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Abstract

We consider the role played by the EU Emission Trading System (EU ETS) as a possible driver of outward Foreign Direct Investments (FDI henceforth).

In particular, we aim at assessing whether EU ETS has any effect on outward FDI patterns of Italian firms. Using a novel panel dataset of about 59,000 firms covering the first two phases of the EU ETS and the pre-EU ETS period, we are able to observe the patterns of FDI by destination country of firms, distinguishing between those with plants covered by the EU ETS and other firms. Results show that, on average, firms in the EU ETS do not increase their presence in other countries. However, EU ETS firms operating in sectors particularly exposed to international competition increase their outward FDI towards countries not covered by the EU ETS.

Keywords: EU ETS, FDI, carbon leakage

JEL: F23, L23, Q50

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1 Introduction

In the last few years the European Emission Trading Scheme (EU ETS) has attracted much attention among scholars and policy-makers as it represents the central policy instrument adopted by the EU to mitigate climate change. The capacity of the EU to unilaterally develop the first transboundary system of emission trading has made the EU ETS a prototype for several other ETSs that are rapidly spreading around the world (Ellerman, 2010).

However, the lack of an internationally coordinated environmental policy has raised increasing concerns about the potential competitiveness losses deriving from a stringent unilateral environmental regulation like the EU ETS. In particular, it has been argued that in the presence of global externalities such as the ones generated by CO2 emissions unilateral environmental interventions may end up being not effective in environmental terms while provoking socio-economic consequences in terms of job losses.

Some European production sectors are regarded as particularly vulnerable to the risk of carbon leakage, i.e. the delocalisation of production (and corresponding carbon emissions) of involved industries towards environmental policy-free geographical areas. The issue of carbon leakage has been recognised by the Commission that exempted from the auctioning of emission allowances those sectors more exposed to the risk of leakage, at least for the second commitment period of the EU ETS (2013-2020).

Surprisingly enough, however, this debate on the risks of carbon leakage lacks empirical evidence so far on whether the EU ETS can actually induce European firms to change their location, moving their production towards countries that are not subject to the EU ETS (to avoid the consequences of this regulation). Our paper aims at providing empirical evidence on this relevant issue.

The relocation risks provoked by unilateral environmental regulation are the object of a long-standing and extensive theoretical and empirical literature (e.g. Hoel, 1991; Dean, 1992; Lucas et al., 1992; Motta and Thisse, 1994). In this regard, one can distinguish two main research strands in this field: one on the so-called Pollution Haven Hypothesis (PHH) and the other on the Pollution Haven Effect (PHE). The former hypothesis argues that domestic regulatory stringency may trigger outward flows of FDI, while the latter claims that regulatory stringency 'at home' may negatively affect exports or inward flows of FDI. Both hypotheses have been investigated by several authors, mainly with respect to outward FDI from developed to developing countries, reaching contrasting results (see, among the others, Hanna, 2010; Eskeland and Harrison, 2003). Although different types of environmental policies have been taken into account to assess the validity of the PHH, the role played by the EU ETS as a driver of outward FDI has not been examined so far, mainly due to the lack of available data.

This paper contributes to the current literature by providing an empirical investigation about the potential carbon leakage effects of the EU ETS for firms operating in Italy, one of the major countries subject to this regulation.[1]

To examine the issue described above, the paper will be structured as follows. Section 2 reviews the relevant literature on the Pollution Haven Hypothesis. Section 3

[1] According to our calculations for the period 2005-2012, Italian plants covered by the EU ETS represent 9.5 percent of total EU plants covered by the EU ETS, have received 10 percent of overall allocations of permits and have contributed to 10.3 percent of total CO2 emissions.

describes in detail the EU ETS, the data we use and the empirical strategy. Section 4 discusses the results of our empirical analysis. Section 5 draws some concluding remarks that emerge from the analysis.

2 Literature review

Our paper relates to the wide literature on two separate but intertwined effects: the first one takes place when the Pollution Haven Hypothesis (PHH) is verified, while the second refers to the possible carbon leakage effect of the environmental regulation we are studying (EU ETS).

The literature on the PHH is the object of a long-lasting and heated debate, which dates back to the early 1990s when some seminal contributions on this issue first appeared (e.g. Lucas et al., 1992; Copeland and Taylor, 1994; Markusen et al. 1993; Chichilnisky 1994; Motta and Thisse 1994).[2] The Pollution Haven Hypothesis (PHH) predicts that multinationals will shift their production to countries with laxer environmental standards and regulations. This claim has been investigated both from a theoretical and empirical point of view. Among the theoretical contributions in this field, many early studies (Baumol and Oates, 1975, 1988; Markusen et al., 1993; Chichilnisky, 1994; Motta and Thisse, 1994; Oates and Schwab, 1988; Hillman and Ursprung, 1992, 1993; Rauscher, 1995; Fredriksson, 1997, 1999; Cole et al., 2006) emphasised the existence of a possible comparative advantage of developing countries in producing environment-intensive goods which may attract FDI from developed countries. This theoretical advantage, although intuitively appealing, has found little or no support from the empirical evidence over the last three decades (see below). On the contrary, most studies agree that environmental compliance costs are not a main concern that induces firms to relocate their production and that other factors generally have more influence on investment decisions (e.g. institutional and legal contexts, corruption, the technological gap, the level of human capital and the development of financial markets in the host economies, etc.). The theoretical literature, therefore, has subsequently tried to identify the factors that may weaken the PHH or even make it totally vanish. Smarzynska and Wei (2001), for instance, argue that the attractiveness of laxer environmental standards may be counterbalanced by corruption in the FDI-receiving country, which can lower the incentive of multinationals to invest in the host country.

Other papers (Markusen et al., 1995; Hoel, 1997; Ulph and Valentini, 2001; Kayalica and Lahiri, 2005; Cole et al., 2006; De Santis and Stahler, 2009) have emphasised the possible existence of a reverse causality: environmental regulation may affect FDI (as suggested by the PHH), but the opposite can also be true so that the presence of FDI can affect the stringency of the environmental regulation in the host country. In particular, Elliott and Zhou (2012) set forth a two-country model of firm entry in which firms try to enter the foreign market either through export or through FDI in the host country. FDI, therefore, are seen as a strategic decision that foreign firms can do to prevent the possible entry of a domestic competitor in the market. The authors show that in a similar context a tightening of domestic environmental regulation can lead to an

[2] See Dean (1992, 2001), Jaffe et al. (1995), Copeland and Taylor (2004), Brunnermeier and Levinson (2004), Erdogan (2014) for surveys of the literatures on the PHH.

increase in capital inflows into the host country (what they define environmental regulation induced FDI).

In recent years a small but increasing number of studies have used game theoretical models to account for strategic motivations underlying FDI decisions. For instance, using a Cournot duopoly model, Dijkstra et al. (2011) find that outward FDI may not necessarily be spurred by more stringent environmental regulation. The authors show that if the relocation cost is sufficiently small, an increase in the environmental tax can encourage the foreign firm to shift from exporting to FDI to enter the domestic market. A similar result is found by Sanna-Randaccio and Sestini (2012). Using a two-country model, they find that when the country with the larger market tightens its environmental policy, relocation might not occur (thus violating the PHH) if unit transport costs are sufficiently high. Also Dong et al. (2012) stress the role played by market size in affecting the PHH. Using a two-country (North-South) model with transboundary pollution, the authors show that if the market size of the two countries is relatively small (and the technological gap between the two countries is also small) FDI raise the environmental regulation of the host country, thus determining a race to the top. If, on the contrary, the countries' market size is sufficiently large (and the technological gap between North and South is moderate) then the South will not strengthen its environmental standards, which may possibly confirm the PHH.

A different theoretical perspective is adopted by Eskeland and Harrison (2003) who examine the effect of both capital intensity and environmental regulation on outward FDI. Using a simplified theoretical framework, the authors show that the effect of pollution abatement costs on industrial relocation is a priori ambiguous, crucially depending on the degree of complementarity between domestic capital and pollution abatement. If capital at home is complementary to pollution abatement and substitute to capital abroad, a stricter domestic environmental regulation can induce firms to invest more at home (since an increase in domestic capital reduces the costs of complying with the domestic regulation) and less abroad (due to the substitutability between domestic and foreign capital), contrary to the PHH. The opposite occurs if the initial assumptions are relaxed. The authors conclude, therefore, that the impact of environmental regulation on investment and output is theoretically ambiguous and can only be resolved through appropriate empirical analyses. However, also the empirical literature has reached ambiguous and sometimes conflicting results so that the debate is far from over (Taylor, 2005).

In his survey of the literature Erdogan (2014) emphasises that studies carried out until the beginning of the '90s did not find any relevant effect of environmental regulations on FDI (e.g. Dean, 1992; Levinson, 1996). In his opinion, the main reason is that the amount of FDI flows started to rise after the '90s. As the author shows, however, even later studies (performed after the 2000s) find no univocal results and highlight only a weak evidence of PHH.

In early studies, the focus of the analysis was mainly on the developed countries, particularly the US. For example, List and Co (2000) and Keller and Levinson (2002) examine this research question using US state level data and try to uncover whether a more stringent environmental regulation at home discourages inbound FDI. More precisely, by searching for an effect of the pollution abatement costs (PACE) on different multinational enterprises (MNEs) dimensions such as capital and employees, Keller and Levinson (2002) find only a moderate effect. List and Co (2000), instead,

look at how the investment decisions of new foreign plants are influenced by four different measures of environmental stringency, claiming a negative effect. Using state-level data over the period 1986-1993, they find that more stringent pollution regulations deter the entry of new firms. In the same way but adopting a different perspective that looks at outward rather than inward FDI (i.e. focusing on the PHH rather than on the PHE), Xing and Kolstad (2002) report that the effect of higher environmental laxity of 22 destination countries was quite relevant for outward US FDI but mainly for specific sectors like chemicals and primary metals sectors. The same deterrent effect is not detected for other industries, that are those for which pollution is less relevant. A similar result is obtained by Cole and Elliot (2005) who limit their analysis to two destination countries, namely, Mexico and Brazil. Their research strategy relies on the complementarity between capital intensity and pollution intensity emphasised in the theoretical approach by Eskeland and Harrison (2003) described above: most polluting sectors are also highly capital intensive, therefore FDI will be mainly directed towards countries such as Mexico and Brazil with high capital endowments relative to the stringency of their environmental regulations. To test this hypothesis, they empirically estimate the determinants of US multi-sector FDI into those countries and find that the latter played indeed the role of pollution havens for the US in the observed period.

Similarly, using panel industry data, Wagner and Timmins (2009) examine the role played by environmental regulations across several host countries in affecting the amount of outward FDI of German manufacturing industries over the period 1996-2003. The most relevant contribution of this study is that it accounts for the presence of agglomeration economies as possibly veiling the PHH[3]. Controlling for agglomeration economies, they find that only the chemical industry turns out to be subject to the PHH. Also Manderson and Kneller (2012) tend to reject the PHH. By analyzing outward FDI for the UK and controlling for firm heterogeneity, they find that more pollution intensive MNEs are not likely to delocalise their plants in countries with less stringent environmental policy. In the same way, also Javorcik and Wei (2004) account for firm heterogeneity and idiosyncratic factors that may affect multinational firms' propensity to invest. The authors analyse the investment choices of MNEs that decide to locate across transition economies, such as Eastern Europe and the former Soviet Union. Although some empirical evidence suggests that FDI are negatively correlated with tight standards, their estimates do not find strong cross-industry differential impact of environmental regulation on FDI. This seems to reject the PHH, although Taylor (2005) points out that the failure to find cross industry effects may be due to other confounding factors.

Most of these studies do not take into account what can happen when a firm-level type of regulation is considered. The paper by Hanna (2010) goes in this direction analyzing whether the Clean Air Act Amendments (CAAA) had any impact on the amount of outward FDI in the period 1966-1999. Controlling for the "quality" of FDI, she finds that even though firms involved in the regulation increase both their asset and production abroad, the destination countries are not those in which the environmental regulation may be laxer such as developing countries.

[3] As the authors argue, if agglomeration economies are correlated to the environmental stringency, omitting agglomeration effects from the econometric model estimated equation may cause estimated coefficients to be biased.

However, outward FDI of developed countries are not the only type of flows considered in the empirical analyses to test the PHH. Dean et al. (2009), for instance, examine the Chinese case and find that only equity joint ventures in highly polluting industries coming from Hong Kong, Macao, and Taiwan are driven towards locations characterised by lower environmental standards. Chung (2014) analyses, instead, South Korean FDI over 2000–2007 and finds confirmation that polluting industries display a higher amount of FDI both at the extensive and intensive margin.

