# Does industry concentration matter for pollution haven effects?*

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First Draft: October 2011
This Draft: June 2012

**Abstract**

This paper builds on the existing work of pollution haven effects observed as the increased trade flows in the most polluting sectors from the developing world spurred by regulations in developed countries and introduces one more important consideration into a picture - do industry concentration and market power matter? A firm in a relatively competitive industry with less market power has no option to transfer costs of environmental regulations on to consumers and may be more likely to resort to 'importing pollution' from places with lax environmental standards. This paper studies whether a degree of industry's concentration has an effect on firms' extensive and intensive margins of imports from the developing world that are affected by the EU ETS after the introduction of this regulation in 2005. Results show that firms in more competitive industries import a larger number of and a higher value of products affected by EU ETS from the developing world post 2005.

Keywords: Pollution haven, Imports, Industry concentration, EU ETS, Herfindahl-Hirschman Index

JEL Classification: F18, Q56, L11, C23, C35

*This paper uses confidential micro datasets of the Central Statistics Office Ireland (CSO). The restricted and controlled access to the data was provided in accordance with the Statistics Act, 1993. I am grateful to Kevin Phelan, Gerry Brady, Ben Berstock and Dan Lawlor for the provided assistance. I thank Ron Davies, Robert Elliott, Richard Kneller, Stefanie Haller, participants at the 8th Danish International Economics Workshop, 2012 Midwest International Trade Meeting, the 11th GEP conference, Brixen Workshop and at the 8th ISNE conference for helpful comments and suggestions. My sincere gratitude goes to Justin R. Pierce and Ilke Van Beveren for their help with concording CN8 over time. I would like to gratefully acknowledge funding from the Irish Research Council for the Humanities and Social Sciences (IRCHSS) and the Irish Research Council for Science, Engineering and Technology (IRCSET), the Grantham Foundation for the Protection of the Environment and the Centre for Climate Change Economics and Policy, funded by the UK's Economic and Social Research Council and by Munich Re.

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# 1 Introduction

The existence of pollution haven effects has been a long contended issue in both theoretical and empirical academic and policy research. Early theoretical works of Pethig (1976) and McGuire (1982) have first brought into light the possibility that the increased stringency of environmental regulations at home would, upon more trade liberalisation, lead to plant reallocation to or increased imports from countries with laxer environmental standards. Since this would have dire economic consequences, pollution haven debate has not lost its edge since and is still a focus of intense attention. Despite an impressive volume of both theoretical and empirical studies the debate has not been settled yet.[1] The more recent literature by e.g. Ederington et al. (2005) and Cole et al. (2010) argues for a more differentiated empirical approach to pollution havens by stressing, amongst other things, the importance of looking at the imports from developing countries versus total imports and the importance of focusing on the most polluting sectors of the economy.

This paper takes that notion one step further into trying to disentangle the mechanisms of the pollution haven effects by asking whether industry concentration and market power matter. The intuition behind it is as follows: if a firm is in a relatively concentrated industry where each firm has more market power, it has more opportunities and may be more likely to pass costs incurred due to environmental regulations through on to a consumer. On the other hand, if a firm is in a very competitive industry and has no option to transfer costs of environmental regulations on to consumers, it may be more likely to resort to 'importing pollution' from places with lax environmental standards. More specifically, this paper answers a following empirical question - does the degree of an industry's concentration affect firms' extensive and intensive margins of 'dirty' imports from the developing world after the introduction of the EU ETS (European Union Emissions Trading System)?

The EU ETS is an EU wide regulation of emissions trading system introduced in 2005 whereby large $CO_2$ emitters in the EU were allocated a number of emission allowances. Ireland was under-allocated in a first phase of the EU ETS so a it is a good case to study since firms in Ireland found a biding constraint of whether to import from places with less strict environmental regulations or to produce or source at home (or even from the EU) with higher regulatory induced costs. Although all Irish manufacturing firms are a focus of this analysis, where EU ETS introduction comes into play is the importing decisions firms make. More specifically, this study focuses on EU ETS affected imports

[1] See Copeland and Taylor (1994), Copeland and Taylor (1995), Markusen et al. (1995), Antweiler et al. (2001), Copeland and Taylor (1997), Copeland and Taylor (2004), Levinson (2009), Levinson and Taylor (2008), Dean and Lovely (2010), Javorcik and Wei (2004), Ederington et al. (2004), List et al. (2003), Keller and Levinson (2002), Cole and Elliott (2003), Cole et al. (2005), Cole and Elliott (2005) for some findings on pollution havens.

by looking at product-firm sources from non-OECD countries with corresponding NACE codes belonging to polluting industries as classified and therefore affected by the EU ETS. So if a firm sources at least one product from the developing world which corresponds to a polluting industry under the EU ETS, this analysis looks at how, if at all, that sourcing pattern is affected post-EU ETS, i.e. post 2005, by the degree of concentration of the industry in which a firm operates.[2]

This is empirical work that uses two Irish micro level datasets provided by the Central Statistics Office Ireland (CSO). The first dataset, the Census of Industrial Production includes all Irish manufacturing firms with more than 3 employees and provides all firm-level performance characteristics such as output, employment, investment, industry classification of main activity, etc. The second dataset provides records from Customs on firms' international trade transactions, such as a country of destination of exports and origin of imports as well as CN8 product classification, value and quantity of transactions. The time period of the combined data is 2000-2009.

The empirical strategy is to assess whether industry concentration after EU ETS introduction in 2005 has an effect on a number of products (extensive margin) or the value of products (intensive margin) sourced by a firm from the non-OECD and whose CN8 code corresponds to industries most affected by the EU ETS introduction.[3] The methodological strategy is to employ a zero-inflated negative binomial model for the count of 'dirty' goods sourced by a firm from the non-OECD and random effects estimations on a log of value of those goods.

Results show that firms in more competitive industries import a larger number of and a higher value of products affected by the EU ETS introduction from the developing world post 2005 - adjustments both on extensive and intensive margins. This is not a part of an overall firms' imports trend as firms in more competitive industries tend to import higher number of all products but this effect is not significant post 2005. Neither is there the same outcome for firms' 'dirty' imports from the developed world.

This suggests that when studying a pollution haven effects issue, one more differentiation has to be present - accounting not only for the origin of a firm's imports and their nature (more or less polluting) but also whether a firm is facing a relatively higher or lower competitive pressure in the industry in which it operates.

