Testing the Pollution Haven Hypothesis: Evidence from European Union Emissions Trading Scheme

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Abstract

This paper investigates the possible pollution haven effect caused by European Union Emissions Trading Scheme, using panel bilateral trade flows data between 2000 -2011. I find significant evidence in favor of pollution haven effect within the European Union, while on the other hand, extra European Union trade flows show opposite effect that the member countries have higher exports and lower imports for regulated industries. Whether permissions are auctioned has no significant effect. A shortage of allocated permits pushes a country into a disadvantage with respect to its trading ability.

1 Introduction

One of the most important global climate changes,global warming caused by the emissions of greenhouse gas, has been studied broadly since the end of last century. Gradually increasing global temperatures have the potential to harm entire ecological systems. Aiming to slow down global warming, the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in 1995 which entered into force in 2005. Led by the Kyoto Protocol, European Union Emissions Trading Scheme (EU ETS) was established in 2005. Operated by the European Commission, it is the largest emission trading scheme in the world. It is proceeding until 2020 and is adjusted according to its performance, including emission goals and changes in industrial structures as the system evolves. How and whether those proposed adjustments will be conducted depends on the influence and effectiveness of the current policy.

Generally speaking, EU ETS, like other environmental regulations, generates both benefits of decrease of emissions and also costs for conducting them. Those effects could be reflected in international trade. On one side, as a stringent environmental regulation, EU ETS could impede regulated industries in international competition. This outcome follows naturally from the pollution haven hypothesis which claims that pollution control costs are important enough to measurably influence trade and investment. The Heckscher-Ohlin-Samuelson model provides theoretical foundation for this perspective. Since relative factor endowments associated with pollution control costs change in regulated countries, the production of pollution-intensive goods may shift to other countries without emission regulations.

On the other side, EU ETS is a cap-and-trade scheme with its major allowances freely allocated from its launching point until now. The comparative advantage of industries which have abundant emission permits and lower abatement costs may increase. Because of those inverse effects, the real influence of current EU ETS policies on international trade is unclear.

In this paper I investigate in which direction and by how much the EU ETS shifts the member countries international trade by using bilateral trade data. Recently researchers have focused on EU ETS itself, that is, how the trading scheme affects the efficiency of the policy. Convincing evidence of pollution haven hypothesis based on a global pollutant has not been found, nor has it been fully investigated.

Hintermann (2009) considers the EU ETS impact on the allowance price, finding evidence that prices were not initially driven by marginal abatement costs. Neuhoffa et al. (2006) studied how the allocation allowances affect the electricity sector only. Bruyn et al., (2008) by studying the resulting competitive change examine the pollution haven effect of EU ETS using data on Dutch industries. They found that there is an increase in costs as well as a change in the ratios of export to the total value of domestic production.[1] The limitation of their study is their assumption that EU ETS is under a full auction scenario in which all allowances are auctioned to producers. However, most allowances so far have been given away freely.

There are several differences between this paper and the current literature. First, unlike most of the early research which focuses on local pollutants,[2] I study the pollution haven effect caused by EU ETS, a cross country regulation focusing on a global pollutant, carbon dioxide. The efficiency of an environmental policy requires that the benefit to the environment equals the cost of regulation. But for a global pollutant, possible carbon leakage could weaken the benefit to the environment though the cost remains the same. Moreover, decreasing the greenhouse gas globally could generate free-riders as well. Hence, the balance between the regulation and international competitiveness is much more important for global pollutants.

Additionally, the effect of EU ETS is a two-sided sword, since it could either benefit the regulated industries or restrict them depending on the allocated allowance. As a long-term adjustable environmental regulation, understanding the effect of current policies is necessary for their further improvement. Second, this paper uses a new panel dataset from 2000 to 2011 that combines detailed regulation data with bilateral international trade flows, by carefully matching the industry specific allocated allowance with the 2- or 3-digit SITC classification of trade flows. The analysis is based on the gravity equation. It is well known that the gravity equation may suffer from endogeneity when evaluating the effect of trade-relevant policies. In this paper, I uses fixed effects to capture each country's characteristics and considering the uniform standard and enforcement of EU ETS for each. Besides the panel data regression, I also use the difference-in-difference method.

The plausible endogeneity of the quantity of allocated allowances is controlled with instruments. Since the national allocation plans which determine the detailed allocated allowances for each industry also take international trade into account, this paper applies moments of heteroscedasticity to instrument for freely allocated

[1] In this paper, they investigate the cost and export ratio changes separately for each industry. For example, the aluminium firms face an increase of cost by 5%, the export ratio changed by 76%.

[2] The toxicity index for the local pollutants depends on the damage to the air, like sulfur dioxide, poisoned substance to the soil and water. Generally, regulation in one country is less likely to affect the environment in another country, not considering boundary, wind and precipitation.

allowances (Lewbel, 2012). This is quite different from the majority of literature that uses abatement costs to measure the environmental policies and deal with endogeneity.

Empirical results in this paper suggest several importation policy implications. As for total trade flows, the pure effect of EU ETS is to increase EU imports and decrease EU exports,, indicating that EU ETS has cause a deterioration in EU's comparative advantage. I look into the trade flows by separating them into intra EU and extra EU trade. The effects for EU and non EU countries have the same trend in imports and exports. The effect on the non EU country is slightly larger comparing to EU countries. However, due to the larger flows within EU, the pooled regression coefficients are much closer to intra EU results. Member countries whose allocated allowances are not enough for production, or the net emission trade flows are negative (in short position), do face a larger disadvantage in international competition.

These results suggest that there is a pollution haven effect caused by the EU ETS. However, the shift is only within the EU. In particular, those countries in short positions suffer more from EU ETS. As most reports indicated, there is excessive allocation for several industries, such as glasses, pottery and ceramics. The total effect of EU ETS on them is to increase imports while decrease exports. Thus, further emission cuts should be laid on them. The amount of freely allocated allowances shift trade flows significantly, and their directions are predictable. Thus, the social planner could adjust firms' emissions and productions through controlling their free allocated allowance.

This paper is outlined as follows. In section II, I give a short description of the current literature on the pollution haven hypothesis. In section III, I describe EU ETS and its possible outcomes in detail. In sections IV and V, the dataset and methodologies are introduced respectively. In section VI, I discuss the results. Section VII offers robustness checks. The conclusion follows in section VIII.

2 Literature Review

There are numerous studies of the role of environmental regulations on the pattern of trade, both theoretical and empirical. Siebert (1977), Pethig (1976) and McGuire (1982) provide the possible background for pollution haven hypothesis by studying a two-goods open economy. They all conclude that the environmental policy will increase social welfare if marginal social costs of production are higher than the marginal utility of consumption. The comparative advantage model implies that a country will have a production advantage if it has abundant resources.

However, in terms of empirical evidence, researchers have not reached an agreement on whether environmental policy affects trade. Copeland and Taylor (2004) group empirical studies into pre-1997 and post-1997. The early research mainly relied on cross-sectional data, while the later one uses panel data methods to deal with possible endogeneity problems. The most widely cited empirical work is Tobey (1990) in which two methods are used to test the hypothesis that the strictness of environmental regulations is related to exports of polluting industries. His work fails to find evidence that domestic environmental regulation has a significant impact on exports of polluting industries. Only one of the twelve included factor endowments is significant in three commodity groups. Van Beers and Van Den Bergh (2001) find no significant effect of environmental policy on exports of dirty goods for resource-intensive industries using a gravity model. Their result suffers from an endogeneity problem because of their cross-sectional dataset of 21 OECD countries in a single year only.

Controlling for endogeneity and heterogeneity using a two-stage least squares approach, Wilson, Otsuli and Sewadeh (2002) examine whether environmental regulations affect exports of dirty goods in 24 countries from 1994 to 1998. They do find some evidence that there is some tradeoff between stringent environmental regulations and trade expansion for some industries. Ederington and Minier (2003) use the environmental abatement cost as the measurement of the stringiness of regulations and treat it as endogenous in the U.S. from 1978 to 1992. They find the impact of regulation on the net trade flow is significantly high. Levinson and Taylor (2008) develop a theoretical model and test it empirically to examine the effect of environmental regulations on trade flows between the U.S., Canada, and Mexico, for 130 manufacturing industries from 1977 to 1986 and that industries' hardest hit by regulations experienced the largest increases in net imports. Their main contribution is to deal with the endogeneity for foreign unobserved regulations by applying instrumental variables which are generated by weighted state characteristics.