A step further, is made by Naughton (2014), who considers the role played by both the home and the host country regulation on the bilateral FDI flows of 28 OECD countries. He observes that while a stricter host country regulation contributes to decrease the amount of FDI, a non-linear effect is at work for home country regulation: when the home regulation is low, this could spur higher FDI flows until a threshold value is reached. Beyond that point, higher levels of regulation contribute to diminish FDI flows.

From this brief survey of the literature, we evidence that most of the studies carried out so far do not use firm level information but they are rather carried out using sector/country data. The high heterogeneity of results is due to the different types of proxies used to account for regulations and countries analyzed.

2.1 The role of the EU ETS

Our paper contributes to the still growing literature on the impact of the EU ETS. As Martin et al. (2015) point out in their survey of the literature, one can distinguish three different though related impacts of the EU ETS: on technological innovation, emissions abatement and firms' performance.

Much of the literature focused on the so-called "induced innovation" effect through surveys of managerial interviews and/or estimation of econometric models (see Abrell et al., 2011; Aghion et al., 2009; Anderson and Di Maria, 2011; Borghesi et al., 2015; Calel and Dechezleprêtre, 2016; Hoffman, 2007; Rogge et al., 2011; Schmidt et al., 2012). Among them, a particularly interesting contribution is provided by Calel and Dechezleprêtre (2016) who carry out a comprehensive investigation of the EU ETS innovation effects during the first 5 years of its implementation. The large dataset used (over 5500 firms running more than 9000 plants) allows the authors to make a comparison between firms that are subject to the regulation and firms with similar resources and patenting history that were not covered by the regulation, considering their behaviour before and after the EU ETS was launched. By adopting matching techniques they find that the EU ETS system positively benefited the low-carbon patenting activities of ETS firms. The latter, however, account for only a small fraction of all patents, so that the authors estimate that only 2% of the increase in the patenting of low-carbon technologies can be ascribed to the EU ETS.

The EU ETS impact on emissions reduction is at the centre of a few contributions. Early studies (e.g. Ellerman and Buchner, 2008; Ellerman et al., 2010; Anderson and Di Maria, 2011) focusing on the first commitment period 2005-2007, estimate that emission reductions were around 3% in Phase I, although results differ substantially across countries. Extending the analysis to the second commitment period, later studies (Cooper 2010; Kettner, et al., 2011; Germà and Stephan, 2015) tried to disentangle the impact on emissions abatement of the EU ETS from that of the economic crisis reaching

similar conclusions: most of the abatement in Phase II can be ascribed to the economic recession.

As far as the impact on firm performance is concerned, most studies carry out ex-ante assessments rather than ex-post evaluations. Among the latter, a number of contributions estimate the EU ETS impact on employment, output and profits. For example, using a sample of European firms analyzed over the years 2005-2008 Abrell et al (2011) find that the EU ETS did not have any statistically significant impact on companies' added value and profit margins, while it had only a small but statistically significant effect on their employment which is estimated to have fallen by about 0.9% among EU ETS firms in the observed period. As the authors point out, however, their results might be driven by the trend of a specific sector, non-metallic minerals, that has been affected by the ETS regulation to a greater extent than the other sectors.[4]

With respect to other measures of competitiveness such as international trade or foreign direct investments (the object of our analysis) very scarce empirical evidence is present in the literature. Focusing on the impact of Phase I on EU15 countries, Costantini and Mazzanti (2012) estimate that at the sectoral level, the EU ETS acted as deterrent of exports in all industries except for medium-low technology industries. Rainaud and Agency (2008) focus instead on imports of aluminium in the EU27 countries and find no evidence of any structural break between the periods before and after the implementation of the EU ETS.

Most of the papers in this research strand do not deal with the issue of its impact on the possibility of opening new plants abroad, as our papers does.

A relevant exception in this sense is represented by Martin et al. (2014a). Using survey data on more than 700 firms spread over 6 countries, the authors propose an innovative measure of carbon leakage risk based on managers' interviews. They then analyse correlation between this measure and the criteria adopted by the EU to exempt from permit auctions the sectors at risk of relocation, namely, carbon intensity and trade exposure, and find that the former criterion is highly correlated to carbon leakage whereas the latter is not. This leads them to propose two main modifications of the current exemption criteria: (i) consider a sector at risk of carbon leakage only if it is both trade intensive and carbon intensive and (ii) adopt a more specific measure of trade intensity that focuses on trade with less developed countries rather than all non-EU countries.

The EU ETS exemption criteria is also the object of a companion paper by Martin et al. (2014b) in which the authors formalise the theoretical framework for efficient compensation of industries at risk of relocation. Their work shows that compensation should not go to firms that have the highest propensity to relocate but rather to those that ensure the highest marginal improvement of the government's objective function. From the application of the proposed industry compensation scheme to the EU ETS, the authors conclude that the exemption criteria adopted by the EU lead to inefficient allocations.

More recently, Dechezleprêtre et al. (2015) examine the carbon leakage effect from the point of view of multinational firms using a sample of 1785 multinational

[4] Interestingly, Abrell et al. (2011) also find that emissions abatement in the period 2007-2008 were 3.6% higher than in the period 2005-2006, which can be ascribed to a change in the stringency of the scheme from the first to the second phase. Other specific country-level studies using firm-level data about pre-treatment emissions concern France and Germany (Wagner et al. 2013; Petrick and Wagner, 2014).

companies over the period 2007-2014, deriving from the Carbon Disclosure Project (CDP). The originality of their contribution is that of studying whether the EU ETS may influence the relocation of CO2 emissions within a multinational firm, by comparing emissions in Europe and outside Europe by the same company. The ratio underlying their analysis is that since these firms operate across different countries they might escape compliance costs by shifting their production to less regulated jurisdictions. The authors, however, find no evidence of any carbon leakage effect in general, and the same applies with respect to those sectors deemed at risk of carbon leakage.

3 Empirical framework

Before discussing our data sources (section 3.2) and our empirical framework (section 3.3), a detailed description of the EU ETS (section 3.1) is needed to identify the issues at stake.

3.1 The EU ETS

The EU ETS was introduced by the Directive 2003/87/EC[5] as the pillar of the European climate change mitigation policy to reach the Kyoto targets and comply with other current and future regional or international targets. It is a cap-and-trade scheme for CO_2 in which emissions permits are allocated to the participants at the beginning of each period, either for free (grandfathering) or auctioned. At the end of each period participants are required to return an amount of emission permits corresponding to the actual amount of emissions. In the meantime, permits can be transferred between participants at a price per ton of CO_2 that, in equilibrium, should be equal to the marginal abatement cost, leading to efficient distribution of abatement across participants. Within the EU ETS, the penalty for non-complying (i.e. not being able to return a sufficient number of emission permits at the end of the compliance period) was set to 40 euros per ton in the pilot phase (2005-2007) and to 100 euros per ton in the first commitment period (2008-2012).

This type of regulation was set in place with a double objective: reducing the overall abatement costs of carbon emissions as well as providing the economic incentives to induce firms to develop low carbon technologies (Calel and Dechezleprêtre, 2016). The reason for pursuing this latter goal is that the political acceptance of the regulation is likely to be higher if induced innovation effects are expected.

Three main periods can be identified: the period 2005-2007, in which the system was set up, represented a pilot phase. No banking was allowed between the pilot phase and subsequent EU ETS phases. The first commitment period (2008-2012), leading to the Kyoto commitment period (2012), extended the scope of the scheme to aviation (2012). Finally, the second commitment period (2013-2020) introduced a single EU-wide cap for total emissions and a rising use of auctioning in the allocation of the permits, with some exception for selected sectors.

The EU ETS covers now all EU28 countries plus Norway, Iceland and Lichtenstein. Being characterised by substantial sunk and fixed costs (including administrative and monitoring costs for participants and governments), the Commission decided to include in the scheme only the biggest emitters of CO2. These emitters are identified by their

[5] Emended by the Directives 2004/101/EC and 2008/101/EC, the Regulation 219/2009 and the Directive 2009/29/EC.

sector of operation (or type of activity) and by the size of the plant in terms of production capacity. The scheme currently covers about 11,000 plants in Europe that contribute to around 45 percent of overall European GHG emissions[6]. The sectors and thresholds are reported in Annex I of the Directive and have been emended twice since 2003[7].

The possible carbon leakage effect, that is the phenomenon for which firms may relocate part of the production in countries where regulation is not in place, may hinder the policy effectiveness of the regulation. The practice of exempting specific sectors from existing regulations is not uncommon: as Martin et al. (2014b) recall, since the introduction of carbon taxes back in the '90s, most of the countries involved grant some sort of exemptions to energy intensive firms to avoid their relocation.

In this light, a major amendment to the Directive concerned the differentiation of the allocation scheme across sectors for the second EU ETS commitment period (2013-2020) according to the criteria described in the new Articles 10 *bis* and 10 *ter* (Directive 2009/29/EC). The Decision of the European Commission 2010/2/EU '*Determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage*' provided a list of 4-digit NACE sectors for which permits could be grandfathered rather than auctioned also in the second commitment period due to potentially relevant risks of off-shoring of these production activities deriving from the EU ETS. These sectors were identified through qualitative and quantitative analysis on the importance of potential carbon leakage and, to some extent, through a political negotiation. Three main criteria were included in the amendment to identify the list of sectors to be exempted from auctioning[8]:

- the first is a 'trade-based' criterion according to which industries (4-digit NACE) having a non-EU trade intensity (import plus export over domestic production) greater than 30% are exempted from auctioning (trade criterion);
- the second refers to those industries (4-digit NACE) that are expected to experience additional (direct and indirect) costs as a consequence of the implementation of the ETS Directive greater than 30% of their gross value added (emission criterion);

[6] http://ec.europa.eu/clima/policies/ets/index_en.htm, last accessed: 30/9/2015.

[7] The 2003 Directive refers to the following activities (with corresponding capacity thresholds – Annex I of the Directive 2003/87/EC): Combustion installations with a rated thermal input exceeding 20 MW (except hazardous or municipal waste installations); Mineral oil refineries; Coke ovens; Production and processing of ferrous metals; Metal ore (including sulphide ore) roasting or sintering installations; Installations for the production of pig iron or steel (primary or secondary fusion), including continuous casting, with a capacity exceeding 2,5 tonnes per hour; Installations for the production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or lime in rotary kilns with a production capacity exceeding 50 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day; Installations for the manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day; Installations for the manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day, and/or with a kiln capacity exceeding 4 m3 and with a setting density per kiln exceeding 300 kg/m3; Industrial plants for the production of (a) pulp from timber or other fibrous materials (b) paper and board with a production capacity exceeding 20 tonnes per day. The list has been further extended to other sectors (refer to the consolidated version of the Directive 2003/87/EC).

[8] A fourth criterion refer to qualitative assessment (Art. 10bis.17) of the likely impact of the EU ETS on production costs, investments and profit margins.

- the last criterion concerns industries (4-digit NACE) having at the same time moderate trade intensity and implementation costs (trade intensity greater than 10% and costs greater than 5% of gross value added).[9]

This list was subsequently further emended to add other sectors with the decisions of the European Commission 2012/498/EU (that added sector 2614 'Manufacture of glass fibres') and 2014/9/EU (that added sector 2653 'Manufacture of plaster' and sector 2662 'Manufacture of plaster products for construction purposes').

This characterisation of the policy is particularly relevant for our analysis as no exemption was in place in the period we consider. This means that we cannot evaluate whether the exemption was successful in limiting the risk of carbon leakage, but rather whether outward FDI were growing in these sectors due to the EU ETS, even before the introduction of auctioning, so that their exemption from auctioning was actually justified.

3.2 Data sources

Our empirical analysis is based on a set of administrative data. We retrieved information on balance sheet, profit and loss account, region (NUTS2) and industry (NACE rev. 1.1, 4-digit) for a large sample of about 59.000 Italian manufacturing firms from the AIDA (Bureau van Dijk) database.[10]

For what concerns the construction of the dependent variable, the AIDA database provides only the latest available information about proprietary structure and subsidiaries, with some lag. Given that in each release information refers to several different years (e.g. the release of March 2011 reports information on subsidiaries ranging from 2007 to 2011, 64 percent of which refers to 2009), the assessment of the annual number of subsidiaries is rather problematic. We thus decided to measure the number of subsidiaries for three time windows: 2002-2004 (pre-ETS), 2005-2007 (pilot phase of the ETS) and 2008-2010 (first commitment period of the EU ETS). For each of them we count the number of subsidiaries over the three years.

We selected only industrial subsidiaries (excluding financial and other types of subsidiaries) and use 10 percent of ownership as the threshold to consider participation as an actual subsidiary. We split the count of subsidiaries according to the country of destination of the FDI. In particular, we identify foreign subsidiaries in countries not covered by the EU ETS[11]. One possible drawback of this approach is that we cannot measure the actual size and relevance of these subsidiaries in terms of monetary value (total assets, turnover) or number of employees.[12] This means that we cannot measure how much firms have moved their activities and their production abroad towards

[9] These criteria are thoroughly discussed in the following document:
http://ec.europa.eu/clima/policies/ets/cap/leakage/documentation_en.htm

[10] Missing information about 4-digit Nace sector and employment for some of the firms has been retrieved from the ASIA (Archivio Statistico delle Imprese Attive) database (National Institute of Statistics, Istat).