The remainder of the paper is structured as follows: Section 2 describes the empirical methodologies employed in the paper and their main issues, Section 3 details the two

[2]A more narrow approach would be to focus on firms in industries affected by EU ETS introduction and their imports of 'dirty' goods from the non-OECD. This analysis, though very restrictive in terms of sample size, confirms the main empirical findings.

[3]Those industries are manufacturing of paper products, of petroleum and nuclear fuel products, of non-metallic products and of basic metals, although alternative broader definitions are also explored with similar results.

datasets combined for the analysis and their main variables. Section 4 outlines the key findings, Section 5 then gives a summary of robustness checks and Section 6 concludes.

# 2 Empirical Strategy

The paper aims to look at the effect of industry concentration on both the extensive and intensive margins of trade of a firm post EU ETS policy introduction, that is, post 2005. There is a series of methodological issues that have to be addressed here. The first deals with different estimation techniques for assessing the effect on extensive margin - number of products and intensive one - (log) value of products. The second focuses on the measure of industry concentration and describes how the measure is constructed as well as various alternative measures that have been considered to ensure the validity of results.

This section is then going to proceed as follows. It starts by outlining an estimation equation and its main components. It then proceeds to discussing two distinct estimation techniques for obtaining main results - zero-inflated negative binomial model for extensive trade margin estimations and linear panel models for intensive trade margin estimations. It goes on to discuss the issues of measuring concentration of an industry, the measure chosen here to derive base results and several other approaches that test and support the findings.

The baseline regression has the following form:[4]

$$TradeMargin_{it} = \alpha Concentration_{jt} + \beta Concentration_{jt} * post05 + \gamma post05 + \delta X_{it} + \epsilon_{it} \tag{2.1}$$

where the dependent variable - trade margin - is twofold and represents either a number of products that correspond to heavily polluting industries - 'dirty' products (extensive margin) or a log of total value of these products (intensive margin) imported from non-OECD countries. 'Dirty' products are products corresponding to industries of manufacturing of paper products (21), of petroleum and nuclear fuel products (23), of non-metallic products (26) and of basic metals (27) as these are the industries most

[4]Note that this is a regression differences-in-differences approach as described in Angrist and Pischke (2009).

affected by the EU ETS introduction.[5] The variable of interest here is an interaction term between a measure of concentration of an industry a firm is in and a dummy that switches from 0 before 2005 to 1 at 2005 and till 2009 - post EU ETS introduction effect. I cannot directly observe the consequences of EU ETS regulation but since it has been introduced in 2005, the dummy switching on post 2005 is meant to capture this effect on firms in the dataset.[6] And because I specifically focus on imported products corresponding to the EU ETS affected industries, the post 2005 dummy should be a good approximation for the analysis.

The expectation here is that firms in less concentrated industry post 2005 will tend to import more 'dirty' products from the non-OECD world. Because the concentration rate is lower the more competitive the industry, $\beta$ is expected to have a negative sign. Additionally, this specification controls for a separate effect of industry concentration and any other post 2005 influence. It also controls for a number of firm characteristics, such as a dummy for being an exporter, ownership dummy (where 1 assigns a foreign ownership and 0 - a domestic one), log labour productivity and log energy spendings, capital proxy, share of materials purchased from affiliates. It also includes product effects on 2 digit level.

## 2.1 Dependent variables

Due to the nature of the dependent variables two separate estimation techniques have to be employed to look at the effect that the concentration of an industry has on trade margins post ETS introduction.

Extensive trade margin is measured as a number of products. Firstly, the outcome of interest here is a count. Secondly, since a variable of interest is specifically a number of 'dirty' products - products whose code corresponds to industries affected by EU ETS introduction and that are imported from non-OECD countries, there is a considerable zero-inflation - about 70% of all observations for this variable are zeros. Thirdly, dependent variable is a firm level variable and data form an unbalanced panel.

Because the dependent variable is discrete, the probability mass of the distribution is concentrated only on nonnegative values. Further, the data are heteroskedastic with the variance increasing with the mean, see Cameron and Trivedi (2005). This calls for

[5]Section 5 confirms the same pattern of findings when EU ETS affected industries also include manufacture of fabricated metal products (28) and printing and publishing (22). NACE 2 digit level codes given in parentheses are codes corresponding to NACE Rev. 1.1.

[6]A number of checks is performed on the timing of the dummy switching, see Section 5 for more details.

nonlinear estimations by way of count regressions.[7] Furthermore, the large number of zeros needs to be modelled in as well. Two choices present themselves - zero-inflated Poisson model or zero-inflated negative binomial model. Both add a binary process to the count density. Following the work by Lambert (1992) these models add a binary process with density $f_1(\cdot)$ to a count density $f_2(\cdot)$. So, following Cameron and Trivedi (2005), if the binary process takes a value 0 with probability $f_1(0)$, then $y = 0$ and if it takes a value of 1 with probability $f_1(1)$ then $y$ takes count values 0, 1, 2 .... from the count density $f_2(\cdot)$. Thus the zero count can occur in two ways - as a realisation of a binary process or a count process when the binary random variable takes a value of 1.

The density is:

$$g(y) = \begin{cases} f_1(0) + (1 - f_1(0))f_2(0) & \text{if } y = 0, \\ (1 - f_1(0))f_2(y) & \text{if } y \geq 1. \end{cases} \tag{2.2}$$

Here $f_1(\cdot)$ is a logit model and $f_2(\cdot)$ is a negative binomial density although Poisson density is tried in this study as well.

Both models have been run and zero-inflated negative binomial model proved to provide a better fit to the data with the overdispertion parameter being highly statistically significant so the main results are given using this model, although zero-inflated Poisson model provides a similar pattern of results.[8] Alternative zero-inflated Poisson model with random effects using Markov Chain Monte Carlo (MCMC) methods is used to confirm the main outcomes of the above two models, it provides the same pattern of findings.[9] Lastly, to try and to a certain degree account for a panel structure of the dataset and firm fixed, time-invariant effects in the model, main firm control variables are demeaned. Standard errors are clustered at a level of a firm to account for repeated product observations per firm and an unbalanced nature of the longitudinal data.