One study that focuses on EU environmental regulations is Cavea and Blomquistb (2011). They apply the Toxic Release Inventory (TRI) index as a measure of pollution to test the pollution haven hypothesis generated by the signing of the Maastricht Treaty in 1993 on EU imports at the 2-digit SITC level from 1970 to 1999. They find no significant increase in the amount of EU toxic-intensive trade with poorer countries, although there is some increase in EU imports of toxic goods from poorer OECD and non-EU European countries, though this result is not robust. My paper studies the following years, from 2000 to 2011 and tests the pollution haven hypothesis generated by EU ETS for a global pollutant.

3 European Union Emission Trading System

EU ETS is the first large emission trading scheme in the world encompassing 27 EU countries plus Iceland, Norway, and Liechtenstein, covering more than 10,000 installations with a net heat excess of 20 MW in energy and industrial sectors which are collectively responsible for half of the EUs emissions of carbon dioxide. It was launched on January, 1, 2005 as an outcome of the Kyoto Protocol. There are three phases of EU ETS. Phase I ran from January, 1, 2005 to 31st December, 2007 and covered only carbon dioxide emissions from energy activities (combustion installations with a rated thermal input exceeding 20MW, mineral oil refineries, coke ovens), production and processing of ferrous metals, mineral industry (cement clinker, glass and ceramic bricks) and pulp, paper and board activities. Phase II ran from January, 1, 2008 to December, 31, 2012. During this period, EU ETS includes revised monitoring and reporting rules, more stringent emissions caps and additional combustion sources. New industries were included, such as airlines being added at the beginning of 2012. Phase III started on 1st January 2013 and will go until December, 31, 2020. This period will bring major changes, such as harmonized allocation methodologies and inclusion of additional greenhouse gases and emission sources. EU ETS will be expanded to include petrochemicals, ammonia and aluminum industries and additional gases in 2013. The cap will be cut by as much as 20% compared to Phase II.

The distribution of emission allowances also differs across phases. Phase I is based on historical emissions and installation levels.[3] Phase II retains Phase I methodology but also includes several other options, such as option 2 based on historic output/capacity ratio; option 3 based on benchmarking; option 4 based on installation-level projections using any metric (emissions, input, output); and option 5 based on the marginal abatement cost. The choice of which option to apply rests with each member state. There is another significant difference in Phase III in that as much as 50% of allowances will be auctioned rather than given away. In the previous two phases only a small amount of allowances were distributed via auction, 5% and 10% in Phase I and Phase II respectively.

[3] The detailed methods for different sectors are varied. For example, the combustion installations are equal their 2002 direct emissions multiply projected output growth rate between 2002 and the first phase then multiply by change in energy per unit output required target between 2002 and the first phase. Also, those values are also adjusted by the possible growth rate.

For each EU ETS phase, the total quantity of allowance to be allocated by each Member State is defined in the Member State National Allocation Plan (NAP) (equivalent to its UNFCCC-defined carbon account.) The European Commission has oversight of the NAP process and decides if the NAP fulfills the 12 criteria set out in Annex III of the Emission Trading Directive (EU 2003/87/EC). The first and foremost criterion is that the proposed total quantity is in line with a Member States Kyoto target.

The main participants in the allocation process are the European Commission, the member state governments, and firms that were to be included in the scheme and would be the main recipients of allowances. The role of these participants varies according to the two main issues to be decided: the 'macro' decision concerning the total number of allowances to be created by each member state, and the micro decision concerning how this total would be allocated to affected firms in each member state. Each member state took the initiative in proposing in its National Allocation Plan (NAP) total and in specifying the allocation to installations, but both aspects were subject to review by the commission. The allocation of the shortage to the EU15 resulted from the structure of the member-state commitments under the Kyoto Protocol.

In each trading period, the large emitters obtain trading permits from the NAPs and purchase EU and international trading credits as well. For each member state it allocates allowances to each industrial sector. Since the electricity utility sector does not face severe non-EU international competition, most EU15 countries allocated the shortage to the power sector. The power plants account for a large amount of carbon emissions and face the largest regulation constraints, which could be uneven among EU countries. This is one reason why I focus on within-EU trade flow changes before going to the international carbon leakage effects.[4]

The price of the permission per ton of carbon is determined by the market demand and supply. The trading price is equal across the EU. Excessive allowances will result in a low carbon price, and reduced emission abatement efforts (Newbery, 2009). Too few allowances will result in too high a carbon price (Hepburn, 2006, p. 239). Since most of the allowances are currently given away freely, it could be viewed as endowments for each member country. Because of the mechanism of allocation and possible leakage, which is the effect of emissions increasing in countries or sectors that have weaker regulations; there is a potential pollution haven effect since the permits

[4]Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country with a strict climate policy.

are distributed and traded among countries, even though the trade price is the same across the EU. It is possible that, within EU countries, there are countries with more stringent regulations that attained fewer quotas compared to what they could have attained, and weaker regulated countries that possess more.

One traditional way of environmental regulation is to add taxes on emitted pollutants. Similarly, a cap-trade scheme with purchased permission also raises the cost through increases of abatement costs. However, the possible outcomes of EU ETS are not clear. The freely allocated allowance is viewed as a windfall asset for manufacturers, the comparative advantage for those who have abundant emission quotas will increase. Additionally, some countries do have a very small proportion of allowances sold through auctions rather than given freely. Though the amount is limited, less than 5% in the first phase, and 10% in the second phase, they could have entirely opposite effects compared to the freely allocated allowances. The possibilities could be summarized in three main points: First, launching of EU ETS is a strict environmental policy which could result in a disadvantage in international competition. Even if there is no shortage for other industries, 64% of companies responding to an October 2008 survey said they had average annual costs of monitoring and reporting of £26,000 and average annual verification costs of £9,000. Second, some industries claim that the allocation is a windfall financial asset which could benefit their international competitiveness because in Phase I and Phase II, most allowances are given away freely. Regions will export goods that use locally abundant factors, that is, countries in the long-position may export more goods that emit more CO2 within the EU. Thirdly, carbon leakage may occur. External EU trading partners, not constrained by EU ETS, could have larger emissions of carbon by producing more than before due to their comparative advantage.

4 Theoretical Background

Assume there are two countries, called North and South. North is regulated with a cap-and-trade environmental policy while South is not. North produces two kinds of goods, x and y. x is Cournot competed with South (duopoly in the international market) while y is a monopoly in the international market. Both goods are regulated by the environmental policy so I am going to generate a partial equilibrium under the situation. The demand functions for goods x and y are:

$$P_x = a - bQ_x^N - \delta Q_x^S$$

$$P_y = d - cQ_y$$

The production function in each country follows the Taylor and Copeland (2004):

$$Q_j^i = A_j^i L_i^j (1 - \theta_i),\ with\ i \in S, N\ and\ j \in x, y,\ \theta_i = 0\ for\ i = S$$

θ_x and θ_y stand for the effort input on abatement, labor inputs are shown in L_x^N, L_y and L_x^S, and A stands for the technology term of each country. In this model, I assume that the social planner in North will distribute the emission allocation before firms make production decisions. The freely allocated allowance is z_x and z_y. Firms could trade their allocations freely and with no costs. The price of permission is determined by the market. The effort of abatement is given as θ_i for each firm and it is known by the government. $\phi(1-\theta_i)Q_i^N$ is the final emissions of firm i. Thus, the profit function for each producer in both countries is:

$$\Pi_x^N = Q_x^N P_x - w_N L_x^N - P * (\phi(1-\theta_x)Q_x^N - z_x)$$

$$\Pi_y^N = Q_y^N P_y - w_N L_y^N - P * (\phi(1-\theta_y)Q_y^N - z_y)$$

$$\Pi_x^S = Q_x^N P_x - w_S L_x^S$$

Utility function for a representative consumer in country North follows a Cobb-Douglas function and their income is composed of labor income only. Goods are sold in the international market and consumers are price takers. Emissions from both countries generate negative utility.

$$U = x^{\alpha} y^{1-\alpha} - H(E_x^N + E_y^N + E_x^S)$$

$$s.t.\ P_x x + P_y y \leq w_N(L_x^N + L_y^N)$$

The demand of product x and product y in the domestic country is:

$$Q_x = \frac{1}{P_x}\alpha w_N\left[\frac{Q_x^N}{A_x^N(1-\theta_x)} + \frac{Q_y^N}{A_y^N(1-\theta_y)}\right]$$

$$Q_y = \frac{1}{P_y}(1-\alpha) w_N\left[\frac{Q_x^N}{A_x^N(1-\theta_x)} + \frac{Q_y^N}{A_y^N(1-\theta_y)}\right]$$