[11] Countries adhering to the EU ETS are: Austria, Belgium, Bulgaria (from 2008), Croatia (from 2013), Cyprus (from 2008), Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland (from 2013), Ireland, Latvia, Lichtenstein (from 2008), Lithuania, Luxembourg, Malta (from 2008), Netherlands, Norway (from 2008), Poland, Portugal, Romania (from 2007), Slovakia, Slovenia, Spain, Sweden and the UK.

[12] This information is rarely available in the AIDA database, limiting substantially its use for our purposes.

existing or new subsidiaries, but only whether they have opened or acquired (or closed down or sold) foreign subsidiaries.

It is possible that for some firms information about the presence and composition of subsidiaries is not available because of data collection problems. In other words, some of the zeros we observe in the number of subsidiaries may simply reflect missing values. This incidental truncation could create some selection bias. As it will be shown below, our empirical strategy also aims at correcting such biases.

Finally, we identified Italian firms with plants covered by the EU ETS by matching unique identifiers (when available) and firm names in the Community Independent Transaction Log with the name and unique identifier in AIDA. We identified a total of 371 firms (309 of which operate in manufacturing sectors) with at least one plant subject to the EU ETS.

From the same dataset we single out the control variables we use in the regressions as well as those used to carry out propensity score matching, namely, size (logarithm of average number of employees), capital intensity (stock of tangible fixed assets per employee), and wages (average compensation per employee).

The latter variable accounts for the degree of human capital a firm can be endowed with, which may also represent its degree of skills and, to some extent, a proxy for technological capabilities. More generally, the variables that are used to estimate the propensity score are selected to capture other possible determinants of FDI beyond the EU ETS, and account for the stylised fact that firms that are bigger, more productive and more capital intensive, have a greater propensity to invest abroad.

3.3 Empirical strategy

Identification of plants that should be included in the the EU ETS (i.e. assignment to treatment) is not random but depends on a series of observable characteristics of the plant, that is its capacity (sector-specific) and its sector of operation. This makes the identification of a suitable counterfactual problematic. Plants belonging to different sectors and with different production capacities are likely to evolve differently due to several reasons, thus leading to a failure of the identification assumptions of a difference-in-differences approach (i.e. pre-treatment common trend assumption). On the other hand, matching at the plant level is not possible, because if plants operate in the same sector and are similar in size, they should be either (both) covered by the EU ETS or (both) exempted from it. As discussed by Calel and Dechezleprêtre (2016) in their analysis of ETS-induced clean patents, while no credible matching is possible between treated and non-treated plants, when moving to company-level analysis a 'matching' approach turns out to be a suitable route.

[Table 1 about here]

Table 1 shows the distribution of firms across industries, regions, size classes and EU ETS status for our sample of firms. Considering the whole sample the share of firms that own plants subject to the EU ETS is quite low (0.5%). These firms tend to be concentrated in three main sectors: manufacturing of food products, beverages and tobacco (DA), manufacturing of pulp, paper and paper products (DE) and manufacturing other non-metallic mineral products (DI), which jointly account for

about 60 percent of EU ETS firms. As expected, big firms (more than 250 employees) tend to be over-represented: 11.1 percent of big firms own plants subject to the EU ETS, as compared to only 0.1 percent of micro and small firms. Finally, when looking the geographical distribution of the Italian EU ETS firms, no apparent difference emerges between North, Centre and South in relative terms (i.e. as a share of total firms). However, when considering absolute values the higher amount of ETS firms turns out to be located in the North of Italy. This is not surprising since big firms are mainly concentrated in that macro-region. As we will discuss hereafter, EU ETS firms differ substantially from other manufacturing firms in many other respects, which motivates the need to identify a proper counterfactual by means of matching techniques. These differences point to the need to select a control group of firms among those that are not subject to the same treatment (in our case the EU ETS) that has the highest degree of similarity in observable features before the treatment occurred.

In order to account and limit these systematic differences, we estimate the propensity score which represents the probability of being selected in the treatment group according to some firm's characteristics. We match our EU ETS firms on a number of visible features. Besides industry and regional (NUTS1) dummies, we include three dummies that capture their exposure to leakage as defined by the European Commission at the 4-digit NACE (rev 1.1) level (see Section 3.1). We also match EU ETS firms on size (log of number of employees, also squared), age of the firm and capital intensity. Finally, we balance our sample of control firms in terms of the probability of having or not having foreign subsidiaries (split into subsidiaries in countries covered by the EU ETS and other countries) and in terms of the corresponding count of subsidiaries. All these variables are measured in the pre-treatment period. Results of the probit model used to estimate the propensity score are reported in Table 2. The probability of owning a EU ETS plant is positively related with size and capital intensity. This is in line with the fact only bigger emitters are subject to ETS. On average, firms in sectors exposed to leakage are more likely to own EU ETS plants, particularly if they belong to sectors with high expected compliance costs (emission criterion) and relatively less if they belong to sectors with high trade exposure (trade criterion). Finally, firms with at least one subsidiary in countries covered by the EU ETS are less likely to own EU ETS plants while the opposite is true for firms with at least one subsidiary in countries that are not covered by the EU ETS. On the contrary, the count of subsidiaries both for ETS and non ETS-firms is unrelated to the probability of owning EU ETS plants.

[Table 2 about here]

Among the different possible matching algorithms, we employ the nearest neighbours (up to 10 neighbours) matching with caliper as our favourite approach, while we report in Appendix C results based on kernel matching. Selecting more than one nearest neighbour allows to reduce the risk of selecting too many control firms with zero subsidiaries (thus reducing the risk of losing too much information). Moreover, the fact of conditioning control firms to be within a certain radius (1 percent probability of being treated in our case) also excludes potential controls that are too different from our set of treated firms. Figure 1 shows the distribution of the predicted propensity score for treated and matched controls. Black dots represent EU ETS firms for which no match was possible since even the nearest neighbour was too far (more than 0.01) in terms of propensity score. Following the approach of Calel and Dechezleprêtre (2016), we

excluded these 17 EU ETS firms from the analysis. After matching, we excluded unmatched non-ETS firms from the analysis and employ matching weights as time-invariant regressions weights in our difference-in-differences.[13]

[Figure 1 and Table 3 about here]

As it is visible from Table 3, after matching EU ETS firms with similar firms with no plant covered by the EU ETS, we obtain a much more credible counterfactual. EU ETS and other firms were significantly different, before matching, in all the dimensions considered here: EU ETS firms were older, bigger, more capital intensive, more likely to have subsidiaries and more likely to belong to sectors exposed to leakage. However, when focusing on the matched sample of non EU ETS firms, the t-tests on the comparison of means for all dimensions between treated and control firms suggests that we cannot reject the null hypothesis of equal means in the two groups. This result confirms that firms matched on the propensity score are likely to be a good counterfactual.

[Figure 2, Figure 3 and Table 4 about here]

While matching allows us to balance the level of observable features of treated and untreated firms, it could be the case that the two groups of firms, though similar 'in levels', were experiencing different trends in outward FDI even before the ETS was in place. In the absence of data on foreign subsidiaries prior to 2002, we can evaluate the trend in total financial assets for a subsample of firms starting from 2000. Total financial assets measure the book value of all subsidiaries (including Italian subsidiaries) directly owned by a firm. Figure 2 and Figure 3 show the trends in average financial assets for a selection of firms that can be observed over the whole period 2000-2012. We split our sample into three groups: ETS firms, non-ETS firms and a sub-sample of the latter that includes matched non-ETS firms. While unmatched non-ETS firms have on average much smaller financial assets than ETS and matched non-ETS firms, the trends for the three groups are very similar up to 2004. Starting from 2005 we observe a reduction in financial assets for ETS firms, while non-ETS firms continue to grow. In any case, pre-treatment trends look very similar. We test the similarity of trends between ETS and non-ETS (matched or unmatched) firms, also splitting the two groups of firms in 'leakage' and 'non-leakage' sectors, by estimating a fixed effect model for the period 2000-2004 in which we include time dummies and interaction terms between treatment dummies and time dummies. If the latter turn out to be jointly statistically significant, we would have systematically different trends between treated and control firms. In all cases (Table 4) we find no significant pre-treatment differences between the trends of ETS and non-ETS firms.

As discussed in the previous section, another issue arises in our sample as we may have the possibility that some of the zeros of our dependent variables, that represent about 90 percent of our sample (depending on the variable), are missing values

[13] If a treated firm is matched with 10 non-treated firms (and these are not matched with other treated firms), then we assign a unitary weight to the treated firm and a 1/10 weight to each of the control firms. Similarly, if only 9 non-treated firms are matched (because the potential tenth firm is out of the interval as defined by the caliper), each of the untreated firms is weighted 1/9.

(incidental truncation) and not actual 'zeros'. This could give rise to a selection bias if the incidental truncation is not random. To correct for this potential problem, our preferred estimator is the Heckman sample selection model[14].

A natural candidate variable to be used as an exclusion restriction is the variable that measures whether the firm owns Italian subsidiaries or not. This variable can be a proxy for the firm's decision to invest abroad. In fact, if a firm is already coordinating a network of firms in Italy, it will be more prone to extend such a network abroad for the experience already accumulated as well as for the sunk costs involved in the coordination process. Moreover, the fact that Italian subsidiaries have been identified by Bureau van Dijk may suggest that the firm has been 'surveyed' about its subsidiaries, thus increasing the likelihood of observing also foreign subsidiaries. We allow this variable to exert a different effect for the three different period of estimation by interacting it with time dummies.

We estimate the following 'difference-in-differences' equation on the matched sample of firms:

$$FDI_{i,t} = \alpha \times ETS_i + \beta_t \times D_t + \gamma_t \times ETS_i \times D_t + \sum_j \omega^j \times X^j_{i,t=0} + \sum_j \delta^j \times X^j_{i,t=0} \times t + \xi_k + \theta_l + \varepsilon_{i,t}$$

where:

- $FDI_{i,t}$ is our dependent variable, that is the number of foreign subsidiaries by firm *i* in period *t*;
- ETS_i is a time invariant dummy variable taking the value of 1 for those firms *i* with at least one facility covered by the EU-ETS and 0 otherwise;
- D_t is a time dummy;
- $X^j_{i,t=0}$ is a set of control variables, measured in the period 2002-2004, interacted with a linear time trend;
- $X^j_{i,t=0} \times t$ is a set of control variables, measured in the period 2002-2004, interacted with a linear time trend;
- ξ_k represents a set industry dummies (subsection, Nace rev 1.1);
- θ_l a set of regional dummies (NUTS1);
- $\varepsilon_{i,t}$ is the error term.

Our parameter of interest is γ_t, with *t*=2005 for the assessment of the effect of the pilot phase of the EU-ETS and *t*=2008 for the effect of the first commitment period of the EU-ETS.

As our set of control variable is likely to be influenced itself by the EU ETS, they were likely to be 'bad controls' in our equation as they would have incorporated some of the effects of the EU ETS on FDI (Angrist and Pischke, 2009). For this reason, we

[14] Recently Semykina and Wooldridge (2010) developed an extension of the Heckman sample selection model to the case of longitudinal data and endogenous explanatory variables that allows to account for individual unobserved heterogeneity. As a robustness check, we repeat our analysis using their proposed estimator, showing that our results remain unchanged.

allow the average level of FDI and linear trends in FDI to differ depending on the initial (i.e. pre-treatment) level of our control variables.

In a first step, our set of control variables (besides regional and industry dummies) contains only the logarithm of firm size (number of employees) while in a second step we also include capital intensity (stock of fixed assets per employees) and the logarithm of average labour compensation per employee. In a third richer specification we also add industry-specific and region-specific linear trends to account for shocks that hit particular regions or sectors.

Finally, to evaluate the differential effect of the EU ETS on firms in sectors that are deemed to be at risk of carbon leakage (as a whole or split according to the various criteria described above) we estimate the following equation:

$$FDI_{i,t} = \alpha \times ETS_i + \beta_t \times D_t + \gamma_t \times ETS_i \times D_t + \phi \times LeakSect_i + \eta_t \times LeakSect_i \times D_t + \psi_t \times LeakSect_i \times ETS_i \times D_t + \sum_j \omega^j \times X^j_{i,t=0} + \sum_j \delta^j \times X^j_{i,t=0} \times t + \xi_k + \theta_l + \varepsilon_{i,t}$$

Our parameter of interest is here ψ_t, with t=2005 and t=2008, that measures the differential impact of the EU-ETS on firms belonging to sectors that are expected to be particularly exposed to leakage as opposed to the effect of the EU-ETS on firms belonging to other sectors (γ_t, with t=2005 and t=2008).

