be completely different as well. It would be useful to understand how are their neighboring countries or close trade partners affected by the new ETS. In addition, some attention can be paid to identifying the effects on employees in the affected sectors using similar technique, for example, exploring whether workers are better or worse off if the sector they are working on is affected by domestic or external ETS.

References

Aichele, R. and Felbermayr, G. (2015). Kyoto and carbon leakage: An empirical analysis of the carbon content of bilateral trade. *Review of Economics and Statistics*, 97(1):104–115.

Al-mulali, U. and Foon Tang, C. (2013). Investigating the validity of pollution haven hypothesis in the gulf cooperation council (gcc) countries. *Energy Policy*, 60:813–819.

Annicchiarico, B., Correani, L., and Di Dio, F. (2018). Environmental policy and endogenous market structure. *Resource and Energy Economics*, 52:186–215.

Antweiler, W., Copeland, B. R., and Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review*, 91(4):877–908.

Battaglini, M. and Harstad, B. (2016). Participation and duration of environmental agreements. *The Journal of political economy*, 124(1):160–204.

Bayer, P. and Aklin, M. (2020). The european union emissions trading system reduced co2 emissions despite low prices. *Proceedings of the National Academy of Sciences*, 117(16):8804–8812.

Ben Kheder, S. and Zugravu, N. (2012). Environmental regulation and french firms location abroad: An economic geography model in an international comparative study. *Ecological Economics*, 77:48–61.

Botta, E. and Koźluk, T. (2014). Measuring environmental policy stringency in oecd countries. *OECD Economics Department Working Papers*.

Cole, M. A. and Elliott, R. J. (2003). Determining the trade–environment composition effect: the role of capital, labor and environmental regulations. *Journal of Environmental Economics and Management*, 46(3):363–383.

Copeland, B. R. and Taylor, M. S. (1994). North-South Trade and the Environment*. *The Quarterly Journal of Economics*, 109(3):755–787.

de Perthuis, C. and Trotignon, R. (2014). Governance of co2 markets: Lessons from the eu ets. *Energy Policy*, 75:100–106.

Dechezleprêtre, A., Dechezleprêtre, A., Glachant, M., and Glachant, M. (2014). Does foreign environmental policy influence domestic innovation? evidence from the wind industry. *Environmental and Resource Economics*, 58(3):391–413.

Dechezleprêtre, A., Nachtigall, D., and Venmans, F. (2018). The joint impact of the european union emissions trading system on carbon emissions and economic performance. (1515).

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, 70(5):1741–1779.

Elliott, R. and Shimamoto, K. (2008). Are asean countries havens for japanese pollution-intensive industry? *The World Economy*, 31:236–254.

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.

Healy, S., Schumacher, K., and Eichhammer, W. (2018). Analysis of carbon leakage under phase iii of the eu emissions trading system: Trading patterns in the cement and aluminium sectors. *Energies*, 11(5).

Hintermann, B. (2010). Allowance price drivers in the first phase of the eu ets. *Journal of Environmental Economics and Management*, 59(1):43–56.

IMF (2017). World economic outlook. `https://www.imf.org/en/Publications/WEO/weo-database/2017/October`. Accessed: 2021-04-25.

Koźluk, T. and Timiliotis, C. (2016). Do environmental policies affect global value chains? (1282).

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *The American Economic Review*, 70(5):950–959.

Kuroishi, Y. (2020). Global supply chain and corporate environmental responsibility. `https://www.dropbox.com/s/8w6ch0v3x8zaw33/GSC_CER_YK.pdf`. Accessed: 2021-02-25.

Levinson, A. (2009). Technology, international trade, and pollution from us manufacturing. *American Economic Review*, 99(5):2177–92.

Levinson, A. and Taylor, M. S. (2008). Unmasking the pollution haven effect. *International Economic Review*, 49(1):223–254.

Levitt, C. J., Saaby, M., and Sørensen, A. (2019). The impact of china's trade liberalisation on the greenhouse gas emissions of wto countries. *China Economic Review*, 54:113–134.

Lilliestam, J., Patt, A., and Bersalli, G. (2021). The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex-post evidence. *WIREs Climate Change*, 12(1):e681.

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

Managi, S., Hibiki, A., and Tsurumi, T. (2009). Does trade openness improve environmental quality? *Journal of Environmental Economics and Management*, 58(3):346–363.

Marchiori, C., Dietz, S., and Tavoni, A. (2017). Domestic politics and the formation of international environmental agreements. *Journal of Environmental Economics and Management*, 81:115–131.

Markusen, J. R. (1975). International externalities and optimal tax structures. *Journal of International Economics*, 5(1):15–29.