Therefore, the main results of the effect of a concentration ratio of an industry a firm operates in after EU ETS introduction in 2005 on the number of 'dirty' products imported from non-OECD (extensive trade margin) are derived from the zero-inflated negative binomial model with demeaning and with robust standard errors clustered on a level of a firm.[10] Numerical outcomes are shown in table 1 in section 4. The coefficients

[7] See Cameron and Trivedi (1986), Cameron and Trivedi (1998) and Cameron and Trivedi (2009) for more detail.

[8] Long and Freese (2005) package SPost was used to run a comparison of the models, although no robust standard error option was allowed. Outcomes of the *countfit* command suggested zero-inflated negative binomial model was a better fit to the data.

[9] The model is run using Hadfield (2010) package.

[10] Similar results are found when employing Poisson model with firm fixed effects that does not account for zero-inflation.

in this table cannot be directly interpreted due to nonlinear nature of the model, but they give a good indication of the direction of the effects.

Intensive margin estimations are more straightforward. Value of 'dirty' imports from non-OECD is taken in logs and to circumvent the issue of zeros, a very small number is added to those observations to allow for log transformation.[11] Estimation results are then derived from running both fixed and random effects linear panel models with robust standard errors clustered on a level of a firm.

The models are obtained by subtracting the time-averaged model from the original model, see Cameron and Trivedi (2005) and Wooldridge (2002) for more detail.

$$y_{it} - \overline{y_{it}} = (x_{it} - \overline{x_{it}})'\beta + (\epsilon_{it} - \overline{\epsilon_{it}}) \tag{2.3}$$

## 2.2 Industry Concentration

Another important question to be addressed in this section is how to measure industry concentration. A measure of industry concentration reflects how much market power a firm has within an industry. If an industry is populated by only a few very large firms it is reasonable to expect each firm to have a lot of market power and industry concentration to be quite high. On the other hand, if an industry is characterised by a high number of small firms, concentration is small and each firm faces a high competitive pressure by other companies within this industry. A fairly standard approach to measure industry concentration is to calculate a Herfindahl-Hirschman Index (HHI). Herfindahl-Hirschman Index (HHI) is calculated by taking a sum of the squares of the market shares of firms within an industry.

A formula for Herfindahl-Hirschman Index is:

$$HHI = \sum_{i=1}^{N} s_i^2 \tag{2.4}$$

where $s_i$ is a market share of a firm $i$ in an industry and $N$ is a number of firms in that industry. The higher the value of the Herfindahl-Hirschman Index the higher the level of industry concentration. A competitive setting is therefore characterised by low values of HHI.

[11] As pointed out by Silva and Tenreyro (2006), albeit for a gravity model, such an approach could lead to biased estimates so zero-inflated negative binomial model is also run on values of 'dirty' imports with similar results although significance values differ depending on an industry concentration measure.

For this study the Herfindahl-Hirschman Index was constructed in a variety of ways. Base results are derived from calculating HHI with firm's turnover within an industry taken to be a market share and a level of aggregation to be NACE 2 digit level. However, to ensure the validity of findings, NACE 3 digit level of industry aggregation has been tried out too with similar outcomes. Further, because Irish economy is very open and export-oriented, a firm's market share was also taken to be turnover minus its export share to try and proxy for a share of a company on the domestic market. The main findings remain similar.

However, even taking out the exported share of turnover of Irish firms does not account for sales made in Ireland by firms from outside of Ireland. One could also think of the market for Irish firms being broader than home country and encompassing the whole of the EU. Since the data on the concentration ratio of the EU industries are not available, an attempt to circumvent the issue was made by using Rauch classification of differentiated versus homogenous goods. The underlying intuition for using this classification is that firms face more competition in the homogenous goods industries. Using this as a proxy for industry concentration measure provided broadly similar outcomes, see section 5 for details.

Another important issue with the Irish data is that CSO only records an industry code of a primary activity of a firm - the activity that accounts for the largest share in its turnover. It is possible, therefore, that over time firms that have their activities spanning several NACE 2 digit industries are recorded in the data as changing their industry classification. This happens when the largest share of turnover shifts from one industry activity to another within a firm. Those firms are not a majority within the dataset, certainly not on 2 digit level but they are present and need to be dealt with.[12] For the base estimations, those firms are removed. Leaving them in the dataset does not alter main conclusions.

To try and solve these problems I double check the findings with yet another measure of industry concentration - total market share of several top firms in an industry. CR3, CR5 or CR4 and CR8 are used frequently in the literature. CR3 is a measure showing a total market share held by 3 largest firms in an industry. CR5 would total a market share of 5 largest firms in an industry, etc. It is calculated as a sum of market shares of the top firms. For example, CR3 is calculated as follows:

$$CR3 = \sum_{i=1}^{3} s_i \tag{2.5}$$

[12]Firms changing their industry classification represent about 9% of the total.

Multiple estimations with CR3/CR4/CR5 and CR8 industry concentration indices, both time variant and averaged over the data period show the findings holding consistently for the intensive margin. Extensive margin findings are slightly less robust although the direction of the effect stays the same.

And finally, for the main results presented here HHI is constructed as a time variant index, varying year by year. Time invariant, averaged over 10 years of data index is calculated too, proving to have similar effect on extensive and intensive trade margins of 'dirty' goods from the non-OECD after the introduction of the EU ETS.[13]

# 3 Data

This study builds on a combined firm-product level dataset of Irish manufacturing firms. This dataset spans a period of 2000-2009. Below is the description of the two datasets comprising the combined one used in the paper. The matching of the two datasets was performed by statisticians at the Central Statistics Office Ireland (CSO).

## 3.1 CIP Dataset and main variables

The main source of firm level data on manufacturing firms used in this study is the Irish Census of Industrial Production (CIP) - an annual census of manufacturing, mining and utilities firms. The Census is conducted by the Central Statistics Office (CSO) at both enterprise and plant level.[14] The CIP covers all enterprises or plants with 3 or more people engaged. The period of the CIP data is 1991-2009. The list of manufacturing industries used is given in Table 4 in Appendix A.[15]

The CIP dataset on manufacturing firms provides an unbalanced panel spanning 19 years and over 10000 firms in total. The relevant variables in the Census of Industrial Production are primary industrial classification (at 2, 3 and 4 digit NACE level), country of ownership, total turnover, export share (as a % of turnover exported), employment (measured as total employed), skill level, total labour costs, total gross earnings (wage),

[13]More checks for the measure of industry concentration have been undertaken and are outlined in section 5.