4 Results

Table 5 describes the evolution of the average number of subsidiaries and of the share of firms with subsidiaries for (i) ETS firms, (ii) our sample of matched control firms and (iii) the full set of potential control firms. Looking at the table, at a first glance we can notice for both measures a rising trend in outward FDI between pre-ETS and ETS phase II especially among the matched sample of non-ETS firms. The only exception is the number of foreign subsidiaries of ETS firms and the non-matched sample of non-ETS firms, which are substantially stable along the three periods. However, this trend is particularly evident when considering the amount and the share of foreign subsidiaries in non-ETS countries.

[Table 5 about here]

In absence of apparent differences in the trends of foreign subsidiaries in ETS firms compared to similar non-ETS firms, we move to our regression analysis and look at the average effect of the EU ETS on the number of foreign subsidiaries. The main results are shown in Table 6, while Table 10 in Appendix A reports the results of the corresponding selection equation. Columns 1 and 4 include only a reduced set of control variables (region and sector dummies and firm size), while columns 2 and 5 consider more controls (wages and capital intensity) and columns 3 and 6 account also for sector-specific and region-specific trends. First of all, we note that the $\chi 2$ test of independence

is significant in all specifications leading us to conclude that the Heckman model is appropriate in our case as selection bias is an issue. As to our variable of interest, that is, the effect of the EU ETS in the time windows in which the EU ETS was in place, we observe no significant effect on the number of foreign subsidiaries (either subsidiaries in all foreign countries or subsidiaries in countries that do not participate to the EU ETS). For both phases of the EU ETS and all specifications, the point coefficients of our treatment variables are very small in magnitude and far from being significant. Among the control variables[15], the one measuring workers skills (wages) is always positive and strongly significant across all specifications. Even the magnitude of the coefficients is quite large compared to the other variables. This suggests that the amount of human capital owned by a firm is one of the most important drivers of FDI irrespective of the country in which the firm invests. However, when interacted with the time trend the variable becomes negative and sometimes not significant, meaning that this determinant produces a declining effect over time. The variable measuring size is not significant, but appears positive and significant only when interacted with time in the case of non-EU ETS countries. This effect disappears when other control variables are included in the estimations. Results for the selection equation (Table 10) reveal that the variable we used to discriminate among the equations, our exclusion restriction, is a good predictor of the likelihood of observing positive values of our main dependent variable. The main difference with respect to the outcome equation is that the variable measuring size is always positive and significant: bigger firms are more likely to own foreign subsidiaries.

[Table 6 about here]

Besides the results obtained for firms investing in countries not covered by EU ETS, which is the "core" of our paper, we think it is important to provide benchmark estimates for outward FDI towards EU ETS countries (Table 14 in Appendix B). In this way, we are able to verify whether EU ETS firms behave differently from other firms in terms of outward FDI because of unobserved time-varying heterogeneity. If these firms, for some reason that is not accounted for by our control variables, were more likely to do FDI of any kind, that means that our estimates in Table 6 do not represent a treatment effect. On the other hand, if no difference was observed in the outward FDI directed towards countries covered by the EU ETS between the two group of firms, that would mean that unobserved heterogeneity does not play a relevant role. Results in Table 14 do not detect any significant differential effect for EU ETS firms after the EU ETS was in place in terms of outward FDI directed towards EU ETS countries. Effects are very small in magnitude and far from being statistically significant, which confirms the validity of our approach.

4.1 Differential effect for sectors exposed to leakage

As the EU ETS *per se* does not seem to influence the strategies of Italian firms in terms of foreign subsidiaries, we dig deeper to evaluate whether the absence of an average effect on EU ETS firms hides heterogeneous effects depending on the extent to

[15] Since our dependent variable expressed in log, coefficients of continuous variables should be interpreted as elasticities.

which firms are exposed to risks of leakage. Table 7 shows the estimation results when accounting for possible differential effects for firms belonging to industries identified by the European Commission as exposed to risks of leakage.[16] Out of 294 treated firms, 241 (82 percent) belong to these sectors.[17] Also in this case, no impact is found, neither for firms in sectors not exposed to leakage (*ETS x Phase I* and *ETS x Phase II*) nor for firms in sectors exposed to leakage (*Leakage Sectors x ETS x Phase I* and *Leakage Sectors x ETS x Phase II*). The results previously obtained for the other control variables are confirmed.

[Table 7 about here]

It should be noted that plants operating in these sectors have historically received more free permits than they actually needed at the end of each period, when compared to plants in other sectors. Figure 4 plots the trends in total allocated and verified emissions for each year separately for plants in 'leakage-exposed' sectors and for plants in other sectors. Evidence shows that 'over-allocation' was substantial for these 'leakage-exposed' sectors, while 'under-allocation' is found for other sectors.[18] This means that allocation plans already favoured these sectors even before the amendment to the EU ETS directive of 2009 and the decision of the European Commission (2010) on the sectors to be exempted from auctioning. As we expect 'leakage-exposed' sectors to be particularly penalised (i.e. trying to escape the EU ETS through outward FDI outside the EU ETS), our estimates provide a lower bound of the actual effect as these sectors were already over-allocated of permits even in the first two phases.

[Figure 4 about here]

While no differential effect is visible, on average, for sectors deemed to be exposed to leakage, we dig deeper into the 'leakage' definition and look at those sectors that were exempted from auctioning as being particularly trade intensive (i.e. trade criterion, see section 3.1), no matter their emission intensity. Out of 294 ETS firms, 90 belong to these sectors (31 percent). Results are reported in Table 8.[19] Results point to a significant and positive effect in the second phase (2008-2010) of the EU ETS for firms belonging to these trade-intensive sectors when looking at FDI directed towards

[16] Table 11 in Appendix A reports the results of the corresponding selection equations while Table 15 in Appendix B reports results for outwards FDI towards EU ETS countries.

[17] No firm belongs to sectors that satisfy both the 'trade intensity' and 'emission intensity' sufficient criteria. 21 firms belong to sectors that satisfy the 'emission intensity' sufficient criterion (none of which also satisfy the 'intermediate trade intensity' criterion). These firms operate in the Cement (10 firms, NACE Rev 1.1 code 2651) and Lime (11 firms, NACE Rev 1.1 code 2652) industries. 91 firms belong to sectors that satisfy the 'trade intensity' sufficient criterion (34 of which also satisfy the 'intermediate emission intensity' criterion). 83 firms belong to sectors that satisfy both the 'intermediate emission intensity' and 'intermediate trade intensity' criteria. The small number of firms that satisfy the 'emission intensity' sufficient criterion does not allow to provide consistent estimates on the differential effect of the EU ETS on this group of firms.

[18] It should be noted, however, that the observed systematic difference between allocated and verified emissions may reflect over-abatement of emissions in these sectors rather than over-allocation of permits.

[19] Table 12 in Appendix A reports the results of the corresponding selection equations while Table 16 in Appendix B reports results for outward FDI towards EU ETS countries.

countries not included in the EU ETS while, in the richer specification (last column of Table 8) we even find a negative effect for EU ETS firms not belonging to these sectors (i.e. they reduced their outward FDI towards non-EU ETS countries). The magnitude of the effect for trade-exposed sectors is, in all specifications, quite big and coefficients are always significant at 1% level.[20] A possible reason for such results is that firms belonging to sectors more exposed to international competition are unable to load costs on their customers (pass-through), therefore they may be induced to "escape" from the home country to avoid domestic regulation. Another possible explanation is that sectors more exposed to trade may also be those that are more prone to invest abroad. Indeed, firms belonging to these sectors are also those that may have already entered foreign markets through exports. Therefore, to avoid the compliance costs imposed by the environmental regulation, they may prefer to acquire or build a new plant in another country rather than produce at home and then export goods. This may happen because the total cost of producing at home in presence of the EU ETS (cost of export and production cost, which includes the cost of complying with the EU ETS) may be greater than the cost of producing abroad (cost of FDI and production cost abroad, that does not include the cost of complying with the EU ETS).

[Table 8 about here]

This effect turns out to be more diluted when we also include in the 'leakage-exposed' category those firms in sectors with a moderate level of trade intensity (non-EU trade intensity between 10% and 30%) coupled with moderate costs of implementation (between 5% and 30% of gross value added) (Table 9).[21] Out of 294 firms, 195 fall in this category (66 percent). In this case, while no effect is found for investment in all foreign countries, the effect turns to be positive as in the previous regressions for those firms investing in non EU ETS countries in the second phase. The effect throughout all specifications is always significant but at 10% or 5% level. A positive effect is also detected when the dummy controlling for the first phase is interacted with leakage sectors: this stands for the fact that - leaving the ETS issue aside - firms in those sectors are increasingly willing to go abroad.

[Table 9 about here]

4.2 Robustness checks

In this section we present some robustness checks we have performed with respect to our baseline estimates. The first one regards the algorithm we use to match EU ETS firms to similar control based on the propensity score. As an alternative to nearest neighbour(s) matching, we here apply kernel matching, according to which the weight

[20] In the specification of column 5 of Table 8 the effect in the second phase for firms in trade-intensive sectors is 0.479 (0.845-0.366) log points, which corresponds to a predicted increase of about 61 percent when compared to untreated firms. The net effect for these is even higher, being equal to 0.583 (1.089-0.506) log points, which corresponds to a predicted increase of 79 percent.

[21] Table 13 in Appendix A reports the results of the corresponding selection equations while Table 17 in Appendix B reports results for outward FDI towards EU ETS countries.

attributed to each matched control firm is a decreasing nonlinear function of the distance in terms of propensity score. We apply this criterion as the high amount of zeros in the dependent variable may result (accidentally) in a selection of matched firms that provides very little information (many zeros). Using kernel matching more information is retained even though at the cost of potentially reducing the similarity of the matched sample. It should be noted, however, that matching based on kernel still results in good 'balancing properties' of the matching. Results are reported in Appendix C (Table 18, Table 19, Table 20 and Table 21). All our findings discussed in section 4.1 are confirmed in terms of statistical significance and magnitude of the effects. In particular, the differential effect for firms in leakage-exposed EU ETS sectors is detected only for trade-exposed sectors and only in the second phase of the EU ETS.

Secondly, in all our estimates we used pooled Heckman estimator to account for the selection issue explained above. As a robustness check, we follow Semykina and Wooldridge (2010) and apply an estimator that takes into account the panel dimension of the dataset (i.e. unobserved heterogeneity) and the potentially time-varying nature of the selection bias. Semykina and Wooldridge (2010) extend Wooldridge (1995) by considering possible selection bias in presence of variables correlated with idiosyncratic error. The estimator they build is valid also when arbitrary correlation between unobserved heterogeneity and explanatory variable is present in the data. In summary, Semykina and Wooldridge (2010) propose to estimate a year-by-year selection equation, extract period-specific Mills' ratios and interact them with time dummies in the main specification estimated on the 'selected' sample. This latter estimate should also include individual averages of time-varying variables to account for unobserved heterogeneity (Mundlak-like correction).

We also compare these results based on Semykina and Wooldridge (2010) with pooled estimates on the sub-sample of firms with one or more subsidiaries ('selected' sample): in presence of selection bias, however, these estimates should be biased. Results confirm that selection is an issue similarly to the pooled estimator (the Mills' ratio and its interactions with time dummies are always jointly significant). All our findings (Table 22, Table 23, Table 24 and Table 25 in Appendix D) are confirmed in terms of magnitude and statistical significance. Moreover, also pooled-OLS results, despite being affected by selection bias, go in the direction of confirming our baseline findings.

5 Conclusions

The issue of carbon leakage has become widely discussed in the lively debate about climate change as it represents a recurrent threat that can hinder the effectiveness of environmental regulation. As GHG emissions are a global source of pollution the possibility that some firms "escape" environmental regulation by relocating abroad can result in an overall weakening of the effectiveness of mitigation policies. To examine this issue, our research deals with the role played by the EU ETS, the main policy instrument adopted by the EU in the last decade to address climate change. In particular, we have analysed whether the EU ETS may have influenced outflows FDI of Italian firms, especially towards countries that are not subject to this environmental regulation. The period we have analyzed with data coming from the AIDA database goes from 2002 to 2010. In the empirical analysis we considered three different ETS phases: the pre-treatment phase (2002-2004), the pilot phase (2005-2007) and the first commitment

period (2008-2012). Following the approach of other papers, we first had to find a suitable counterfactual for our empirical analysis. We therefore employed the propensity score matching to identify a proper control group.