The social planner's utility is an electoral model, which is in terms of profits of firm x and y, and utility of consumers. The social planner will choose freely allocated allowances for each firm to maximize its electoral function.

$$\max_{z_x, z_y}\ s_1\Pi_x^N + s_2\Pi_y^N + U$$

Combining with the market clearing condition of emissions $E_x^N + E_y^N = z_x + z_y$, I solve the firms' decision given freely allocated allowance known, they are functions of those parameters:

$$P = P(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

$$Q_x^N = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$
$$Q_y^N = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$
$$Q_x^S = Q(A_x^N, A_x^N, A_x^S, \theta_y, \theta_x, w_s, w_n, a, \delta, b, d, c, z_x, z_y)$$

By taking the FOCs of the government electoral function, I have:

$$\begin{aligned}
&\frac{\partial G}{\partial z_x} \\
&= s_1[\frac{\partial \pi_x^N}{\partial Q_x^S}\frac{\partial Q_x^S}{\partial z_x} + \frac{\partial \pi_x^N}{\partial P}\frac{\partial P}{\partial z_x}] \\
&\quad + s_2\frac{\partial \pi_y^N}{\partial P}\frac{\partial P}{\partial z_x} \\
&\quad - H' - H'\frac{\partial Q_x^N}{\partial z_x} \\
&\quad + \frac{\partial U}{\partial Q_x}[\frac{\partial Q_x}{\partial Q_x^N}\frac{\partial Q_x^N}{\partial z_x} + \frac{\partial Q_x}{\partial Q_y^N}\frac{\partial Q_y^N}{\partial z_x} + \frac{\partial Q_x}{\partial p_x}\frac{\partial p_x}{\partial z_x}] \\
&\quad + \frac{\partial U}{\partial Q_y}[\frac{\partial Q_y}{\partial Q_x^N}\frac{\partial Q_x^N}{\partial z_x} + \frac{\partial Q_y}{\partial Q_y^N}\frac{\partial Q_y^N}{\partial z_x} + \frac{\partial Q_y}{\partial p_y}\frac{\partial p_y}{\partial z_x}]
\end{aligned} \tag{1}$$

Overall, the optimal allocations for each firm depend on its competitiveness in international market. The competitiveness depends on the firms' characteristics and stringency of environmental regulations. Since I would like to evaluate environmental regulation in industry level, especially when comparing international trade flow changes before and after EU ETS, environmental regulation becomes a treatment, while all firms' characteristics in each industry and country could be controlled by fixed effects.

5 Data and Summary Statistics

Data contain export and import values for regulated sectors, gravity characteristics, and EU ETS allowances from 2000 to 2011 for EU ETS participants.

This is an unbalanced panel dataset including more than 100,000 observations for both exports and imports. The allowance data are available from the Community

International Transaction Log, version 11 (CITL v.11) provided by the European Environmental Agency (EEA). The data include ten sectors: combustion installations; mineral oil refineries; coke ovens; metal ore roasting sincerity; pig iron or steel; cement clinker or lime; glass including glass fiber; ceramic products by finery; pulp, paper and board and other activities which opted in. The last sector, 'other activities opted in' was included to cover other installations opted in under Article 24 of the EU ETS Directive. In practice, the activity of an installation which is listed under this sector in the CITL is often not clear. Thus, I only focus on the nine sectors which are clearly defined. The amount of allowances for each sector is shown in Figure 1. The combustion installations take most of the total freely allocated allowances and experienced reductions in Phase II. Compared to this, other eight sectors have a relatively constant amount of allowances[5].

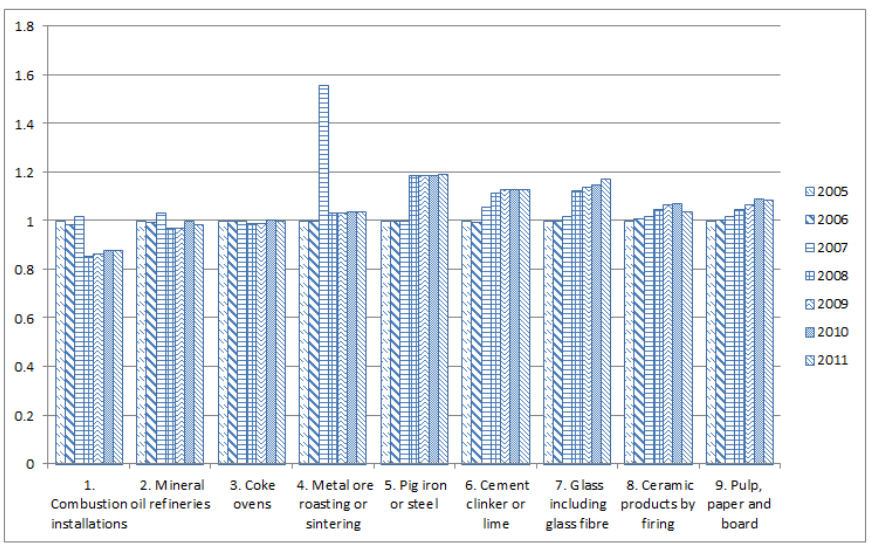

Figure 1: Allowances vary by year for each sector

There are two categories for allocation data, one is freely allocated EU allowances (EUAs) and the other one is verified emissions. Information on verified emissions and freely allocated EUAs is presented for two different scopes: 'Verified emissions (all installations)' and 'Verified emissions (installations with emissions for 2008 until 2011)';

[5]The outlier for metal ore roasting or sintering sector in 2007 is because there were several more countries participating EU ETS in this sector since 2007 while the early members' allowances were not adjusted to fit the cap. Starting from 2008, the first year of Phase II, all allocated allowances were adjusted.

'Freely allocated EUAs' and 'Freely allocated EUAs (installations with emissions for 2008 until 2011)'.

The freely allocated EUAs measure the amount of free allocation received, but does not include allowances bought. The verified emissions are emissions of the installation(s) which have been examined by a verifier. The second scope corresponds to a constant scope: it takes into account the same installations across the years (those for which verified emissions or freely allocated EUAs were reported throughout the second trading period). This constant scope provides time-consistent information, meaningful for a relevant trend analysis. The allowance is in the terms of tons of CO2 equivalent. EU ETS started with the EU-25 in 2005, but the number of countries covered has since increased to 30. Bulgaria and Romania entered EU ETS in 2007, Norway, Iceland and Liechtenstein joined in 2008. Regulation status dummies I used in regressions are generated for each industry by country and by year.

The amount of freely allocated allowances for EU ETS members is shown in Figure 2. The starting point shows the year when the country entered EU ETS. From the graph, we notice that there is no significant cut in emission during Phase I and Phase II. The emissions cap did not decrease during those two periods. The noticeable reduction in Germany (DE) is due to those parts of allowances which are allocated by auction. Besides EU ETS regulations, other Kyoto Protocol members also started sub-national trading schemes. For example, Japan emissions trading in Tokyo started in 2010 ran by the Tokyo Metropolitan Government. Canada started emissions trading in Alberta in 2007 run by the Government of Alberta. The New Zealand Emissions Trading Scheme started in 2008. These trading schemes are smaller in scale and too new. Hence they are omitted in this paper because EU ETS is the only international and broadly spread regulation scheme covering a longer period of time.

Some countries sell some proportions of allowance by auctions. Those data are not directly recorded by the CITL, but are available from other sources. Table 1 summarizes the amount EUAs auctioned or sold by countries and includes the relevant sources. In regressions I generate a dummy for each country's auction status instead of using the amount because its relatively small proportion to the total EUAs.