[14]For more information on this and other datasets described here, please visit web-site of the Central Statistics Office Ireland at http://www.cso.ie/.

[15]CIP uses NACE Revision 1.1 up to 2007. NACE 1.1 is a European statistical classification system of economic activities corresponding to ISIC Rev.3 at European level. From 2008 onwards CIP uses NACE Revision 2 classification which was re-classified back to Revision 1.1. using correspondence tables provided by Eurostat.

outsourced R&D expenses, aggregate investments, freight charges, total purchases of fuel and power (energy): solid fuels, petroleum products, natural and derived gas, renewable energy sources, heat, electricity.[16]

This dataset is used to construct the main variable of interest - industry concentration, as well as utilise firm level information to provide controls at the firm level. Firms' turnover (total sales) information is used to construct industry concentration ratio. For some of the further checks, CIP data are used to deduct a share of exports from the total turnover of a company to proxy the amount of firm's total domestic sales.

CIP provides further information on firm characteristics that are used as control variables in the study. Firm productivity is measured as labour productivity, calculated as a total turnover per employee. There are no data on capital stock in the CIP but there is information on capital flows that is used to construct a capital proxy as an accumulated measure of firm's capital additions built over the whole period minus sales of capital assets, assuming 10% yearly depreciation rate overall. The study further accounts for ownership - by way of a dummy variable taking on a value of 1 if a firm is foreign-owned and 0 for a domestically-owned company. The analysis further controls for a firm's energy use since a more energy-dependent firm may be more likely to be affected by a regulation that is aiming at (the products of) the more polluting industries as those most of the time tend to be very energy intensive too. Further, CIP provides some information on the percentage of materials that are purchased from a company's affiliates. Since the dependent variables in this study are either quantity or value of imports, this would help control for any of the purchases made from affiliated firms.

## 3.2 International trade dataset and main variables

A second dataset used for the analysis is an international trade dataset of Irish firms involved in exporting or importing activities and reporting their transactions to the customs authorities. It includes information on the country of origin of an imported good and the country of destination of an exported good, value and quantity of a good and its classification at CN8 level (8 digit level of Combined Nomenclature classification) and, where available, a corresponding PRODCOM code of a good.[17] The data are available

[16]Monetary values are deflated using Industrial Producer Price Indices with year 2005 as a base, provided by the CSO. Energy variables are deflated using the CSO Wholesale Price Indices for Energy Products with year 2005 as a base.

[17]Classification of CN8 codes changes over time with small adjustments year on year and big CN8 code overhauls in 2002 and 2007. The changes in codes over time are not always one-to-one: some codes are split into several and several old codes may be aggregated into one. Therefore, to account for and concord those classification changes over time I follow closely the methodology as developed by Pierce and Schott (forthcoming) and further elaborated by Van Beveren et al. (2011). Source programmes used

for a period of 2000-2009. Most of the trading firms in the CIP dataset are found in the international trade dataset. The quality of matching is somewhat diminished for very big firms with turnover exceeding €5 bln.[18] For the main analysis those firms are left in the dataset but their exclusion does not alter any main conclusions.

Product codes, value of the transactions and country of origin information provide the main ingredients for constructing dependent variables for the analysis. Although the CN8 code of the product provides a very rich detailed information of what kind of product it is and how or what it is made of, this information is not used in the study. The product code and where possible PRODCOM codes are mapped into a more narrow classification of 2, 3 and 4 digit NACE level to help identify products that correspond to the EU ETS affected industries of paper products, petroleum and nuclear fuel products, non-metallic products and basic metals. The study also uses this more aggregated classification to control for fixed effects on products side.

This information is then used to create a count of products that a firm imports from a certain destination region. What this in actuality does is count the number of different goods or varieties falling under a polluting EU ETS classification that a firm imports from non-OECD region thus creating one of the dependent variables for the analysis - a firm's extensive margin of trade. Where applicable, the dataset provides information on the quantity of a good in tonnes and a value of a good in Euro thousands. Due to the fact that the quantity information is not as widely available, this paper settles down on just counting a number of different goods a firm imports and not their physical quantity. The analysis also looks at the combined value of those products. The log transformation of the total value of the products that correspond to the EU ETS affected industries imported from the non-OECD represents a second dependent variable for the analysis - a firm's intensive margin of trade. Information on country of export destination and import origin is given as a country code or a full name of a country.[19] Import origin information is used to classify an origin of imports as non-OECD country (developing world) or OECD or the EU country for robustness analysis later in the paper to compare imports from developing with imports from developed world dynamics.[20]

While the Irish economy is well-known for being very export-oriented, it also relies heavily on imports. The mean number of products an Irish firm exported over the period

courtesy of Justin R. Pierce and Ilke Van Beveren.

[18]This is due to the fact that two datasets use different identifiers - a firm's id in the CIP and VAT number for the international trade dataset and the mapping is not very clear-cut for very big companies in the datasets.

[19]The international trade dataset has some limitations. I cannot trace whether a firm re-sells an imported product to another firm or sells it to a final consumer. This, however, should not significantly affect the results. Neither is it documented in the international trade dataset if a firm buys an imported product from a retailer in Ireland, only direct imports by manufacturing firms are observed.

[20]EU here is taken to include all new members who joined post 2004 to avoid breaks in classification.

2000-2009 is just over 100 and the average number of products it imported during the same period is almost three times as high. On the other hand, exports are much more diversified destination wise with an average number of firm's export destination countries between years 2000 and 2009 being 44 and the average number of import origin countries being 32. The mean value of exports is also several times higher than that of imports over the period observed. So the Irish firms' export is based on a fewer number of dearer products than their imports but is more geographically dispersed.

To sum up, the firm level dataset CIP provides all main controls used in the study and the studied variable of interest. International trade dataset allows to construct two main dependent variables in this study as well as some additional ones for checking and contesting the main findings. Table 5 in Appendix A presents a full list of variables used in this analysis and their definitions.[21]

# 4 Effect of industry concentration on extensive and intensive margins

This section presents the findings on both external and internal margins of imported goods from non-OECD whose code corresponds to the NACE code of an industry affected by the EU ETS introduction in 2005. Methodological issues and models are discussed in the previous section 2. Results for both trade margins are shown and discussed separately.