After this step, we employed a difference-in-differences empirical approach while considering possible selection bias through the use of the Heckman regression method. We indeed found that our data were affected by selection bias due to the way the dataset was built. We run regressions according to the different criteria used to classify sectors at risk of carbon leakage. Our main findings suggest that the amount of foreign affiliates abroad has not increased, on average, for firms covered by the EU ETS. However, when considering the sectors that are more exposed to carbon leakage, especially the ones classified according to the "trade" criterion, we find that the positive effect of the EU ETS on outward FDI (towards countries not covered by the EU ETS) is particularly large, while it turns out to be insignificant for the other sectors. One possible reason is that firms that are part of sectors more exposed to trade have to remain competitive on both domestic and international markets to survive. Therefore, rather than sustaining higher compliance costs by continuing to produce at home, they may prefer to adopt the strategy of investing abroad through FDI. Acting in this way, and specifically by investing in ETS-free countries, these firms can continue to be competitive on the market. A still positive but less significant effect is detected when another criterion is used to classify sectors (that is, a moderate level of trade intensity together with moderate compliance costs). This effect remains relevant for those firms investing in countries not covered by EU ETS.

As highlighted in the paper, assessing the effect of EU ETS in an aggregate manner can hide important effects which are displayed by some sectors. We find confirmation that some of them, and in particular those more exposed to carbon leakage, are more likely to relocate their production in countries not subject to the same environmental regulation. We also found confirmation that the criteria used to classify different sectors matter and that the FDI effect of the EU ETS in sectors more exposed to international trade differs from that in sectors belonging to other categories.

Finally, we would like to emphasise that the existence of idiosyncratic features obviously limits the possibility to extend the results emerging for Italy in the present study to other countries. In our opinion, however, the Italian experience can provide interesting insights on the FDI effects of the EU ETS that may be of help to identifying general trends that can apply also to other national contexts. It would be desirable that similar analyses were performed for other countries in the future in order to identify whether and how the FDI of different countries subject to the EU ETS react differently to the same regulation.

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Tables and figures

Table 1 – Firms by industry, region and size class

Industry	Total firms	of which ETS	Share ETS over tot firms
DA	4819	56	0.0118
DB	6160	20	0.0032
DD	1932	2	0.0010
DE	4588	72	0.0170
DF	259	7	0.0270
DG	2362	26	0.0114
DH	3640	9	0.0027
DI	3676	51	0.0152
DJ	12848	29	0.0023
DK	9031	9	0.0010
DL	3734	3	0.0008
DM	1472	8	0.0054
DN	4487	2	0.0004
Region	**Total firms**	**of which ETS**	**Share ETS**
Centro	8816	52	0.006
Nord	37914	186	0.005
Sud	12278	56	0.005
Size class	**Total firms**	**of which ETS**	**Share ETS**
1-49	50296	69	0.001
50-249	7646	116	0.016
250+	1066	109	0.111
Total	59008	294	0.005

Table 2 – Estimate of the propensity score

	Pr(ETS=1)
Has ETS subs	-0.244**
	(0.115)
Has non-ETS subs	0.203*
	(0.120)
# ETS subs	-0.00388
	(0.0160)
# Non-ETS subs	-0.00148
	(0.0229)
Age	0.00239
	(0.00172)
log(K/L)	0.529***
	(0.0351)
log(L)	0.522***
	(0.0914)
log(L) squared	0.00776
	(0.00961)
Dummy leakage sectors (trade)	-0.319***
	(0.0862)
Dummy leakage sectors (emissions)	0.859***
	(0.190)
Dummy leakage sectors (any criteria)	1.419***
	(0.103)
Chi2	2024.0
pseudo R sq	0.5241
N	59008

Probit model. Pre-ETS period. Standard errors in parenthesis. * p<0.1, ** p<0.05, *** p<0.01. Other control variables: 2-digit Nace dummies, macro-region (NUTS1) dummies.

Table 3 – Balancing properties of the control sample based on propensity score (10 nearest neighbours with 0.01 caliper)

		ETS	no-ETS	t-test	p-value
Has ETS subs	Not matched	0.239	0.027	22.74	0
	Matched	0.226	0.225	0.04	0.972
Has Non-ETS subs	Not matched	0.194	0.017	23.83	0
	Matched	0.188	0.209	-0.63	0.53
# ETS subs	Not matched	1.958	0.064	31.15	0
	Matched	1.462	1.367	0.18	0.855
# Non-ETS subs	Not matched	1.042	0.039	25.75	0
	Matched	0.832	0.844	-0.04	0.97
Age	Not matched	28.851	17.147	16.57	0
	Matched	28.185	29.102	-0.52	0.601
log(K/L)	Not matched	12.182	10.425	22.17	0
	Matched	12.123	12.203	-0.89	0.374
log(L)	Not matched	5.174	2.776	36.86	0
	Matched	5.127	5.124	0.02	0.983
Dummy leakage sectors (trade)	Not matched	0.295	0.434	-4.93	0
	Matched	0.308	0.275	0.89	0.372
Dummy leakage sectors (emissions)	Not matched	0.068	0.002	21.84	0
	Matched	0.055	0.046	0.47	0.637
Dummy leakage sectors (any criteria)	Not matched	0.832	0.518	11.01	0
	Matched	0.825	0.814	0.37	0.712
Has IT subs	Not matched	0.445	0.389	1.77	0.077
	Matched	0.445	0.525	-1.93	0.055
# IT subs	Not matched	2.277	1.568	2.74	0.006
	Matched	2.277	2.541	-0.63	0.532
log(VA/L)	Not matched	11.195	11.081	2.28	0.023
	Matched	11.195	11.211	-0.26	0.796
log(wages)	Not matched	10.545	10.504	1.00	0.316
	Matched	10.545	10.610	-1.15	0.252

Figure 1 - Distribution of the propensity score for ETS and matched non-ETS firms (dots: off-support ETS firms)

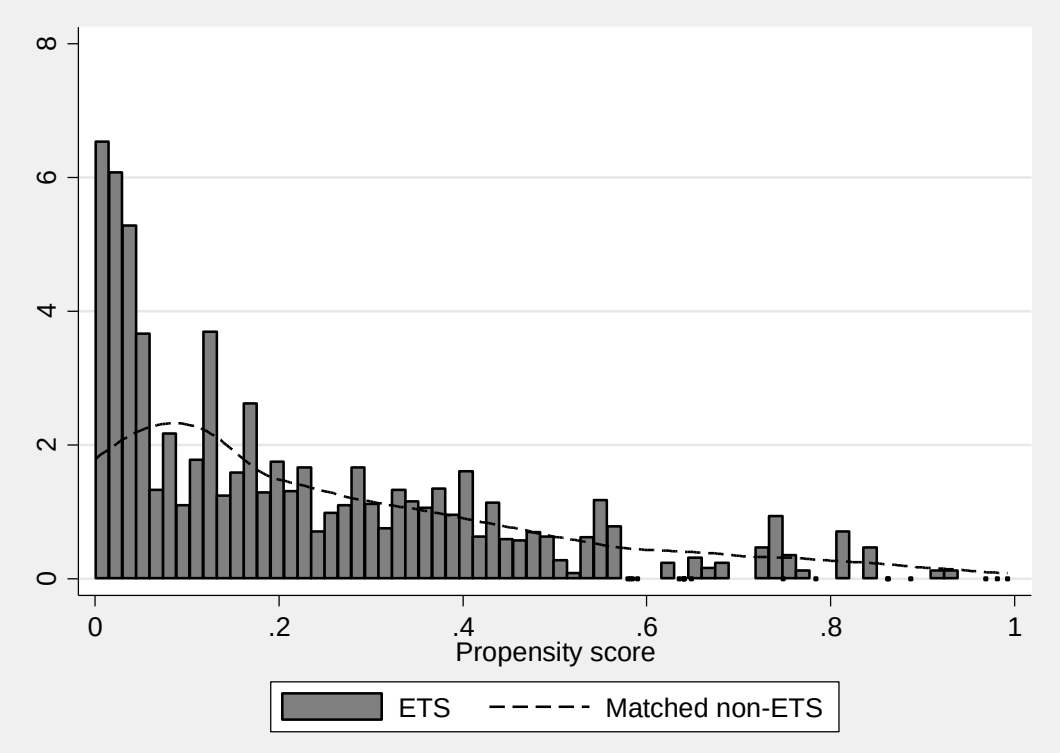


Table 4 – Test of pre-treatment common trend in total financial assets

Sample	F	p-value	N
All - unmatched	0.63	0.6767	51010
All - matched	0.77	0.5738	6125
Leakage - unmatched	0.44	0.8188	16877
Leakage - matched	0.96	0.4423	1504
Non-leakage - unmatched	0.54	0.7496	34133
Non-leakage - matched	0.49	0.7815	4621

Test on interaction between year dummies and treatment status based on fixed effect regressions. Dependent variable: log of financial assets. Year dummies included. Standard errors clustered by firm.

Figure 2 - Trends in average financial assets (in million euros)

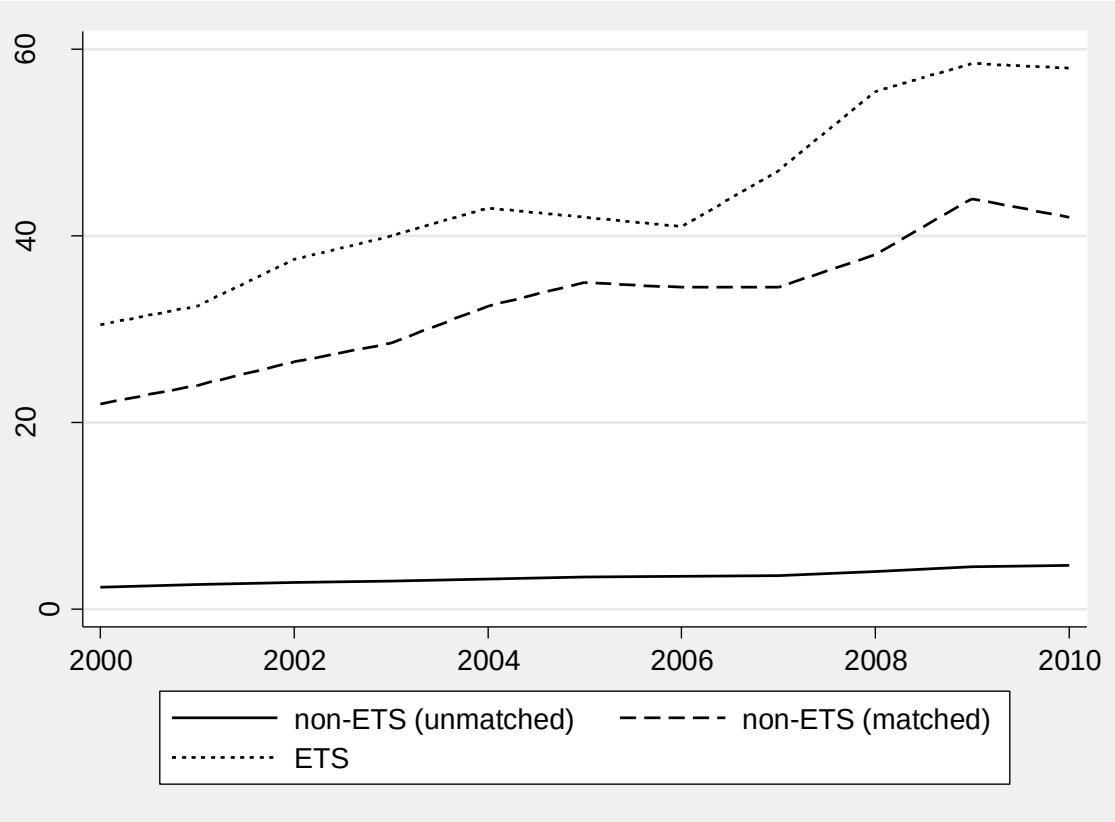


Figure 3 - Trends in average financial assets (2000=1)