The international trade data are from EuroStat reflecting 2- or 3-digit SITC bilateral trade flows in values from 2000 to 2011. The countries participating in EU ETS are referred to as reporters. Table 2 shows how the SITC classification is matched with EU ETS industry sectors. Since the combustion installations are not defined as industrial sectors, the power generation equipment is used to approximate the demand for further expansion of combustion installations. I selected four countries,

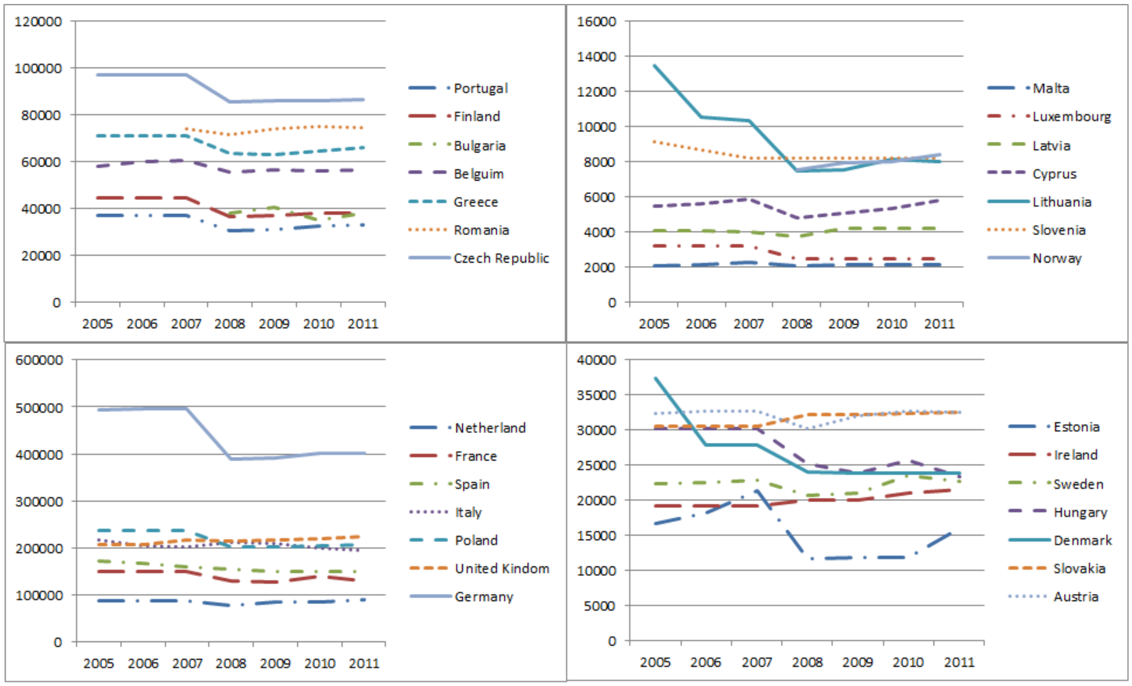

Figure 2: Total Allowances by Country and Year

United Kingdom and Spain which are short in their allocated allowance, France and Germany which are excessive in their allowances. Their imports and exports by year and industry are shown in Figure 3a and 3b. For most industries, there is no obvious trade flow change before and after EU ETS, especially for mineral oils which shows a zigzag shape.

The necessary gravity variables are from the CEPII gravity dataset which includes common language, GDP, population, distance, area, time difference, legal origins, GATT/WTO status and whether they have a common currency. CEPII data are only available until 2006. I expanded it to 2011 by adding GDP and population obtained from World Bank's World Development Indicators (WDI). Other gravity variables do not change over time.

6 Methodology

To estimate the effect of EU ETS on trade flows, I regress trade flows on gravity variables plus regulation status for EU ETS member countries (reporter countries above). Furthermore, the effect of auction–whether an EU ETS member country auctioned their allowances or not, on trade flows will be estimated. First a cross-sectional approach is used, and then I move to fixed effects. The difference-in-difference approach

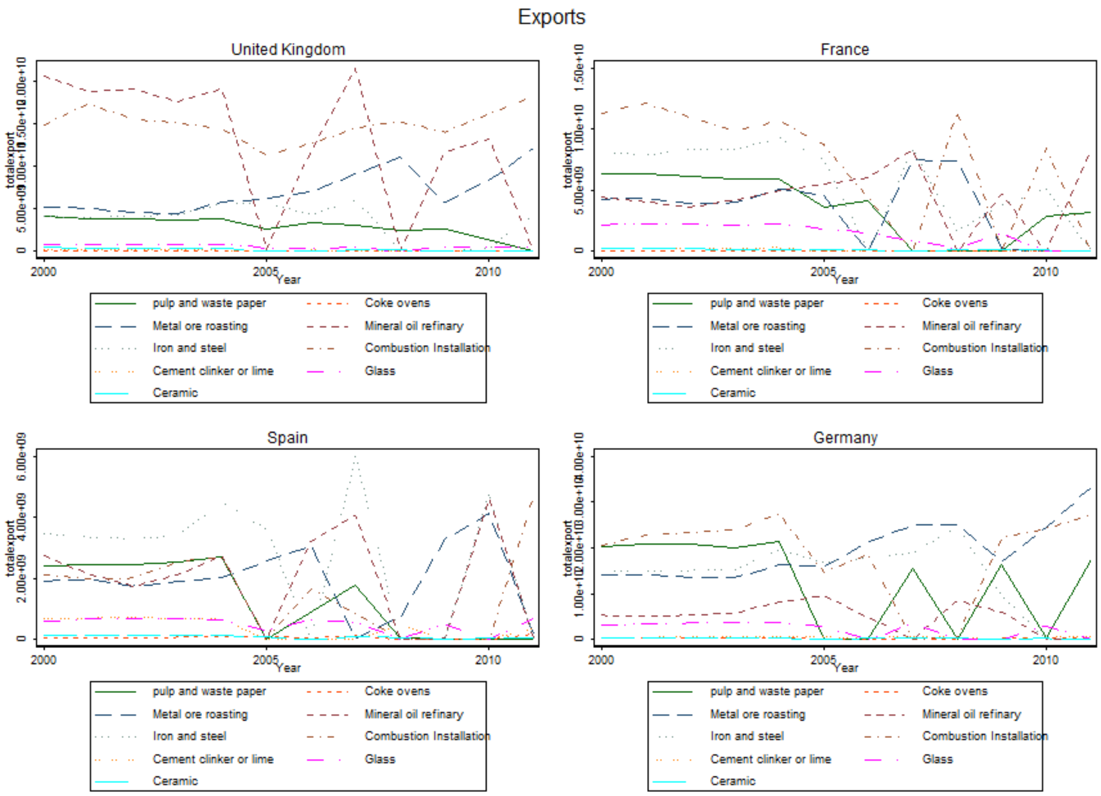

Figure 3: Export

is used to control for the 'real' regulated status.[6] For all the models, regressions are on samples of imports and exports for EU ETS member countries with more than 200 partner countries, then intra-EU trade and extra-EU trade are investigated separately.

The linear regression model is:

$$\log x_{ijts} = \beta_0 + \beta X_{ijt} + \gamma D + \delta R + \sigma * (sectordummies * R) + \epsilon_{ijts}$$

where X_{ijst} stands for the trade flow from country i to country j at time t in sector s. X_{ijt} includes all gravity variables such as GDP per capita and population for origins and destinations in log terms, area, distance, legal origins and common language, common boarder dummies. R stands for the regulation status for home country (origins in exports and destinations in imports). D is the full set of dummies for industries and years. For partner countries of EU ETS members, regulation policies on carbon dioxide are unclear or their emission trading policy is not comparable to EU

[6]The real regulated status is defined if a member state in EU ETS receives less allocated allowances than it needs, either in the amount value or the finance flows. This is defined as 'short position' and 'net short position' correspondingly. Further explanations are given in the following.