## 4.1 Extensive Margin

Table 1 presents the results of the zero-inflated negative binomial model with demeaning of the main control variables and controls for product codes on 2 digit level. The model as described in section 2 consists of two parts - firstly, it looks at what variables make it more or less likely that a firm has a zero outcome on the dependent variable - a count of imported products and then it estimates for the whole distribution the direction of effect of independent variables of interest. The first part of the model is shown under the heading *Inflate* and is estimated using a logit model. It shows that only one firm level variable has a significant negative probability of a firm having a zero outcome variable. Specifically, foreign firms are more likely to have a non-zero number of 'dirty' products

[21]Some data cleaning has been done prior to running the analysis. Any negative or missing values of main firm level variables, such as energy use or turnover, in few instances where possible were replaced using values from previous and later years, the rest - set to missing. The top .25 percentile of energy intensity observations is removed to control for extreme outliers.

Table 1: Extensive trade margin outcomes

| Zero-inflated negative binomial regression | | |
|---|---|---|
| | Coefficient | S.E. (clustered by id) |
| HHI | 11.5678 | (50.3279) |
| HHI*Post 2005 | -149.8183** | (70.8419) |
| Post 2005 | 0.659*** | (0.1294) |
| Exporter | 0.9351 | (0.7095) |
| Ownership | -0.0115 | (0.2198) |
| Log Labour Productivity | 0.1862 | (0.1341) |
| Energy Intensity | 13.1067*** | (4.8267) |
| Capital | -2.18e-07*** | (7.87e-08) |
| % materials from affiliates | 0.0005 | (0.0019) |
| *Inflate* | | |
| Exporter | -0.315 | (0.9665) |
| Ownership | -0.9246** | (0.3369) |
| Log Labour Productivity | -0.3072 | (0.2186) |
| Energy Intensity | 3.7703 | (2.9864) |
| Capital | -0.00004 | (0.00004) |
| alpha | 0.6389 | (0.1882) |
| Number of observations | 921619 | |
| Nonzero obs | 280586 | |
| Zero obs | 641033 | |
| Number of firms | 3403 | |
| Wald chi2(41) | 465.68 | |
| Prob > chi2 | 0.0000 | |
| Log pseudolikelihood | -895598.3 | |
| Inflation model | logit | |

Standard errors, clustered by id, in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
Dependent variable: firm's count of 'dirty' products imported from non-OECD.
The model includes 2 digit product dummies, means of explanatory variables and a constant, which are not reported here.

imported from the developing world. The top part of the results in table 1 shows the effects of interest, namely the effect of concentration ratio - Herfindahl-Hirschman Index (HHI) post 2005, after the EU ETS introduction, on the number of 'dirty' products being imported from non-OECD. Also included are the concentration index itself and post 2005 time dummy to account for the overall effects of industry concentration and the EU ETS introduction, as well as a number of firm level controls, means of main control variables and dummies for products at 2 digit level. The coefficients in the table show the direction of the effect, as the model is nonlinear, one cannot directly interpret the results.

Regarding the directionality of the effects, what the signs of the coefficients in table 1 suggest is that if a firm is operating in a more competitive setting (lower HHI) it is more likely to import a larger number of 'dirty' products from non-OECD after 2005, i.e. a larger number of products with codes corresponding to industries affected by the

introduction of the EU ETS in 2005. And vice versa, firms in relatively more concentrated industries tend to import fewer of the 'dirty' products from non-OECD post 2005. Introduction of the EU ETS in general seems to have encouraged all firms to increase the import of 'dirty' products from non-OECD.[22] Additionally, more energy intensive firms import more products from non-OECD, as they could be seen to be more reliant on 'dirty' imports. Higher capital translates into fewer 'dirty' products imported from the developing world and might reflect an effect of a technology upgrade.

To help understand the magnitude of the effect of interest and gauge the economic significance of the result, the following calculations were performed. A one standard deviation increase in the Herfindahl-Hirschman Index (HHI) post 2005, which would mean a 1 standard deviation increase in concentration of an industry after 2005, would reduce the mean number of 'dirty' products imported from non-OECD by *8.5 percentage points*. And bringing that index to a maximum value of industry concentration observed in the sample would reduce the mean count of 'dirty' products imported from non-OECD by *50 percentage points*.

So the results suggest that the effect of introduction of the EU ETS differs for firms in relatively more versus relatively less concentrated industries. And the higher the competitive pressure the more are firms inclined to import the products affected by the regulation from regions with laxer environmental standards and legislation.

## 4.2 Intensive Margin

Results for estimating the intensive margins of 'dirty' imports from the developing world reveal similar dynamics. Tables 2 and 3 show output for estimating, accordingly, random and firm fixed effects models with log value of 'dirty' imports affected by the EU ETS introduction from non-OECD as a dependent variable. Post 2005 HHI concentration ratio has the same effect on the value of 'dirty' products from non-OECD as on their number - the more concentrated the industry the lower the value of ETS affected products a firm imports from the developing world and, vice versa, the more competitive the setting a firms finds itself in, the higher the value of EU ETS affected products that it imports from countries with laxer environmental regulations. Post 2005 variable similarly has a positive effect on the log value of imported products for all firms. And more energy intensive firms also tend to import higher value of 'dirty' products from non-OECD. Unlike the extensive margin estimations, more productive and capital using firms import a higher (log) value of ETS affected, 'dirty' products from developing world. Although

[22]The results are largely driven by known big polluters such as China, India, Russia, Brazil but removing these countries from the data does not reverse the results.