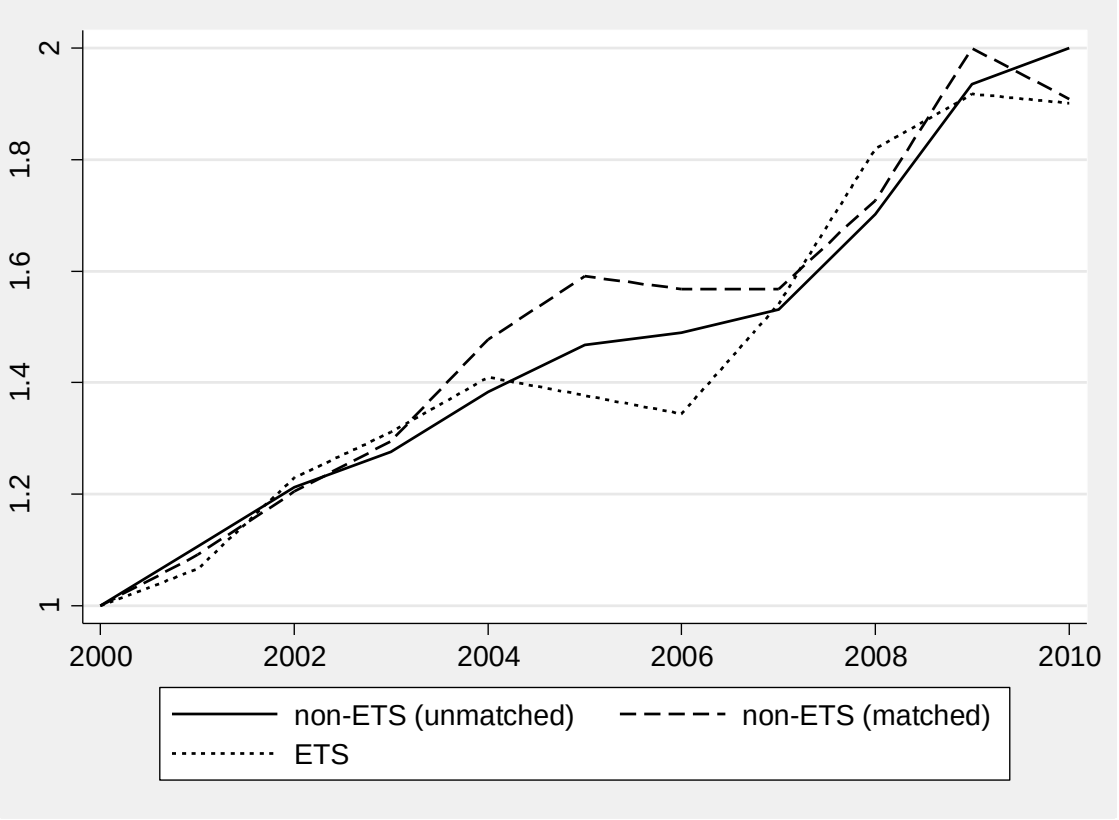


Table 5 – Number of subsidiaries and share of firms with subsidiaries

	# of foreign subsidiaries			# of foreign subsidiaries in non-ETS countries		
	Non-ETS	Non-ETS (matched)	ETS	Non-ETS	Non-ETS (matched)	ETS
Pre-ETS	0.1032	2.2108	2.2945	0.0394	0.8440	0.8322
ETS phase I	0.0964	1.9992	2.2089	0.0362	0.8319	0.9623
ETS phase II	0.1851	2.5762	2.2123	0.0899	1.2862	1.1164
	Share with foreign subsidiaries			Share with foreign subsidiaries in non-ETS countries		
	Non-ETS	Non-ETS (matched)	ETS	Non-ETS	Non-ETS (matched)	ETS
Pre-ETS	0.0340	0.2823	0.2808	0.0166	0.2091	0.1884
ETS phase I	0.0330	0.3003	0.2808	0.0151	0.1918	0.1644
ETS phase II	0.0646	0.3296	0.3048	0.0380	0.2532	0.2123

Table 6 – Baseline estimates

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.141	-0.169	-0.145	-0.133	-0.194	-0.164
	(0.160)	(0.160)	(0.163)	(0.159)	(0.151)	(0.160)
Phase I	-0.377**	0.458	0.638	-0.170	0.826	0.830
	(0.184)	(0.879)	(0.843)	(0.177)	(0.770)	(0.808)
Phase II	-0.359	1.351	1.711	-0.415	1.592	1.610
	(0.316)	(1.763)	(1.698)	(0.316)	(1.527)	(1.610)
ETS x Phase I	0.0725	0.0921	0.0699	0.0449	0.0950	0.0673
	(0.142)	(0.144)	(0.145)	(0.161)	(0.162)	(0.166)
ETS x Phase II	-0.0515	-0.0215	-0.0511	0.0146	0.0532	0.0188
	(0.143)	(0.141)	(0.144)	(0.152)	(0.147)	(0.157)
Size (t=0)	-0.0210	0.0113	0.0260	-0.0271	0.0166	0.0316
	(0.0890)	(0.103)	(0.102)	(0.0916)	(0.0990)	(0.0973)
Capital intensity (t=0)		0.0258	0.00110		0.103	0.0945
		(0.149)	(0.145)		(0.139)	(0.140)
Wages (t=0)		0.429***	0.477***		0.230**	0.240**
		(0.151)	(0.140)		(0.109)	(0.119)
Size (t=0) x time trend	0.0364	0.0370	0.0292	0.0541**	0.0419	0.0361
	(0.0257)	(0.0285)	(0.0285)	(0.0257)	(0.0264)	(0.0263)
Capital intensity (t=0) x time trend		0.00557	0.0174		-0.0367	-0.0324
		(0.0469)	(0.0459)		(0.0441)	(0.0439)
Wages (t=0) x time trend		-0.0862	-0.110**		-0.0454	-0.0491
		(0.0545)	(0.0453)		(0.0309)	(0.0374)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.689	-0.668	-0.669	-0.618	-0.616	-0.606
Sigma	1.181	1.145	1.142	0.997	0.983	0.971
Lambda	-0.814	-0.764	-0.764	-0.616	-0.605	-0.588
Chi2 test of independence	47.85***	34.36***	32.85***	30.11***	24.30***	21.68***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 7 – Separate effect for sectors exempted from auctioning (all criteria)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.260	-0.225	-0.196	-0.0424	-0.0629	-0.108
	(0.297)	(0.306)	(0.320)	(0.288)	(0.291)	(0.300)
Phase I	-0.650**	0.119	0.221	-0.488*	0.576	0.371
	(0.300)	(0.913)	(0.869)	(0.282)	(0.774)	(0.816)
Phase II	-0.559*	1.058	1.280	-0.280	1.923	1.580
	(0.339)	(1.782)	(1.722)	(0.352)	(1.510)	(1.604)
ETS x Phase I	0.383	0.417	0.392	0.203	0.296	0.352
	(0.334)	(0.334)	(0.343)	(0.339)	(0.332)	(0.346)
ETS x Phase II	0.317	0.344	0.297	-0.0615	-0.103	-0.0186
	(0.291)	(0.297)	(0.321)	(0.299)	(0.300)	(0.320)
Leakage sectors	-0.279	-0.249	-0.279	-0.0641	-0.0279	-0.177
	(0.248)	(0.255)	(0.275)	(0.263)	(0.270)	(0.294)
Leakage sectors x ETS	0.117	0.0359	0.0237	-0.163	-0.217	-0.145
	(0.352)	(0.361)	(0.380)	(0.345)	(0.350)	(0.370)
Leakage sectors x Phase I	0.350	0.363	0.395	0.432	0.440	0.592*
	(0.292)	(0.291)	(0.298)	(0.275)	(0.280)	(0.310)
Leakage sectors x Phase II	0.275	0.248	0.290	-0.0790	-0.147	0.0962
	(0.183)	(0.190)	(0.255)	(0.236)	(0.241)	(0.332)
Leakage sectors x ETS x Phase I	-0.398	-0.418	-0.410	-0.171	-0.237	-0.321
	(0.374)	(0.375)	(0.383)	(0.379)	(0.375)	(0.389)
Leakage sectors x ETS x Phase II	-0.473	-0.471	-0.442	0.0956	0.200	0.0813
	(0.332)	(0.336)	(0.367)	(0.349)	(0.349)	(0.380)
Size (t=0)	-0.00435	0.0299	0.0400	0.00225	0.0505	0.0652
	(0.0864)	(0.103)	(0.101)	(0.0883)	(0.0961)	(0.0927)
Capital intensity (t=0)		0.0219	-0.00800		0.104	0.0833
		(0.149)	(0.147)		(0.142)	(0.145)
Wages (t=0)		0.421***	0.468***		0.245**	0.256**
		(0.153)	(0.140)		(0.109)	(0.117)
Size (t=0) x time trend	0.0345	0.0343	0.0282	0.0492*	0.0351	0.0302
	(0.0254)	(0.0282)	(0.0285)	(0.0252)	(0.0258)	(0.0251)
Capital intensity (t=0) x time trend		0.00709	0.0211		-0.0371	-0.0265
		(0.0463)	(0.0460)		(0.0435)	(0.0442)
Wages (t=0) x time trend		-0.0821	-0.105**		-0.0504*	-0.0538
		(0.0542)	(0.0447)		(0.0301)	(0.0357)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.665	-0.644	-0.649	-0.582	-0.586	-0.576
Sigma	1.158	1.123	1.121	0.972	0.961	0.949
Lambda	-0.770	-0.723	-0.727	-0.566	-0.563	-0.546
Chi2 test of independence	42.34***	28.48***	27.46***	23.44***	19.17***	17.16***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 8 – Separate effect for sectors exempted from auctioning (trade criterion)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.0540	0.0535	0.113	0.237	0.191	0.274
	(0.230)	(0.231)	(0.239)	(0.255)	(0.248)	(0.263)
Phase I	-0.338*	0.488	0.677	-0.0521	1.017	0.984
	(0.202)	(0.887)	(0.841)	(0.192)	(0.759)	(0.779)
Phase II	-0.213	1.492	1.869	-0.163	2.001	1.946
	(0.313)	(1.777)	(1.697)	(0.305)	(1.492)	(1.529)
ETS x Phase I	0.0648	0.0724	0.0155	-0.129	-0.0641	-0.149
	(0.184)	(0.188)	(0.192)	(0.236)	(0.236)	(0.244)
ETS x Phase II	-0.188	-0.142	-0.245	-0.389*	-0.366	-0.506**
	(0.198)	(0.197)	(0.214)	(0.235)	(0.233)	(0.256)
Leakage sectors	-0.265	-0.286	-0.279	-0.142	-0.144	-0.140
	(0.207)	(0.206)	(0.211)	(0.209)	(0.212)	(0.228)
Leakage sectors x ETS	-0.405	-0.453	-0.544	-0.711**	-0.727**	-0.850**
	(0.329)	(0.326)	(0.335)	(0.328)	(0.328)	(0.341)
Leakage sectors x Phase I	0.0874	0.115	0.103	-0.0713	-0.0601	-0.0632
	(0.178)	(0.176)	(0.178)	(0.183)	(0.184)	(0.197)
Leakage sectors x Phase II	-0.0501	-0.0417	-0.0637	-0.179	-0.190	-0.195
	(0.150)	(0.148)	(0.186)	(0.154)	(0.159)	(0.214)
Leakage sectors x ETS x Phase I	-0.0304	-0.0167	0.0716	0.323	0.294	0.419
	(0.270)	(0.269)	(0.274)	(0.307)	(0.306)	(0.307)
Leakage sectors x ETS x Phase II	0.306	0.261	0.449	0.822***	0.845***	1.089***
	(0.288)	(0.287)	(0.310)	(0.305)	(0.315)	(0.332)
Size (t=0)	0.0155	0.0510	0.0700	0.0209	0.0654	0.0900
	(0.0871)	(0.103)	(0.101)	(0.0856)	(0.0927)	(0.0922)
Capital intensity (t=0)		0.0166	-0.0103		0.110	0.0886
		(0.143)	(0.138)		(0.134)	(0.132)
Wages (t=0)		0.436***	0.481***		0.227**	0.235**
		(0.150)	(0.135)		(0.102)	(0.107)
Size (t=0) x time trend	0.0263	0.0268	0.0176	0.0392	0.0264	0.0172
	(0.0258)	(0.0290)	(0.0291)	(0.0249)	(0.0260)	(0.0255)
Capital intensity (t=0) x time trend		0.00573	0.0191		-0.0440	-0.0318
		(0.0471)	(0.0460)		(0.0454)	(0.0437)
Wages (t=0) x time trend		-0.0862	-0.108**		-0.0439	-0.0459
		(0.0544)	(0.0437)		(0.0290)	(0.0335)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.693	-0.666	-0.665	-0.617	-0.611	-0.595
Sigma	1.172	1.132	1.127	0.982	0.967	0.949
Lambda	-0.812	-0.754	-0.749	-0.607	-0.592	-0.565
Chi2 test of independence	45.11***	31.92***	29.66***	27.93***	21.95***	18.32***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