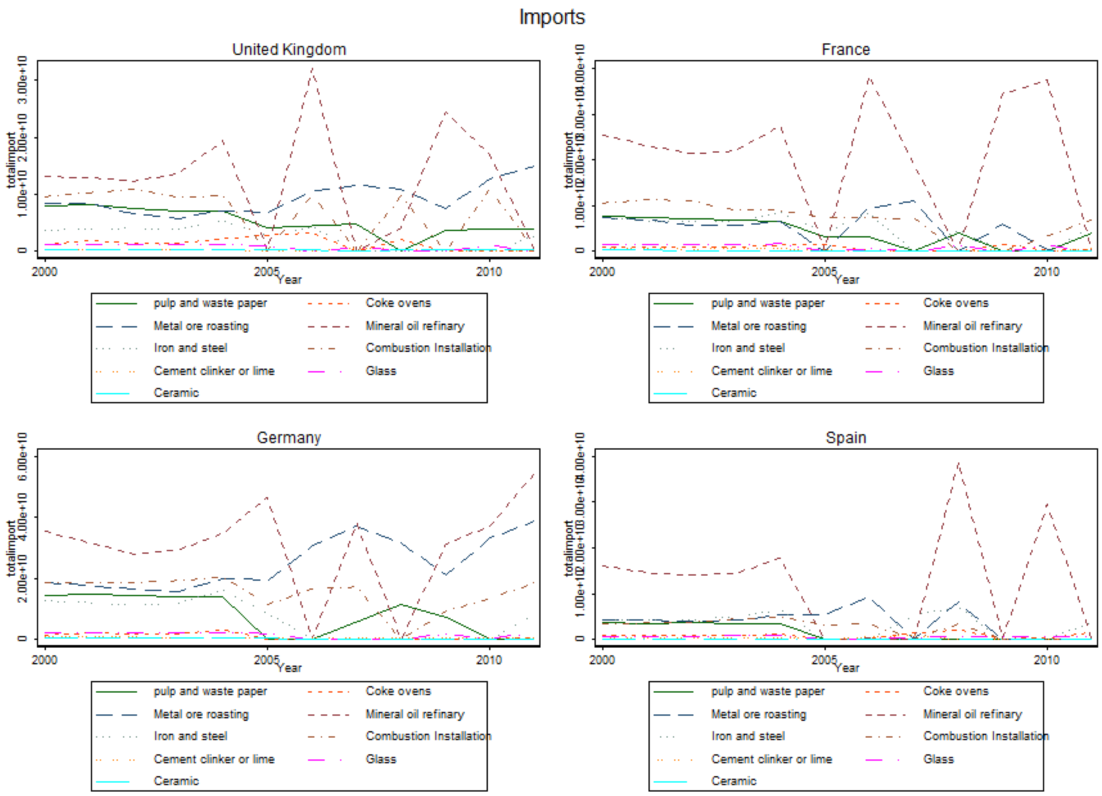

Figure 4: Import

ETS. Thus, interaction of country and year dummies are included. The interactions of regulation and industries are used to make the regulation effect more accurate because sectors are not regulated at the same time in each country.

The fixed effects model contains the same regressors in addition to the full set of dummies for importers and exporters. Dummies control for the unobserved partner characteristics, in particular, for environmental policies other than EU ETS. There are more than 20,000 groups (home country and partner country for certain industry) with 170,000 observations on imports and exports. The panel data approach deals with endogeneity, in particular for non EU ETS member countries.

In the fixed effects model, I focus on the change before and after EU ETS for its member countries. However, even among the member countries, they are not in the same position. Thus, a method to evaluate the effect of regulation for different countries on international trade is to use the difference-in-difference approach. The data however, only include the participants and industries under EU ETS, implying that finding the appropriate control and treatment group becomes very important. According to the Climate Report for the first phase of EU ETS, most countries are actually in the long position, meaning that more allowances were allocated in the first phase than were needed by covered installations. The countries in the short positions are Ireland, Spain, Italy and the United Kingdom. Noticeably, the carbon price decreases sharply at the end of Phase I due to excessive quantity of permissions. Considering the carbon price was high at the beginning of each phase and lower in later stages of each phase, it is possible that installations in one country bought more than they sold but did not appear as net buyers because the price was high when they were selling and low when they were buying. Thus, with respect to net finance flows which are calculated for each year using the average yearly price of Phase I spot allowances weighted by yearly net flows of allowances, the United Kingdom, Spain, Italy, Austria, Ireland, Slovenia are in the net short position. France, Poland, Germany and the Czech Republic have a large proportion excessive in carbon allowances to their needed. I use these two different treatments to conduct difference-in-difference analysis.

When considering the impacts of the amount of allocated allowances on international trade flows, the situation is more complicated. Even though the regulation is forced for every EU member in larger emitting industries, the detailed allocation plans are chosen by each country. The allocated amount is endogenous because taking the emissions into account, the shortage of allowance is allocated to the industries that face less severe international competition such as combustion installations. The most common way to deal with endogeneity is to find an outside instrument, such as emission rates for each industry and each country. Unfortunately, corresponding emission rates at the 2- or 3-digit SITC levels is not available to best of my knowledge. In this paper, heteroscedasticity is used as an instrument following Lewbels (2012). This model is listed below:

$$Y_1 = X'\beta_1 + Y_2\gamma_1 + \epsilon_1,$$

$$\epsilon_1 = \alpha_1 U + V_1$$

$$Y_2 = X'\beta_2 + Y_1\gamma_2 + \epsilon_2,$$

$$\epsilon_2 = \alpha_2 U + V_2$$

It requires that the systems in which the correlation of errors across equations are due to the presence of an unobserved common factor U. Besides all the trade related exogenous variables, emission allocation allowance is a function of trade flows. On the other hand, the trade flow is also in terms of allowances. In this model, U, V_1, and V_2 are unobserved variables that are uncorrelated with X and are conditionally uncorrelated with each other, conditioning on X. U is an omitted variable or other unobserved factor that may directly influence both Y_1 and Y_2.

Those two are correlated by an unobserved common factor U which captures the trade-off between the marginal benefit of environmental improvement and marginal cost for industries. The moments of heteroskedasticity can be shown to be correlated with the endogenous variables while uncorrelated with all the exogenous variables. When conducting the empirical analysis, I take natural log value for the allowances. For the non-regulated industries, I give them value equals to 1. The aim of this regression is to find that for regulated countries, how the change in the amount of freely allocated allowances affects international trade flows.

7 Results

Table 4 reports the results for the cross-sectional regressions for imports and exports of EU ETS member countries. The first column is the cross-sectional result. Column 2 and 3 include fixed effects for each country. The gravity variables provide expected results. Both the GDP for home and partner countries have positive and significant coefficients. The coefficients of distance and time difference are negative and significant at 1% level. Other variables, such as common language and colonial relationship have positive and significant coefficients.

After taking country fixed effects into account, the population effect changed relative to cross-sectional results. As expected, the regulation impact including the interaction terms have reverse signs for imports and exports. If regulation benefits manufacturers, I expect increases in exports and decreases in imports. If regulation is impeding production as a result of costs increasing, we should observe decreases in exports and increases in imports. The pooling regression shows a negative effect on exports with a coefficient -0.964 while positive effects on imports with a coefficient 0.282, hence it implies the impeding result.

In column 4, country-by-year fixed effects for home and partner countries are added to the regression. These terms also capture the effects of population and GDP changes. The interactions of fixed effects are aimed to deal with unobservable environmental or other trade policy changes which may affect trade flows. Comparing those results with column 2 and 3, there is no significant quantitative difference. The model may well capture unobservable factors by containing fixed effects.

From table 4, imports increase by 0.28 log-point as a result of the regulation, while exports decrease by 0.96. The differences in magnitudes between imports and exports could be explained as the regulation having greatly changed the behavior of manufacturers. The pollution haven hypothesis implies that as those manufacturers have less comparative advantage than before, their exports to other countries decrease. However, for imports, the case is more complicated.

If manufacturers cut their production in the short run, the total domestic production will decrease as imports increase. In the long run, they may adjust their investment or move to a lower emission technology. Therefore, I expect a smaller impact on the value of imports than exports. The coefficient for auctions is not significant. This may be due to a relatively small amount being auctioned compared to grandfathered allowances.

The interactions of industries and regulation status all have significant coefficients except the mineral oil refinery in imports. The exports for mineral oil refinery increase significantly, while imports decrease. One explanation for this is that the factors which could affect mineral oil trade are more complicated even after controlling for trade and environmental policies. The corresponding SITC is Petroleum, petroleum products and related materials. Especially for petroleum, imports are quite stable. Hence, its result is less obvious compared to other sectors.

The interaction terms coefficients of all industries show significant decreases in imports and increases in exports. Though the pure effect of regulation raises imports and reduces exports. If we combine the pure effect of regulation and the interaction terms, for cements, glass, ceramics and pulp papers, EU ETS decreases exports and also increases imports. While for iron steal industry which has excessive allowances, EU ETS actually increases its exports, decreases imports.

Next I use the same model as in columns 2 and 3, but separate the sample into the intra-EU and extra-EU trade since within-EU trade accounts for a large portion of total trade flows in EU ETS member countries. These results are presented in Table 5. The coefficients of the regulation dummies imply that the overall dimension of trade shifts depends on intra-EU trade. The results suggest that EU ETS changed the trade pattern within EU because of the unbalanced freely allocated allowances among countries and industries. On extra EU trade side, the direction of regulations effects varies across industries.