Table 2: Intensive trade margin outcomes, random effects estimations

| | Firm random effects model |
|---|---|
| HHI | 66.7513 |
| | (62.3537) |
| HHI*Post 2005 | -133.9404** |
| | (54.8484) |
| Post 2005 | 0.5277*** |
| | (0.1044) |
| Exporter | -0.0098 |
| | (0.0615) |
| Ownership | 0.0126 |
| | (0.1163) |
| Log Labour Productivity | 0.495*** |
| | (0.1699) |
| Energy Intensity | 3.9573** |
| | (1.8251) |
| Capital | 1.30e-07* |
| | (7.39e-08) |
| % materials from affiliates | -0.0024 |
| | (0.0054) |
| Number of observations | 921619 |
| Number of firms | 3403 |
| Wald chi2(36) | 143.19 |
| Prob > chi2 | 0.0000 |

Standard errors, clustered by id, in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
Dependent variable: firm's log value of 'dirty' products imported from non-OECD.
The model includes 2 digit product dummies and a constant, which are not reported.

the latter result is likely driven by the outcome that more productive firms import higher value of products overall.[23]

Random effects estimations are the most fitting here as what we are really interested in is the comparison between firms on how the concentration ratio after 2005 affects 'dirty' imports from developing countries. However, within estimations (with firm fixed effects taken out) are very similar in terms of directionality of effects and their magnitudes.

To sum up, the main story told by the outcomes shown here is that when looking for pollution haven effect, it would seem that it affects firms differently depending on how much competitive pressure they are facing from their peers in an industry. If a firm is up against a relatively tougher competitive setting, it is more likely to increase its reliance on importing the products most affected by regulations from countries where such regulations are weak or non-existent. Adding on to previous finding of pollution haven effects being more prominently visible when focusing specifically on 'dirty' imports

[23]A positive link between productivity and importing has been shown in the literature, see e.g. Smeets and Warzynski (2010), Castellani et al. (2010), McCann (2009) or Muûls and Pisu (2009).

Table 3: Intensive trade margin outcomes, firm fixed effects estimations

| | Firm fixed effects model |
|---|---|
| HHI | 55.8722 |
| | (68.4577) |
| HHI*Post 2005 | -131.5425** |
| | (55.6689) |
| Post 2005 | 0.5236*** |
| | (0.1047) |
| Ownership | 0.0087 |
| | (0.1246) |
| Log Labour Productivity | 0.521*** |
| | (0.1793) |
| Energy Intensity | 4.2875** |
| | (1.9934) |
| Capital | 1.25e-07* |
| | (7.34e-08) |
| % materials from affiliates | -0.0024 |
| | (0.0054) |
| Number of observations | 921619 |
| Number of firms | 3403 |
| F(35,3402) | 3.69 |
| Prob > F | 0.0000 |

Standard errors, clustered by id, in parentheses $***p < 0.01, **p < 0.05, *p < 0.1$
Dependent variable: firm's log value of 'dirty' products imported from non-OECD.
The model includes 2 digit product dummies, a constant and firm fixed effects, which are not reported.

from developing world rather than on aggregate trade flows, one might need to factor in an industry concentration to further pinpoint the effect.

# 5 Robustness Checks

A number of additional estimations were performed to test a viability of alternative hypotheses and to expand on the main results.[24]

*Other measures of industry concentration*

Section 2 touches upon issues of measuring industry concentration as this is a crucial variable of interest in this study. For the baseline results shown in section 4 concentration ratio is constructed as Herfindahl-Hirschman Index (HHI) with industries defined at 2 digit NACE Rev 1.1. level and market share taken to be firm's turnover (total sales). These outcomes are confirmed with HHI constructed with industries defined at 3 digit level and when using normalised HHI which also accounts for both firms' market share

[24]Output tables are available on demand.

and a number of firms in an industry. Intensive margin results are further confirmed with firm's market share excluding share of output that is exported and with time invariant HHI index, averaged over 10 years of data. They are also confirmed with using alternative measures of concentration - CR3-8 - sum of market shares of 3, 4, 5 and 8 biggest firms in an industry and with HHI constructed only based on a number of firms in an industry, thus implicitly assuming equal market shares per firm. Extensive margin results for all these measures listed above retain their sign but their significance drops slightly below conventional levels. To further check the pattern of outcomes a different approach to interpreting industry concentration is taken. Specifically, I follow Rauch classification to construct a dummy variable for less versus more market power in an industry. Rauch classification of industries at 2 to 4 digit NACE level is provided courtesy of Fitzgerald and Haller (2010). The idea behind this is that firms in industries producing more differentiated goods would have more market power and firms in industries producing homogenous products would face a higher competitive pressure. To be comparable with HHI results I construct this dummy variable as 0 for industries producing homogenous or reference priced goods - more competitive setting and 1 for industries producing differentiated goods - more concentrated setting. Using this new variable, extensive and intensive margin estimations are repeated. Again, intensive margin results prove more robust and show the same negative and significant effect of interaction term of this new measure of industry concentration and post 2005 dummy, meaning that firms in more competitive industries import relatively more 'dirty' imports from 'dirty' destinations. Extensive margin results though retaining the sign are no longer significant at conventional levels.

*2005 as a switch point*

EU ETS got introduced in 2005, that is why this year has been chosen as a switching point for a dummy that interacted with industry concentration ratio provides the main results for the trade margins. However, a sensitivity analysis should be performed around this date. First, to check whether the observed effect of concentration ratio post 2005 is not something that is part of a general trend over time, post 2005 dummy is replaced with a time trend which is also interacted with HH index. This interaction does not have any significant influence on either the number or the log value of products a firm imports from non-OECD if those products are affected by EU ETS introduction. Second check around the date consisted of falsification or placebo tests when the dummy variable would switch on at a year different from 2005. 2002 and 2003 are tried as switch years instead. Interaction of these dummies with industry concentration ratio has proved to have no significant effect on extensive or intensive margins of 'dirty' imports from non-OECD. The dummies themselves still displayed a positive effect on both margins which means that post 2005 effect observed in the previous section might be a part of a longer

tendency of all firms to increase their imports from the developing countries. However, I find evidence of an anticipation effect of the policy which manifests in some statistical significance of the interaction term between the concentration ratio and the post 2004 dummy.

*Imports from other regions*

What if the observed effect of industry concentration ratio is the same for all imports of a firm and not just those affected by the ETS or, perhaps, for all ETS affected imports irrespective of their country or region of origin? To test the first claim, the estimations as reported in tables 1 and 2-3 are repeated replacing the dependent variable with a count or a log value of all firm's imports. Concentration ratio becomes negative and statistically significant in extensive trade margin estimations suggesting that firms facing more competitive pressure in their industry are more likely to resort to importing more products overall. Although the relationship might run in the opposite direction too. The interaction of the concentration ratio with a post 2005 dummy is insignificant. Regarding the second possibility, the main estimations are once again repeated with dependent variables this time being either a count or a log value of 'dirty' imports from the developed world with higher environmental standards - OECD or EU. The effect of industry concentration ratio post 2005 becomes statistically insignificant for both trade margins. Concentration ratio index itself turns negative and significant in intensive margins estimations suggesting that for imports from the developed world it's the value and not the number of products that is affected by a tougher competitive pressure in an industry.