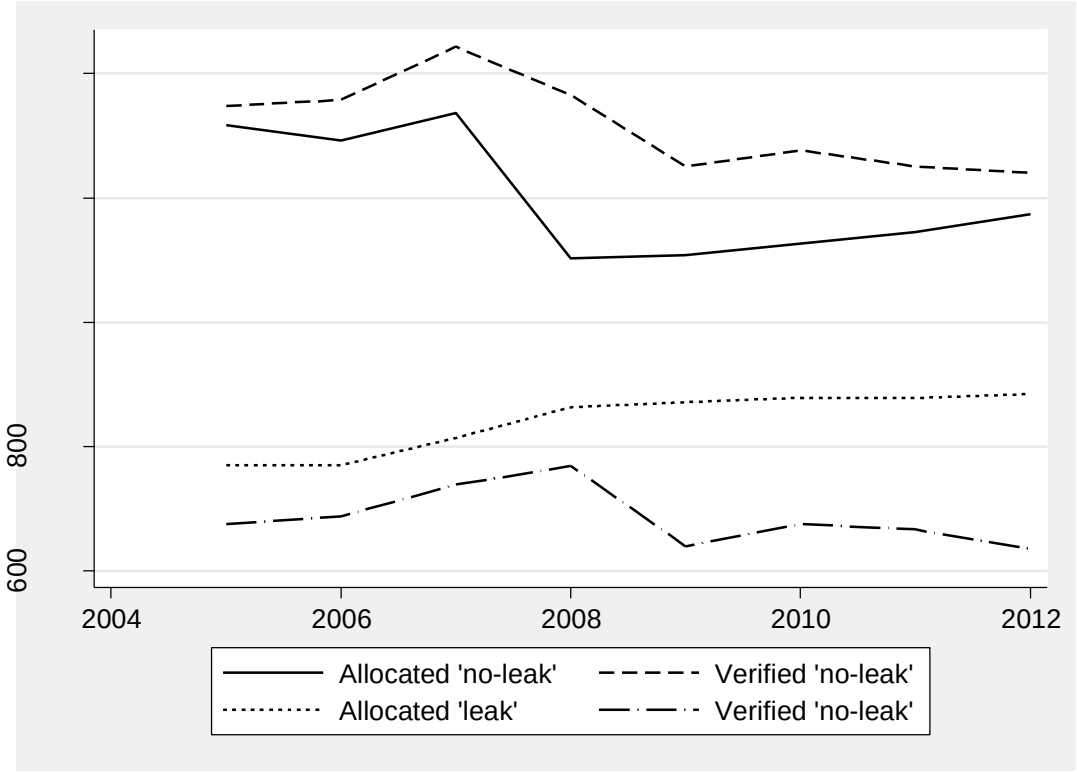
Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 9 – Separate effect for sectors exempted from auctioning (trade >10%)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.115	-0.126	-0.0723	0.0118	-0.0529	0.00522
	(0.292)	(0.286)	(0.293)	(0.310)	(0.292)	(0.296)
Phase I	-0.539**	0.195	0.275	-0.475**	0.530	0.359
	(0.222)	(0.870)	(0.783)	(0.234)	(0.705)	(0.680)
Phase II	-0.490	1.084	1.247	-0.391	1.670	1.346
	(0.309)	(1.739)	(1.589)	(0.313)	(1.398)	(1.359)
ETS x Phase I	0.224	0.266	0.216	0.0990	0.205	0.152
	(0.253)	(0.253)	(0.259)	(0.292)	(0.288)	(0.295)
ETS x Phase II	0.0141	0.000446	-0.0874	-0.362	-0.339	-0.417
	(0.281)	(0.275)	(0.286)	(0.302)	(0.285)	(0.292)
Leakage sectors	-0.354	-0.335	-0.355	-0.424*	-0.430*	-0.487*
	(0.226)	(0.227)	(0.239)	(0.235)	(0.237)	(0.251)
Leakage sectors x ETS	-0.0769	-0.102	-0.152	-0.288	-0.287	-0.357
	(0.340)	(0.340)	(0.346)	(0.343)	(0.331)	(0.328)
Leakage sectors x Phase I	0.264	0.287	0.306	0.457*	0.483**	0.542**
	(0.220)	(0.220)	(0.217)	(0.234)	(0.240)	(0.250)
Leakage sectors x Phase II	0.254	0.200	0.232	0.0294	0.0225	0.137
	(0.182)	(0.180)	(0.208)	(0.202)	(0.203)	(0.244)
Leakage sectors x ETS x Phase I	-0.228	-0.262	-0.217	-0.0694	-0.162	-0.101
	(0.311)	(0.311)	(0.313)	(0.343)	(0.341)	(0.340)
Leakage sectors x ETS x Phase II	-0.0733	-0.0106	0.0834	0.587*	0.620*	0.731**
	(0.323)	(0.319)	(0.330)	(0.350)	(0.336)	(0.334)
Size (t=0)	-0.00360	0.0277	0.0387	-0.00261	0.0374	0.0566
	(0.0875)	(0.104)	(0.102)	(0.0849)	(0.0924)	(0.0907)
Capital intensity (t=0)		0.0000663	-0.0380		0.0673	0.0296
		(0.143)	(0.137)		(0.121)	(0.115)
Wages (t=0)		0.416***	0.462***		0.235**	0.246**
		(0.147)	(0.132)		(0.101)	(0.105)
Size (t=0) x time trend	0.0327	0.0333	0.0275	0.0504**	0.0370	0.0309
	(0.0257)	(0.0286)	(0.0286)	(0.0245)	(0.0255)	(0.0243)
Capital intensity (t=0) x time trend		0.00921	0.0278		-0.0353	-0.0150
		(0.0462)	(0.0445)		(0.0421)	(0.0389)
Wages (t=0) x time trend		-0.0823	-0.105**		-0.0487*	-0.0517
		(0.0539)	(0.0430)		(0.0289)	(0.0331)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.677	-0.654	-0.655	-0.601	-0.613	-0.595
Sigma	1.164	1.129	1.125	0.971	0.965	0.946
Lambda	-0.788	-0.739	-0.737	-0.584	-0.591	-0.563
Chi2 test of independence	41.71***	28.62***	26.77***	22.97***	19.90***	16.13***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Figure 4 - Trends in allocated and verified emissions for 'leakage' and 'non-leakage' sectors (in billion tonnes of CO2-equivalent - all EU ETS plants. Source. European Commission)



Appendix A - Results for selection equations

Table 10 – Baseline estimates (selection equation)

Selection (Has subs=1)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.0510	0.0167	0.0159	-0.0996	-0.121	-0.128
	(0.121)	(0.125)	(0.124)	(0.128)	(0.131)	(0.131)
Phase I	0.336**	0.0884	-0.149	-0.0419	-0.0272	-0.364
	(0.134)	(0.351)	(0.455)	(0.143)	(0.406)	(0.519)
Phase II	0.717***	0.187	-0.297	0.319	0.348	-0.330
	(0.239)	(0.706)	(0.919)	(0.241)	(0.810)	(1.049)
ETS x Phase I	-0.0809	-0.0511	-0.0503	-0.0677	-0.0820	-0.0762
	(0.105)	(0.108)	(0.107)	(0.145)	(0.151)	(0.152)
ETS x Phase II	-0.146	-0.115	-0.114	-0.120	-0.108	-0.101
	(0.0985)	(0.102)	(0.0998)	(0.113)	(0.118)	(0.116)
Size (t=0)	0.519***	0.543***	0.534***	0.356***	0.380***	0.362***
	(0.0656)	(0.0756)	(0.0772)	(0.0624)	(0.0714)	(0.0756)
Capital intensity (t=0)		0.120	0.0930		0.0595	0.0412
		(0.102)	(0.0969)		(0.104)	(0.106)
Wages (t=0)		-0.00268	-0.00258		0.129	0.120
		(0.0851)	(0.0924)		(0.131)	(0.131)
Size (t=0) x time trend	-0.0434*	-0.0394*	-0.0341	-0.0112	-0.00948	-0.000103
	(0.0228)	(0.0238)	(0.0260)	(0.0221)	(0.0232)	(0.0275)
Capital intensity (t=0) x time trend		0.00115	0.0155		0.0135	0.0237
		(0.0222)	(0.0243)		(0.0250)	(0.0300)
Wages (t=0) x time trend		0.0224	0.0217		-0.0174	-0.0135
		(0.0220)	(0.0270)		(0.0299)	(0.0345)
Dummy for IT subs	0.734***	0.726***	0.738***	0.618***	0.610***	0.620***
	(0.118)	(0.129)	(0.128)	(0.130)	(0.139)	(0.141)
Dummy for IT subs x Phase I	0.0530	0.00843	-0.00394	0.0954	0.0792	0.0696
	(0.113)	(0.121)	(0.121)	(0.144)	(0.155)	(0.155)
Dummy for IT subs x Phase II	-0.0331	-0.0732	-0.0881	0.0279	0.0246	0.00896
	(0.123)	(0.134)	(0.135)	(0.134)	(0.145)	(0.146)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.689	-0.668	-0.669	-0.618	-0.616	-0.606
Sigma	1.181	1.145	1.142	0.997	0.983	0.971
Lambda	-0.814	-0.764	-0.764	-0.616	-0.605	-0.588
Chi2 test of independence	47.85***	34.36***	32.85***	30.11***	24.30***	21.68***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 11 – Separate effect for sectors exempted from auctioning (all criteria, selection equation)

Selection (Has subs=1)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.322	0.331	0.322	0.229	0.290	0.344
	(0.267)	(0.283)	(0.281)	(0.261)	(0.273)	(0.265)
Phase I	0.610***	0.480	0.324	0.444*	0.546	0.412
	(0.214)	(0.360)	(0.432)	(0.263)	(0.439)	(0.527)
Phase II	0.958***	0.643	0.320	0.617**	0.784	0.503
	(0.273)	(0.669)	(0.892)	(0.305)	(0.801)	(1.060)
ETS x Phase I	-0.189	-0.191	-0.182	-0.365	-0.435	-0.489
	(0.285)	(0.296)	(0.294)	(0.355)	(0.363)	(0.352)
ETS x Phase II	-0.305	-0.313	-0.293	-0.365	-0.347	-0.459
	(0.296)	(0.310)	(0.311)	(0.343)	(0.361)	(0.317)
Leakage sectors	0.118	0.248	0.268	0.108	0.212	0.329
	(0.226)	(0.243)	(0.251)	(0.234)	(0.253)	(0.267)
Leakage sectors x ETS	-0.341	-0.389	-0.377	-0.415	-0.510*	-0.577*
	(0.300)	(0.316)	(0.313)	(0.297)	(0.310)	(0.302)
Leakage sectors x Phase I	-0.333	-0.353	-0.369*	-0.571**	-0.587**	-0.700**
	(0.222)	(0.229)	(0.221)	(0.286)	(0.292)	(0.282)
Leakage sectors x Phase II	-0.292	-0.304	-0.340	-0.339	-0.325	-0.551**
	(0.223)	(0.231)	(0.230)	(0.268)	(0.279)	(0.267)
Leakage sectors x ETS x Phase I	0.120	0.158	0.148	0.323	0.394	0.461
	(0.307)	(0.318)	(0.314)	(0.389)	(0.399)	(0.388)
Leakage sectors x ETS x Phase II	0.200	0.245	0.218	0.298	0.289	0.424
	(0.312)	(0.326)	(0.326)	(0.359)	(0.376)	(0.333)
Size (t=0)	0.512***	0.541***	0.541***	0.355***	0.380***	0.370***
	(0.0661)	(0.0773)	(0.0792)	(0.0632)	(0.0736)	(0.0783)
Capital intensity (t=0)		0.126	0.105		0.0549	0.0488
		(0.103)	(0.100)		(0.108)	(0.111)
Wages (t=0)		0.00375	0.00231		0.134	0.124
		(0.0852)	(0.0923)		(0.134)	(0.133)
Size (t=0) x time trend	-0.0449**	-0.0419*	-0.0413	-0.0134	-0.0127	-0.00705
	(0.0221)	(0.0233)	(0.0255)	(0.0215)	(0.0227)	(0.0269)
Capital intensity (t=0) x time trend		-0.00271	0.00803		0.0107	0.0146
		(0.0216)	(0.0246)		(0.0248)	(0.0306)
Wages (t=0) x time trend		0.0179	0.0181		-0.0207	-0.0161
		(0.0210)	(0.0259)		(0.0300)	(0.0340)
Dummy for IT subs	0.712***	0.712***	0.725***	0.582***	0.578***	0.594***
	(0.120)	(0.129)	(0.129)	(0.132)	(0.140)	(0.143)
Dummy for IT subs x Phase I	0.0600	0.0161	0.00261	0.101	0.0894	0.0739
	(0.112)	(0.119)	(0.119)	(0.146)	(0.155)	(0.156)
Dummy for IT subs x Phase II	-0.0112	-0.0555	-0.0683	0.0478	0.0464	0.0308
	(0.123)	(0.132)	(0.133)	(0.138)	(0.148)	(0.149)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.665	-0.644	-0.649	-0.582	-0.586	-0.576
Sigma	1.158	1.123	1.121	0.972	0.961	0.949
Lambda	-0.770	-0.723	-0.727	-0.566	-0.563	-0.546
Chi2 test of independence	42.34***	28.48***	27.46***	23.44***	19.17***	17.16***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 12 – Separate effect for sectors exempted from auctioning (trade criterion, selection equation)