For example, exports from EU countries on iron steel are actually increasing after EU ETS as a result of excessive freely allocated allowances to those industries. On the other side for iron steel, regulations decrease imports. Similarly, the results are more significant on exports than imports.

The auction status is still insignificant. It suggests that countries which tried auction rather than giving allowances away export more to other EU countries and import more from non-EU countries. Notably, intra EU exports of combustion installations related equipment increases significantly. A reason for this is that if the national allocation plan allocates the shortage mostly on the combustion installation sectors, it may increase the demand for fewer emissions and more efficient equipment. Similarly, the increase in exports to EU countries in combustion installation sectors could be explained by this.

In order to further test the pollution haven effect, I separate extra EU trade partners into five groups according to their income level. The country class level is obtained from World Bank. The results are shown in Table 6. The detailed results also vary across industries; however, the trend implies that after EU ETS, exports to relatively poor countries decrease, while to the rich countries they increase. This result is consistent with the right side of the U-shape environmental Kuznets curve. On the imports side, after EU ETS, EU countries are importing more from lower middle income and upper middle income countries but not from lower income countries. This result is consistent with the left side of the U-shaped Kuznets curve. The pollution haven may generate to middle income and upper middle income countries.

The two difference-in-difference regressions give similar results as the fixed effects model in Table 7. The magnitude of the effect of regulation on exports and imports are -0.9 and 0.26 correspondingly. The total effects of regulations on member countries that are in short position show a decrease in exports and an increase in imports. The interaction term of net short positions and treatment (regulation) suggests that those countries face both as increase in imports and exports (0.189 comparing to 15.139) after the regulation. This result implies that the current EU ETS policies push countries with more demand in carbon emissions into a disadvantage vis-á-vis international competition.

Table 8 shows how the quantity of allocated allowances affects international trade flows. The two panels of this table stand for imports and exports respectively. All columns control for country $\times$ year fixed effects. Columns (1) does not control for the possible endogeneity of allowances. On exports side, one percent change in freely allocated allowances will bring up exports by 2.7% and this result is significant at 1% level. Auction status is significant and negative in this analysis. Imports side has all opposite results to exports, allowances has negative impact on imports and auction has positive impacts on the value of imports, though these results are not significant. These results convinced the hypothesis that more freely allocated allowances give more advantages to the producers, which means more exports, but less imports. After controlling for the endogeneity, there is not change for the sign, but the coefficient are larger. Also, I separate the samples into intra EU and extra EU trade as before, it yields constant results, and only on exports coefficients are significant. The effect of the amount of freely allocated allowances is larger within EU than extra-EU. The IV parts are plausible taking the excessive allowances into account. Moreover, as discussed above, the regulations change the manufacturers' behavior rather than the demand in the market. Hence, for exports the results are significant.

8 Robustness

I conduct several robustness checks. Results are reported in Table 8. The first robustness check is to use three-year windows for the dataset since the industries could make adjustment according to the regulations, and those adjustments will not manifest themselves in trade flows until several years later. The second one is to limit the sample to EU-15 countries only because EU-15 countries are forced into EU ETS rather than opted in. The third robustness check is changing the contained industrial sectors in the sample, such as excluding iron and steel sectors or combustion installations.

The three-year window gives the same results as before. EU-15 countries which face the emission cut have a significant increase in exports, while the change in exports is not significant. After excluding the combustion sector (SITC 71), the results are still robust. Also, according to the *Climate Report*, the sector with the largest excessive allocated allowance is iron and steel. Excluding iron and steel sectors, the regulation effect is still negative, but insignificant. When excluding both combustion installation and iron and steel sectors, all results are unchanged.

9 Conclusion and Further study

In this paper, I use the cross-section, cross-time bilateral trade flow data to evaluate the EU Emission Trading Scheme effect on international trade with a gravity model based on the pollution haven hypothesis. The impact of auctions is also examined. The difference-in-difference approach is used to study the regulation effect on countries which are in shortage of allowances. To examine the effects more precisely, the samples are separated into intra EU trade and extra EU trade. Moreover, trade flows changes are also examined for different country income level. The effects of the amount of freely allocated allowances on trade flows are also investigated through an

IV model.

EU ETS increases imports and decreases exports. The separate regression implies that the pollution haven is generated with respect to the middle income and upper middle income countries. The member countries which are in the (net) short position do face reductions in comparative advantage. The effect of auctions is not significant due to the small portion of the total allowances. Those results suggest that there is a pollution haven effect caused by EU ETS among EU countries.

The empirical results in this paper suggest several importation policy implications. EU ETS increases imports into its member countries and decrease exports by a larger amount. Especially for countries in the short or net-short position in emission trading, their comparative advantage in international trade is weakened by EU ETS. The further tightening of the emission cap or increases in the compliance cost for producers (auctioned) could disadvantage regulated countries in the international competition. Pollution haven was generated by EU ETS, particularly for industries short in allowances. Considering that greenhouse gas is a global pollutant, further sacrificing EU economic benefits may not be an optimal choice.

Even though, there are still excessive allowances for current EU ETS policies. For some industries, such as iron and steel, the total effect of EU ETS is to increase their comparative advantages. Thus, in order to achieve the emission goals in the third phase, their allocated allowances could be cut, or auctioned. Also, according to my results, the trade pattern is controllable by varying the freely allocated allowances. But, the effect of auction on international trade is still unclear.

The trade shifts within EU away from the countries with abundant permissions to others. The domestic production and foreign direct investment should also be investigated since the pollution haven hypothesis also suggests that polluted industries relocated from countries with stringent regulations to the countries with less stringent regulations. Controls for the partners corresponding regulations would be beneficial. Also, how to measure those different regulations and compare them with EU ETS merits further study.

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Table 1

Auctions/Sales	2005	2006	2007	2008 million EUA	2009	2010	2011	Sources
Austria					0.4	0.4	0.5	www.climex.com, www.co2markt.at,www.oekv-energy.at
Germany				41	41.1	41.1	40.7	www.bmu.de, www.dehst.de
Greece								
Hungary		1.2	1.2					www.euets.com
Ireland		1.2			0.2	0.2	0.2	www.pointcarbom.com, www.ec.europa.eu
Lithuania			0.6				0.9	
Netherlands						8	4	www.dsta.nl, www.eex.de
Norway					12.7	6.4	6.4	www.regjeringen.no
United Kingdom				4	25	35.8	30.7	www.dmo.gov.uk
EU-25		2.4	1.7	45	66.7	85.5	76.9	
EU-27		2.4	1.7	45	66.7	85.5	76.9	
All countries		2.4	1.7	45	66.7	91.9	83.3	

Table 2

Sectors in allowance	SIT Classification sectors
Combustion installations	71: power generation equipment
Pig Iron or Steel	67: Iron and steel
Metal ore roasting	28: Metalliferous ores and metal scrap
	68: Non-ferrous metals
Coke Ovens	32: Coal, coke and briquettes
Mineral oil refinery	33: Petroleum, petroleum products and related materials
Pulp, paper and Board	25: Pulp and waste paper
	64: Paper, paperboard and articles of paper pulp, of paper or of paperboard
	725: Paper mill and pulp mill machinery, paper-cutting machines and other machinery for the manufacture of paper articles
Cement clinker or Lime	661: Lime, cement, and fabricated construction materials (except glass and clay materials
Glass	664: Glass
	665: Glassware
Ceramic products by fining	666: Pottery

Table 3

Variable	Obs	Mean	Std. Dev.	Min	Max
Reporter's population	172617	2.49E+07	2.58E+07	381363	8.25E+07
Reporter's GPD per Capita	172617	18112.25	10399.7	1579.348	56388.99
Partner's population	167681	6.08E+07	1.90E+08	9419	1.34E+09
Partner's population	163865	10280.55	12244.89	82.67167	67554.23
Import	172617	2.53E+07	2.19E+08	0	1.87E+10
Export	172617	1.81E+07	1.26E+08	0	7.00E+09
Reporter's allocation	52356	1.55E+07	3.60E+07	0	3.85E+08
Partner's allocation	8148	9395979	2.44E+07	0	1.99E+08