Markusen, J. R., Edward, M. R., and Nancy, O. D. (1993). Environmental Policy when Market Structure and Plant Locations Are Endogenous. *Journal of Environmental Economics and Management*, 24(1):69–86.

Montagnoli, A. and de Vries, F. P. (2010). Carbon trading thickness and market efficiency. *Energy Economics*, 32(6):1331–1336.

Naegele, H. and Zaklan, A. (2019). Does the eu ets cause carbon leakage in european manufacturing? *Journal of Environmental Economics and Management*, 93:125–147.

OECD (2005). Opening markets for environmental goods and services. *Trade that Benefits the Environment and Development*, page 178.

Rauch, J. E. and Trindade, V. (2003). Information, international substitutability, and globalization. *American Economic Review*, 93(3):775–791.

Salant, S. W. (2016). What ails the european unions emissions trading system? *Journal of Environmental Economics and Management*, 80:6–19. The economics of the European Union Emission Trading System (EU ETS) market stability reserve.

Shapiro, J. S. (2016). Trade costs, co2, and the environment. *American Economic Journal: Economic Policy*, 8(4):220–54.

Shapiro, J. S. (2020). The Environmental Bias of Trade Policy. *The Quarterly Journal of Economics*, 136(2):831–886.

Tang, J. P. (2015). Pollution havens and the trade in toxic chemicals: Evidence from u.s. trade flows. *Ecological Economics*, 112:150–160.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., and de Vries, G. J. (2015). An illustrated user guide to the world input–output database: the case of global automotive production. *Review of International Economics*, 23(3):575–605.

Tobey, J. A. (1993). *The Impact of Domestic Environmental Policy on International Trade*. Springer Berlin Heidelberg, Berlin, Heidelberg.

van den Bergh, J. and Savin, I. (2021). Impact of carbon pricing on low-carbon innovation and deep carbonisation: Controversies and path forward. *Environmental and Resource Economics*, 80.

Walter, I. and Ugelow, J. L. (1979). Environmental policies in developing countries. *Ambio*, 8(2/3):102–109.

A Appendix: Trade partners, Sector Classification and ETS coverage

The 15 non-EU economies include (Developing) Brazil, China, India, Indonesia, Mexico, Russia, Turkey and (Developed) Australia, Canada, Japan, Korea, Norway, Swiss, Taiwan, USA. They account for over 70% of EU's trade volume.

Code	***Description***	ETS
A01	Crop and animal production, hunting and related service activities	
A02	Forestry and logging	
A03	Fishing and aquaculture	
B	Mining and quarrying	
C10-C12	Manufacture of food products, beverages and tobacco products	
C13-C15	Manufacture of textiles, wearing apparel and leather products	
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
C17	Manufacture of paper and paper products	
C18	Printing and reproduction of recorded media	
C19	Manufacture of coke and refined petroleum products	1
C20	Manufacture of chemicals and chemical products	1
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1
C22	Manufacture of rubber and plastic products	1
C23	Manufacture of other non-metallic mineral products	1
C24	Manufacture of basic metals	1
C25	Manufacture of fabricated metal products, except machinery and equipment	1
C26	Manufacture of computer, electronic and optical products	1
C27	Manufacture of electrical equipment	1
C28	Manufacture of machinery and equipment n.e.c.	1
C29	Manufacture of motor vehicles, trailers and semi-trailers	1
C30	Manufacture of other transport equipment	
C31_C32	Manufacture of furniture; other manufacturing	
C33	Repair and installation of machinery and equipment	
D35	Electricity, gas, steam and air conditioning supply	1
E36	Water collection, treatment and supply	
E37-E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	1
F	Construction	1
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	
G46	Wholesale trade, except of motor vehicles and motorcycles	
G47	Retail trade, except of motor vehicles and motorcycles	
H49	Land transport and transport via pipelines	
H50	Water transport	
H51	Air transport	
H52	Warehousing and support activities for transportation	
H53	Postal and courier activities	
I	Accommodation and food service activities	
J58	Publishing activities	
J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	
J61	Telecommunications	
J62_J63	Computer programming, consultancy and related activities; information service activities	
K64	Financial service activities, except insurance and pension funding	
K65	Insurance, reinsurance and pension funding, except compulsory social security	
K66	Activities auxiliary to financial services and insurance activities	
L68	Real estate activities	
M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities	
M71	Architectural and engineering activities; technical testing and analysis	
M72	Scientific research and development	
M73	Advertising and market research	
M74_M75	Other professional, scientific and technical activities; veterinary activities	
N	Administrative and support service activities	
O84	Public administration and defence; compulsory social security	
P85	Education	
Q	Human health and social work activities	
R_S	Other service activities	
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	
U	Activities of extraterritorial organizations and bodies	