Another way to check the results is to run a triple difference in difference with dependent variable being all 'dirty' imports by a firm. The variable of interest would then be a triple interaction term between a post-2005 dummy, concentration ratio of an industry and a dummy for non-OECD (dirty import origin), after having controlled for all those variables and their respective interactions too. Such triple difference-in-difference exercise shows that extensive margin results hold significantly. Only focusing on companies that import 'dirty' products from both OECD and non-OECD regions also confirms the main findings for 'dirty' imports from non-OECD and OECD as described in the main results section and here. Looking at those firms also suggests that overall, not accounting for concentration of an industry, 'dirty' imports from non-OECD post 2005 might have increased much more compared with 'dirty' imports from OECD after that time. The coefficients are insignificant, as the sample is much smaller, but differ starkly in magnitude. The triple interaction further confirms that 'dirty' imports from non-OECD post 2005 have increased more for firms in more competitive industries.

*Cost of setting up imports*

The results are largely driven by firms that have been importing 'dirty' products

from the developing world prior to the policy taking place. These firms in the more competitive setting increased their imports from this region after the EU ETS relatively more compared to firms in the less competitive industries. The magnitudes of the effects are much larger than those reported in section 4. This suggests that the effects found are mostly due to firms that had already established nonzero imports from non-OECD and therefore new non-OECD importers or even importers who switch from the EU or OECD 'dirty' imports to non-OECD 'dirty' imports as the result of the policy introduction are not likely to be a big issue for the findings here. This is reassuring as the literature has long established significant fixed costs of setting up an import which might be harder to incur in a more competitive industry.

*Alternative definitions of the EU ETS affected industries*

To thoroughly check the findings, I also expand the number of industries affected by EU ETS introduction to include an industry of manufacture of fabricated metal products, except machinery and equipment (NACE Rev. 1.1. 2 digit code of 28) and, to follow some accounts, an industry of printing and publishing (NACE code 22). Both of those broader definitions of EU ETS affected products show exactly the same, if even statistically stronger, as in case of addition of industry code 28, pattern of empirical evidence as demonstrated in section 4.

*Industry level estimations*

Since industry concentration ratio is an industry level variable, all estimations are also re-run on industry level at NACE 2 digit. Dependent variables and control variables are then constructed as mean values within an industry. Since there is no zero inflation problem for the number of products on industry level a negative binomial count model is used to derive extensive trade margin estimations. The main results on industry level display the same dynamics for both trade margins.

*Outliers*

To make sure results are not driven by outliers, the main estimations are repeated with the top and bottom 1% of observations of main control variables removed from the data. This does not change any of the findings.

*Alternative models*

Some alternative models are also run on the basic specification to confirm the results. Apart from already mentioned zero-inflated Poisson model, a zero-inflated Poisson model with random effects using Markov Chain Monte Carlo (MCMC) methods is also employed. Both of those models confirm the main outcomes. Hurdle model also provides the same pattern of findings. Fixed effects Poisson model has also been employed to make sure extensive margin results are not driven by firm fixed effects and the outcome of interest remains unchanged suggesting that it is indeed not due to firms' unobserved effects.

*Ownership*

Including a dummy for ownership status in the regressions does not provide much information about how patterns of margins of 'dirty' import from non-OECD differ for domestic firms and MNEs. To address this issue, I split the sample and run separate trade margin estimations for domestic-owned and foreign-owned firms. Majority of firms in the sample (90%) is domestic-owned. A broad trend of the findings suggests domestic firms react more on the extensive margin to the competitive pressure post EU ETS regulation introduction, whilst MNEs that find themselves in more competitive industries are more likely to adjust their intensive margins of 'dirty' imports from the developing world post 2005.

*Other checks*

Main findings also hold when dependent variables are taken as scales - number or value of 'dirty' products relative to all firm's imports. And results hold when big firms (turnover $>$ €5 bln) for whom the matching of two datasets was more difficult, are taken out.

Triple interaction of HHI, post 2005 dummy and firms producing in 'dirty' industries to see if there is a substitution between production and importing in 'dirty' industries is insignificant in both intensive and extensive margin estimations.

As one industry - of petroleum and nuclear fuel products (23) in Irish data is extremely concentrated, it has been removed from the construction of the concentration ratio to test the robustness of the findings and when this is done, the results still hold on both margins.

# 6 Conclusions

This paper builds on previous extensive research on empirical examinations of pollution haven effect, specifically the recent more heterogeneous approach moving away from studying aggregate trade flows to focusing on 'dirty' goods that are more affected by environmental regulations and their flow from developing country origins to developed world destinations. This study suggests that when looking at pollution havens one more differentiation needs to be considered - that of the extent of industry concentration a firm operates in. If a firm is facing a tougher competition in an industry, introduction of environmental regulation that is likely to increase its costs of production or sourcing will see that firm importing a higher number and value of products affected by the regulation from the developing world with laxer regulations since firms in a more competitive setting have less market power to pass the costs of environmental regulations through on

to consumers. And vice versa, firms in more concentrated industries with more market power will have an option of passing the costs through to consumers and might be less inclined to resort to importing.

This hypothesis is tested here with a firm-product level dataset of Irish manufacturing firms spanning 2000-2009 period. The environmental regulations effect that is being looked at is an introduction of the EU ETS (European Union Emissions Trading System) in 2005 which affected the industries of paper products, petroleum and nuclear fuel products, non-metallic products and basic metals. This study looks at how imports of the products of these industries purchased by a firm from non-OECD countries is affected by the industry concentration ratio post 2005. I focus on both extensive (number of products) and intensive (value of products) trade margins as dependent variables and the effect of industry concentration after the introduction of the regulation.