	EXPORTS				IMPORTS			
	Cross-sectional	Fixed effect	Fixed effect w/ auction	Year-by-country fixed effect	Cross-sectional	Fixed effect	Fixed effect w/ auction	Year-by-country fixed effect
Population(reporter)	1.192***	-4.729***	-4.761***		1.028***	-3.110***	-3.150***	
	(0.01)	(0.43)	(0.43)		(0.01)	(0.56)	(0.57)	
GDP per capita(reporter)	1.153***	0.738***	0.724***		0.711***	1.805***	1.790***	
	(0.02)	(0.14)	0.14		(0.02)	(0.19)	(0.19)	
Population(partner)	0.961***	0.813***	0.814***		1.037***	0.795***	0.799***	
	(0.01)	(0.07)	(0.07)		(0.01)	(0.18)	(0.18)	
GPD per capita(partner)	0.719***	0.061	0.063		1.077***	0.672***	0.674***	
	(0.00)	(0.12)	(0.12)		(0.01)	(0.1)	(0.1)	
Interaction1(pulp paper)	0.847***	0.791***	0.789***	0.878***	-0.722***	-0.701***	-0.699***	-0.629***
	(0.1)	(0.1)	0.1	(0.1)	(0.16)	(0.15)	(0.15)	(0.16)
Interaction2(metal ore roasting)	0.780***	1.003***	1.001***	1.024***	-0.457**	-0.382*	-0.382*	-0.351*
	(0.11)	(0.11)	(0.11)	(0.11)	(0.16)	(0.15)	(0.15)	(0.16)
Interaction4(mineral oil refinary)	1.240***	1.346***	1.345***	1.525***	-0.284	-0.186	-0.184	-0.062
	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction5(pig iron or steel)	1.050***	1.076***	1.074***	1.148***	-0.557***	-0.453**	-0.452**	-0.435**
	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction6(combustion installations)	1.120***	1.121***	1.120***	1.433***	-0.569***	-0.524***	-0.522***	-0.400**
	(0.09)	(0.09)	(0.09)	(0.09)	(0.14)	(0.14)	(0.14)	(0.14)
Interaction7(cement and clinker or lime)	0.774***	0.760***	0.758***	0.852***	-0.619***	-0.589***	-0.587***	-0.502***
	(0.1)	(0.09)	(0.09)	(0.1)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction8(glass)	0.587***	0.594***	0.592***	0.761***	-0.965***	-0.906***	-0.903***	-0.819***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Interaction9(ceramic products by fining)	0.517***	0.615***	0.614***	0.764***	-1.005***	-1.006***	-1.005***	-0.904***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.15)	(0.14)	(0.14)	(0.15)
Regulation	-1.110***	-0.966***	-0.964***	-0.961***	0.267	0.284*	0.282*	0.228
	(0.08)	(0.08)	(0.08)	(0.08)	(0.14)	(0.13)	(0.13)	(0.14)
Auction	-0.059		-0.026		-0.034		-0.026	
	(0.03)		(0.03)		(0.05)		(0.05)	

Gravity

	IMPORT				EXPORT			
	Cross-sectional	Cross-sectional w/ emission	Fixed effect	Fixed effect w/ auction	Cross-sectional	Cross-sectional w/ emission	Fixed effect	Fixed effect w/ auction
Common Language	0.091	0.124	-0.035	-0.035	0.331***	0.379***	0.276***	0.276***
	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05
Common colonizer	1.466***	1.451***	1.484***	1.484***	1.169***	1.233***	1.327***	1.327***
	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
In Colonial Relation	0.321***	0.313***	0.364***	0.364***	0.764***	0.767***	0.818***	0.818***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
Distance	-0.000***	-0.000***	-0.001***	-0.001***	-0.000***	-0.000***	-0.001***	-0.001***
	0	0	0	0	0	0	0	0
Area	-0.000***	-0.000***	0.000***	0.000***	-0.000***	-0.000***	0.000***	0.000***
	0	0	0	0	0	0	0	0
Time Difference	-0.127***	-0.119***	0.200***	0.200***	-0.027***	-0.025***	0.278***	0.278***
	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02
Common legal origin	0.530***	0.538***	0.585***	0.585***	0.430***	0.395***	0.408***	0.408***
	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
2001	-0.084*	-0.076*	-0.042	-0.042	-0.059*	-0.061*	-0.008	-0.008
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2002	-0.121**	-0.114**	-0.078*	-0.077*	-0.089**	-0.092***	-0.009	-0.008
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2003	-0.171***	-0.167***	-0.114**	-0.113**	-0.108***	-0.114***	0.016	0.017
	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
2004	-0.128***	-0.120**	-0.061	-0.059	-0.148***	-0.153***	0.035	0.036
	0.04	0.04	0.05	0.05	0.03	0.03	0.03	0.03
2005	0.086	0.07	0.132*	0.134*	0.167***	0.154***	0.248***	0.251***
	0.05	0.05	0.06	0.06	0.04	0.04	0.05	0.05
2006	0.109*	0.109*	0.148*	0.152*	0.02	0.016	0.215***	0.220***
	0.05	0.05	0.07	0.07	0.04	0.04	0.05	0.05
2007	0.156**	0.141*	0.247**	0.252**	-0.025	-0.038	0.176**	0.180**
	0.05	0.05	0.08	0.08	0.04	0.04	0.06	0.06

2008	0.173***	0.167**	0.213*	0.220**	0.123**	0.130**	0.385***	0.392***
	0.05	0.05	0.08	0.08	0.04	0.04	0.06	0.06
2009	-0.102	-0.095	0.031	0.039	0.015	0.033	0.245***	0.254***
	0.05	0.06	0.08	0.08	0.04	0.04	0.06	0.06
2010	0.006		0.188*	0.197*	0.029		0.339***	0.349***
	0.05		0.08	0.08	0.04		0.06	0.06
2011	-0.076		0.124	0.135	0.175***		0.547***	0.559***
	0.05		0.08	0.09	0.04		0.06	0.07
product==28	-0.003	-0.099	0.105	0.105	-0.820***	-0.870***	-0.843***	-0.843***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
product==32	-3.190***	-3.181***	-3.272***	-3.272***	-4.362***	-4.493***	-4.441***	-4.442***
	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04
product==33	-1.348***	-1.410***	-1.261***	-1.260***	-2.391***	-2.412***	-2.361***	-2.361***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
product==67	-1.216***	-1.246***	-1.046***	-1.046***	-1.207***	-1.212***	-1.100***	-1.100***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
product==71	-2.061***	-2.100***	-1.820***	-1.820***	-1.462***	-1.489***	-1.320***	-1.320***
	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
product==661	-3.795***	-3.834***	-3.640***	-3.640***	-3.843***	-3.858***	-3.824***	-3.824***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
product==664	-2.546***	-2.582***	-2.379***	-2.379***	-2.493***	-2.513***	-2.414***	-2.413***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
product==666	-4.381***	-4.464***	-4.157***	-4.156***	-4.875***	-4.871***	-4.817***	-4.817***
	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.04
R-sqr	0.495	0.499	0.544	0.544	0.542	0.548	0.579	0.579
dfres	101949	87781	101757	101756	140772	120819	140579	140578
BIC	504178.8	432676.3	496016	496027.2	651616.3	556390.2	642230.2	642241.4

* p<0.05, ** p<0.01,***p<0.001

	EXPORTS						IMPORTS					
	Intra EU	Extra EU	Year-country Intra EU	Year-country Extra EU	Intra EU w/auction	Extra EU w/auction	Intra EU	Extra EU	Year-country Intra EU	Year-country Extra EU	Intra EU w/auction	EXtra EU w/auction
Regulation	-0.536***	0.056	-0.434**	-1.337***	-0.541***	0.054	0.122	-0.266*	-0.048	-0.274*	0.116	-0.266*
	(0.12)	(0.09)	(0.13)	(0.11)	(0.12)	(0.09)	(0.13)	(0.13)	(0.15)	(0.13)	(0.13)	(0.13)
Interaction1(pulp paper)	0.326*	-0.250*	0.468**	1.145***	0.330*	-0.248*	-0.549***		-0.350*		-0.540***	
	(0.15)	(0.11)	(0.16)	(0.12)	(0.15)	(0.11)	(0.16)		(0.18)		(0.16)	
Interaction2(metal ore roasting)	0.486**		0.604***	1.326***	0.495**		0.125	0.379		0.118	0.126	0.382
	(0.16)		(0.17)	(0.14)	(0.16)		(0.19)	(0.23)		(0.17)	(0.19)	(0.23)
Interaction3(Coke ovens)									0.237	0.282		
									(0.21)	(0.24)		
Interaction4(mineral oil refinary)	1.405***	0.239*	1.641***	1.712***	1.409***	0.241*	-0.325*	0.358*	-0.24	0.519***	-0.315*	0.359*
	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction5(pig iron or steel)	1.109***	0.011	1.178***	1.398***	1.115***	0.012	-0.13	0.212	-0.028	0.193	-0.126	0.214
	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction6(combustion installations)	0.542***	0.077	0.545***	1.750***	0.545***	0.079	-0.234	0.133	-0.106	0.255	-0.226	0.133
	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)	(0.15)	(0.13)	(0.17)	(0.13)	(0.15)	(0.13)
Interaction7(cement and clinker or lime)	0.373*	-0.340**	0.493**	1.055***	0.380**	-0.339**	-0.584***	0.1	-0.437*	0.169	-0.573***	0.1
	(0.15)	(0.1)	(0.16)	(0.12)	(0.15)	(0.1)	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction8(glass)	0.431**	-0.432***	0.548***	1.052***	0.439**	-0.432***	-0.575***	-0.257	-0.435**	-0.191	-0.566***	-0.256
	(0.14)	(0.1)	(0.15)	(0.11)	(0.14)	(0.1)	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Interaction9(ceramic products by fining)	0.176	-0.401***	0.235	1.068***	0.18	-0.399***	-0.685***	-0.532***	-0.518**	-0.443**	-0.678***	-0.531***
	(0.14)	(0.1)	(0.15)	(0.12)	(0.14)	(0.1)	(0.15)	(0.14)	(0.17)	(0.14)	(0.15)	(0.14)
Auction					0.081	-0.036					-0.113	0.03
					(0.07)	(0.04)					(0.07)	(0.06)
R-sqr	0.649	0.533	0.658	0.547	0.649	0.533	0.631	0.495	0.639	0.51	0.631	0.495

* p<0.05, ** p<0.01,*** p<0.001

Figure 6 Extra EU trade with different country income level

	Export					Import				
	High income Non-OECD	High Income OECD	Low Income	Lower Middle Income	Upper Middle Income	High income Non-OECD	High Income OECD	Low Income	Lower Middle Income	Upper Middle Income
Regulation	-1.710***	0.481*	-0.479	-0.947***	-1.434***	-0.85	-0.535*	-0.23	-0.455	0.282
	(0.27)	(0.23)	(0.39)	(0.23)	(0.17)	(1.2)	(0.25)	(2.26)	(0.39)	(0.31)
Interaction1(pulp paper)	1.468***	-0.176	-0.239	0.517*	1.194***	0.87	-0.405	-0.704	0.394	-0.210
	(0.31)	(0.28)	(0.37)	(0.25)	(0.2)	(1.28)	(0.31)	(2.48)	(0.48)	(0.36)
Interaction2(metal ore roasting)	1.672***	-1.910***	-0.06	0.688*	1.369***	0.816	0.860*	-0.411	0.072	-0.138
	(0.35)	(0.35)	(0.42)	(0.28)	(0.22)	(1.25)	(0.4)	(2.28)	(0.45)	(0.35)
Interaction4(mineral oil refinary)	2.321***	0.339	-1.738**	1.050***	1.741***	1.16	0.612*	-2.206	-0.248	0.085
	(0.29)	(0.26)	(0.55)	(0.24)	(0.18)	(1.21)	(0.28)	(2.3)	(0.42)	(0.33)
Interaction5(pig iron or steel)	1.884***	0.533*	0.357	0.790***	1.494***	0.848	0.291	-0.403	0.259	-0.198
	(0.28)	(0.25)	(0.38)	(0.23)	(0.18)	(1.21)	(0.28)	(2.29)	(0.41)	(0.32)
Interaction6(combustion installations)	2.158***	0.299	-0.223	1.200***	1.749***	0.598	0.211	-0.327	0.652	-0.253
	(0.28)	(0.25)	(0.37)	(0.23)	(0.18)	(1.21)	(0.27)	(2.26)	(0.41)	(0.32)
Interaction7(cement and clinker or lime)	1.362***	-0.623*	0.472	0.594*	1.126***	0.324	0.066	-0.599	0.59	-0.211
	(0.3)	(0.26)	(0.37)	(0.25)	(0.19)	(1.22)	(0.28)	(2.27)	(0.41)	(0.33)
Interaction8(glass)	1.472***	-0.274	0.018	0.424	1.171***	0.161	-0.213	-0.875	0.08	-0.537
	(0.28)	(0.25)	(0.4)	(0.24)	(0.18)	(1.22)	(0.27)	(2.29)	(0.42)	(0.33)
Interaction9(ceramic products by fining)	1.709***	-0.177	-0.381	0.394	1.086***	-0.44	-0.268	-0.208	-0.088	-1.094***
	(0.29)	(0.25)	(0.38)	(0.24)	(0.18)	(1.21)	(0.27)	(2.27)	(0.41)	(0.33)
R-sqr	0.537	0.623	0.431	0.526	0.56	0.432	0.665	0.564	0.484	0.497

* p<0.05, ** p<0.01,*** p<0.001

	EXPORTS					IMPORTS				
	Three-year window	Exempt non-industrial sector	Exempt Iron and steel sector	Exempt Both two	EU15	Three-year window	Exempt non-industrial sector	Exempt Iron and steel sector	Exempt Both two	EU15
Regulation	-0.923***	-0.782***	-0.041	-0.803***	0.292***	0.271	-0.104	-0.111	0.347**	-0.14
	(0.1)	(0.08)	(0.07)	(0.08)	(0.08)	(0.17)	(0.09)	(0.09)	(0.13)	(0.17)
Interactions										
pulp paper	0.733***	0.703***	-0.335***	0.507***	-0.232*	-0.733***	-0.299*	-0.331**	-0.776***	-0.267
	(0.13)	(0.1)	(0.09)	(0.1)	(0.09)	(0.21)	(0.12)	(0.12)	(0.16)	(0.19)
metal ore roasting	1.026***	0.865***		0.821***		-0.417*			-0.458**	0.007
	(0.14)	(0.11)		(0.11)		(0.21)			(0.16)	(0.19)
mineral oil refinery	1.416***	1.295***	0.181*	1.054***	0.534***	-0.074	0.204	0.181	-0.282*	0.171
	(0.11)	(0.09)	(0.08)	(0.09)	(0.08)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
pig iron or steel	1.139***	1.027***			0.142	-0.460*	-0.046			-0.189
	(0.11)	(0.09)			(0.08)	(0.19)	(0.1)			(0.18)
combustion installations	1.194***		-0.025		0.201*	-0.460*		-0.161		-0.169
	(0.11)		(0.08)		(0.08)	(0.18)		(0.1)		(0.17)
cement and clinker or lime	0.561***	0.689***	-0.405***	0.452***	-0.190*	-0.543**	-0.177	-0.234*	-0.670***	-0.371*
	(0.12)	(0.09)	(0.08)	(0.09)	(0.09)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
glass	0.561***	0.530***	-0.552***	0.323***	-0.382***	-0.904***	-0.470***	-0.533***	-0.937***	-0.471**
	(0.11)	(0.09)	(0.08)	(0.09)	(0.08)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
ceramic products by fining	0.527***	0.550***	-0.574***	0.282**	-0.283***	-0.951***	-0.589***	-0.624***	-1.046***	-0.662***
	(0.12)	(0.09)	(0.08)	(0.09)	(0.09)	(0.19)	(0.1)	(0.1)	(0.14)	(0.18)
R-sqr	0.583	0.584	0.586	0.595	0.643	0.538	0.542	0.545	0.545	0.544

* p<0.05, ** p<0.01,*** p<0.001

Table 8: Allocated Allowance and Trade Flows

	Fixed effects			
	No control	IV	IV Intra	IV Extra
	1	2	3	4
Exports				
Allocation	0.027***	0.159***	0.329***	0.127***
	0.00	(0.01)	(0.02)	(0.01)
Auction	-0.604**			
	(0.23)			
R-square	0.59	0.58	0.59	0.54
Imports				
Allocation	-0.02	-0.002	1.46	0.00
	(0.01)	(0.020)	(5.02)	(0.06)
Auction	0.82			
	(3.98)			
R-square	0.540	0.556	0.59	0.51

* p<0.05, ** p<0.01, *** p<0.001