The empirical findings suggest that the EU ETS had an effect on firms' margins of trade in the policy affected goods relatively more in less concentrated industries. In other words, firms in a more competitive setting post 2005 imported both a higher number and a higher value of 'dirty', i.e. affected by the regulation, products from developing countries of non-OECD region which is known for its laxer environmental regulations and standards. So we observe an adjustment on both extensive and intensive margins of trade post regulation in less concentrated industries. These results hold out under a scrutiny of various checks and suggest that when looking at pollution havens it is important to differentiate between more and less competitive industries.

These finding have interesting and somewhat ambiguous policy implications suggesting that if policy makers wish that firms keep producing at home or source locally versus increasing their reliance on imports following an introduction of an environmental regulation, they should increase industry concentration. The latter, however, has a number of negative implications as more competitive setting is associated with lower mark-ups, more innovations, etc. Another policy implication suggested by this study is that perhaps policy makers should consider consumption based pollution tax versus a production based one.

# A Appendix

Table 4: List of NACE 2 digit industries in the Census of Industrial Production (CIP)

| NACE Code | Description |
|---|---|
| 15 | Manufacture of food products and beverages |
| 16 | Manufacture of tobacco products |
| 17 | Manufacture of textiles |
| 18 | Manufacture of wearing apparel; dressing and dyeing of fur |
| 19 | Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear |
| 20 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials |
| 21 | Manufacture of pulp, paper and paper products |
| 22 | Publishing, printing and reproduction of recorded media |
| 23 | Manufacture of coke, refined petroleum products and nuclear fuel |
| 24 | Manufacture of chemicals and chemical products |
| 25 | Manufacture of rubber and plastic products |
| 26 | Manufacture of other non-metallic mineral products |
| 27 | Manufacture of basic metals |
| 28 | Manufacture of fabricated metal products, except machinery and equipment |
| 29 | Manufacture of machinery and equipment n.e.c. |
| 30 | Manufacture of office machinery and computers |
| 31 | Manufacture of electrical machinery and apparatus n.e.c. |
| 32 | Manufacture of radio, television and communication equipment and apparatus |
| 33 | Manufacture of medical, precision and optical instruments, watches and clocks |
| 34 | Manufacture of motor vehicles, trailers and semi-trailers |
| 35 | Manufacture of other transport equipment |
| 36 | Manufacture of furniture; manufacturing n.e.c. |

NACE classification followed in this study is NACE Rev 1.1 - a European statistical classification system of economic activities corresponding to ISIC Rev.3 at European level.

Table 5: Definition of variables

| Variable | Description |
|---|---|
| Count 'dirty' imports from non-OECD | a number of products imported from non-OECD whose code corresponds to industries of manufacturing of paper products (21), of petroleum and nuclear fuel products (23), of non-metallic products (26) and of basic metals (27) as these are the industries most affected by the EU ETS introduction. |
| Log value 'dirty' imports from non-OECD | log value of products imported from non-OECD whose code corresponds to industries of manufacturing of paper products (21), of petroleum and nuclear fuel products (23), of non-metallic products (26) and of basic metals (27) as these are the industries most affected by the EU ETS introduction. |
| Herfindahl-Hirschman Index | HHI is constructed taking firm's turnover as a market share and at a NACE 2 digit level of aggregation. Variety of other options is tried out for robustness. |
| CR3/4/5/8 | Alternative industry concentration measure constructed as a sum of market shares of top 3, 4, 5 or 8 firms in an industry. Market shares are taken to be turnover and a level of aggregation is NACE 2 digit. |
| Total energy use | Total fuel and power purchase (energy) as declared by firms in the CIP. |
| Exporter | Dummy variable equal to 1 if a firm exports in any given year and 0 otherwise. |
| Ownership | Dummy variable equal to 1 if a firms is foreign-owned and 0 if it is a domestic firm. |
| Labour Productivity | Total turnover divided by the number of employees. |
| Capital | Firm's capital additions built over the whole period minus sales of capitals assets, assuming 10% yearly depreciation rate overall. |
| Skill | % of managerial/technical and clerical personnel in total employment. |
| R&D | Research and development services supplied to the enterprise. |
| % materials purchased from affiliates | % of materials that are purchased or imported from affiliates |

Table 6: Summary statistics for the estimation sample

| Variable | Mean | Std. Dev. | Min | Max | N |
|---|---|---|---|---|---|
| Count 'dirty' imports from non-OECD | 0.676 | 1.408 | 0 | 17 | 992056 |
| Log value 'dirty' imports from non-OECD | 0.8433 | 1.9214 | 0 | 10.5134 | 992056 |
| Herfindahl-Hirschman Index | 0.0008 | 0.001 | 0.0002 | 0.0295 | 992056 |
| CR3 | 0.0027 | 0.0035 | 0.0006 | 0.0399 | 991625 |
| CR4 | 0.003 | 0.0038 | 0.0007 | 0.0436 | 991467 |
| CR5 | 0.0032 | 0.0041 | 0.0007 | 0.0473 | 990818 |
| CR8 | 0.0038 | 0.0047 | 0.0007 | 0.0555 | 989560 |
| Total energy use | 2101.52 | 7241.97 | 0 | 141234.7 | 992055 |
| Energy per turnover | 0.0169 | 0.0324 | 0 | 14.8034 | 991770 |
| Log total energy use | 5.7536 | 2.0329 | 0 | 11.8582 | 992055 |
| Export share | 69.6 | 38.273 | 0 | 100 | 992056 |
| Total Turnover | 405351.9 | 1295405.85 | 0 | 13432622 | 991806 |
| Total Earnings | 15268.87 | 30493.98 | 0 | 278681.31 | 991748 |
| Total Employed | 410.67 | 710.018 | 0 | 4515 | 991549 |
| Labour Productivity | 570.62 | 1189.69 | 0 | 15325.18 | 991429 |
| Log Labour Productivity | 5.5297 | 1.1231 | 0.0001 | 9.6373 | 991429 |
| % High-Skilled | 36.65 | 21.137 | 0 | 100 | 992056 |
| Capital | 51879.17 | 272960.64 | -70373.586 | 3116508.3 | 985804 |
| R&D | 2137.77 | 14721.21 | 0 | 1189696.88 | 992056 |
| Ownership | 0.5758 | 0.4942 | 0 | 1 | 992056 |
| % materials purchased from affiliates | 11.658 | 23.2 | 0 | 100 | 992056 |

Reported are mean values over the period of 2000-2009. All monetary values are in EUR thousands.

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