Selection (Has subs=1)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.0536	-0.0215	-0.0349	-0.207	-0.261	-0.276
	(0.154)	(0.161)	(0.161)	(0.168)	(0.174)	(0.172)
Phase I	0.326**	0.111	-0.139	-0.0614	-0.0796	-0.363
	(0.141)	(0.365)	(0.454)	(0.161)	(0.403)	(0.507)
Phase II	0.685***	0.202	-0.303	0.266	0.217	-0.349
	(0.245)	(0.732)	(0.923)	(0.243)	(0.804)	(1.033)
ETS x Phase I	-0.0486	-0.0114	0.00159	0.0395	0.0107	0.0243
	(0.122)	(0.123)	(0.125)	(0.194)	(0.204)	(0.206)
ETS x Phase II	-0.125	-0.0836	-0.0565	-0.0427	-0.0194	0.00369
	(0.118)	(0.123)	(0.129)	(0.148)	(0.158)	(0.158)
Leakage sectors	0.231	0.264	0.249	0.284	0.300	0.275
	(0.169)	(0.168)	(0.175)	(0.181)	(0.184)	(0.193)
Leakage sectors x ETS	-0.0522	0.0527	0.0912	0.194	0.265	0.299
	(0.252)	(0.257)	(0.258)	(0.258)	(0.264)	(0.266)
Leakage sectors x Phase I	-0.0103	-0.0397	-0.0212	-0.0608	-0.0733	-0.0455
	(0.114)	(0.116)	(0.114)	(0.159)	(0.161)	(0.160)
Leakage sectors x Phase II	0.0313	0.0388	0.0702	-0.0699	-0.0599	-0.0112
	(0.108)	(0.110)	(0.120)	(0.105)	(0.108)	(0.131)
Leakage sectors x ETS x Phase I	-0.0804	-0.0883	-0.126	-0.218	-0.176	-0.210
	(0.223)	(0.230)	(0.228)	(0.269)	(0.281)	(0.285)
Leakage sectors x ETS x Phase II	-0.0591	-0.0897	-0.171	-0.154	-0.180	-0.248
	(0.203)	(0.210)	(0.214)	(0.215)	(0.226)	(0.234)
Size (t=0)	0.513***	0.535***	0.526***	0.336***	0.360***	0.348***
	(0.0666)	(0.0770)	(0.0770)	(0.0623)	(0.0731)	(0.0766)
Capital intensity (t=0)		0.134	0.109		0.0711	0.0586
		(0.101)	(0.0962)		(0.103)	(0.105)
Wages (t=0)		-0.0106	-0.0113		0.111	0.108
		(0.0836)	(0.0902)		(0.125)	(0.124)
Size (t=0) x time trend	-0.0418*	-0.0371	-0.0311	-0.00429	-0.00250	0.00418
	(0.0239)	(0.0249)	(0.0259)	(0.0229)	(0.0241)	(0.0275)
Capital intensity (t=0) x time trend		-0.000665	0.0129		0.0125	0.0198
		(0.0221)	(0.0246)		(0.0245)	(0.0295)
Wages (t=0) x time trend		0.0218	0.0215		-0.0127	-0.0116
		(0.0233)	(0.0272)		(0.0292)	(0.0332)
Dummy for IT subs	0.734***	0.727***	0.739***	0.627***	0.620***	0.626***
	(0.118)	(0.130)	(0.130)	(0.132)	(0.140)	(0.143)
Dummy for IT subs x Phase I	0.0581	0.0124	0.000731	0.0935	0.0749	0.0702
	(0.113)	(0.121)	(0.121)	(0.142)	(0.153)	(0.155)
Dummy for IT subs x Phase II	-0.0251	-0.0689	-0.0840	0.0205	0.0156	0.00763
	(0.124)	(0.135)	(0.135)	(0.133)	(0.143)	(0.145)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.693	-0.666	-0.665	-0.617	-0.611	-0.595
Sigma	1.172	1.132	1.127	0.982	0.967	0.949
Lambda	-0.812	-0.754	-0.749	-0.607	-0.592	-0.565
Chi2 test of independence	45.11***	31.92***	29.66***	27.93***	21.95***	18.32***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 13 – Separate effect for sectors exempted from auctioning (trade >10%, selection equation)

Selection (Has subs=1)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.156	0.126	0.103	0.0239	0.0181	0.0286
	(0.194)	(0.203)	(0.203)	(0.198)	(0.206)	(0.203)
Phase I	0.393***	0.224	0.00984	0.155	0.217	-0.0587
	(0.148)	(0.326)	(0.416)	(0.178)	(0.387)	(0.492)
Phase II	0.828***	0.411	-0.0210	0.371	0.471	-0.0872
	(0.225)	(0.650)	(0.872)	(0.238)	(0.752)	(1.014)
ETS x Phase I	-0.0331	-0.0353	-0.0133	-0.0612	-0.104	-0.116
	(0.185)	(0.193)	(0.193)	(0.242)	(0.247)	(0.243)
ETS x Phase II	-0.222	-0.182	-0.138	-0.0485	-0.0355	-0.0587
	(0.198)	(0.206)	(0.211)	(0.230)	(0.239)	(0.225)
Leakage sectors	0.277*	0.316*	0.299*	0.310*	0.328*	0.356**
	(0.159)	(0.165)	(0.165)	(0.169)	(0.176)	(0.177)
Leakage sectors x ETS	-0.156	-0.160	-0.123	-0.174	-0.196	-0.218
	(0.251)	(0.262)	(0.261)	(0.259)	(0.266)	(0.263)
Leakage sectors x Phase I	-0.110	-0.130	-0.113	-0.300	-0.313	-0.341*
	(0.149)	(0.154)	(0.145)	(0.211)	(0.213)	(0.204)
Leakage sectors x Phase II	-0.228	-0.194	-0.165	-0.134	-0.127	-0.179
	(0.155)	(0.160)	(0.154)	(0.170)	(0.173)	(0.153)
Leakage sectors x ETS x Phase I	-0.0848	-0.0341	-0.0678	-0.0395	0.00212	0.0265
	(0.227)	(0.234)	(0.231)	(0.301)	(0.308)	(0.305)
Leakage sectors x ETS x Phase II	0.111	0.0929	0.0233	-0.126	-0.130	-0.0893
	(0.225)	(0.235)	(0.242)	(0.258)	(0.268)	(0.256)
Size (t=0)	0.509***	0.536***	0.532***	0.347***	0.372***	0.359***
	(0.0654)	(0.0755)	(0.0770)	(0.0621)	(0.0716)	(0.0759)
Capital intensity (t=0)		0.136	0.114		0.0694	0.0615
		(0.0996)	(0.0962)		(0.103)	(0.105)
Wages (t=0)		0.00414	0.00316		0.129	0.116
		(0.0849)	(0.0926)		(0.128)	(0.128)
Size (t=0) x time trend	-0.0399*	-0.0368	-0.0341	-0.00799	-0.00697	0.000737
	(0.0232)	(0.0241)	(0.0259)	(0.0223)	(0.0234)	(0.0273)
Capital intensity (t=0) x time trend		-0.00161	0.00985		0.0110	0.0161
		(0.0216)	(0.0246)		(0.0246)	(0.0304)
Wages (t=0) x time trend		0.0197	0.0195		-0.0178	-0.0121
		(0.0215)	(0.0264)		(0.0289)	(0.0339)
Dummy for IT subs	0.739***	0.733***	0.744***	0.613***	0.606***	0.614***
	(0.120)	(0.131)	(0.132)	(0.131)	(0.140)	(0.144)
Dummy for IT subs x Phase I	0.0483	0.00557	-0.00527	0.0811	0.0662	0.0588
	(0.115)	(0.122)	(0.123)	(0.145)	(0.154)	(0.156)
Dummy for IT subs x Phase II	-0.0326	-0.0736	-0.0864	0.0372	0.0376	0.0242
	(0.125)	(0.137)	(0.137)	(0.137)	(0.147)	(0.150)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.677	-0.654	-0.655	-0.601	-0.613	-0.595
Sigma	1.164	1.129	1.125	0.971	0.965	0.946
Lambda	-0.788	-0.739	-0.737	-0.584	-0.591	-0.563
Chi2 test of independence	41.71***	28.62***	26.77***	22.97***	19.90***	16.13***
N censored	3863	3619	3619	4283	4027	4027
N	5097	4827	4827	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Appendix B - Results for subsidiaries in EU ETS countries

Table 14 – Baseline estimates

Intensity (# subs)	ETS	ETS	ETS
ETS	-0.0733	-0.110	-0.0678
	(0.166)	(0.163)	(0.167)
Phase I	-0.488**	0.447	0.722
	(0.195)	(1.060)	(0.982)
Phase II	-0.666*	1.252	1.799
	(0.354)	(2.127)	(1.969)
ETS x Phase I	-0.0873	-0.0406	-0.0823
	(0.130)	(0.133)	(0.133)
ETS x Phase II	0.0648	0.106	0.0300
	(0.158)	(0.154)	(0.156)
Size (t=0)	-0.102	-0.0362	-0.0230
	(0.0898)	(0.107)	(0.109)
Capital intensity (t=0)		0.176	0.169
		(0.175)	(0.170)
Wages (t=0)		0.299**	0.339***
		(0.130)	(0.126)
Size (t=0) x time trend	0.0440	0.0313	0.0266
	(0.0280)	(0.0330)	(0.0325)
Capital intensity (t=0) x time trend		-0.0549	-0.0510
		(0.0592)	(0.0567)
Wages (t=0) x time trend		-0.0196	-0.0392
		(0.0511)	(0.0456)
2-digit Nace dummies	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes
Rho	-0.669	-0.656	-0.656
Sigma	1.060	1.019	1.013
Lambda	-0.709	-0.668	-0.664
Chi2 test of independence	42.00***	29.71***	26.01***
N censored	4114	3861	3861
N	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 15 – Separate effect for sectors exempted from auctioning (all criteria)

Intensity (# subs)	ETS	ETS	ETS
ETS	-0.0834	-0.0397	-0.0674
	(0.291)	(0.306)	(0.327)
Phase I	-0.611***	0.257	0.0204
	(0.224)	(1.104)	(1.038)
Phase II	-0.728**	1.071	0.601
	(0.355)	(2.203)	(2.068)
ETS x Phase I	-0.139	-0.0976	-0.0695
	(0.249)	(0.264)	(0.284)
ETS x Phase II	-0.0757	-0.0564	0.0123
	(0.256)	(0.273)	(0.313)
Leakage sectors	-0.413*	-0.354	-0.619**
	(0.236)	(0.237)	(0.267)
Leakage sectors x ETS	-0.0253	-0.126	-0.0415
	(0.348)	(0.355)	(0.375)
Leakage sectors x Phase I	0.163	0.162	0.413**
	(0.186)	(0.189)	(0.204)
Leakage sectors x Phase II	0.100	0.0750	0.570**
	(0.180)	(0.184)	(0.248)
Leakage sectors x ETS x Phase I	0.0784	0.0836	-0.00175
	(0.289)	(0.301)	(0.317)
Leakage sectors x ETS x Phase II	0.182	0.207	0.0290
	(0.326)	(0.332)	(0.374)
Size (t=0)	-0.0834	-0.0185	-0.0126
	(0.0832)	(0.103)	(0.104)
Capital intensity (t=0)		0.162	0.121
		(0.177)	(0.171)
Wages (t=0)		0.284**	0.312**
		(0.132)	(0.125)
Size (t=0) x time trend	0.0427	0.0298	0.0305
	(0.0270)	(0.0328)	(0.0314)
Capital intensity (t=0) x time trend		-0.0514	-0.0305
		(0.0601)	(0.0573)
Wages (t=0) x time trend		-0.0168	-0.0304
		(0.0516)	(0.0450)
2-digit Nace dummies	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes
Rho	-0.633	-0.618	-0.611
Sigma	1.029	0.991	0.979
Lambda	-0.651	-0.613	-0.598
Chi2 test of independence	34.11***	23.25***	20.01***
N censored	4114	3861	3861
N	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 16 – Separate effect for sectors exempted from auctioning (trade criterion)

Intensity (# subs)	ETS	ETS	ETS
ETS	0.0419	0.0391	0.114
	(0.240)	(0.236)	(0.247)
Phase I	-0.444**	0.455	0.727
	(0.206)	(1.072)	(0.990)
Phase II	-0.543	1.306	1.848
	(0.367)	(2.144)	(1.980)
ETS x Phase I	-0.113	-0.0918	-0.163
	(0.162)	(0.170)	(0.174)
ETS x Phase II	-0.00160	0.0370	-0.106
	(0.217)	(0.217)	(0.230)
Leakage sectors	-0.382*	-0.372*	-0.366
	(0.229)	(0.224)	(0.237)
Leakage sectors x ETS	-0.176	-0.244	-0.319
	(0.335)	(0.333)	(0.339)
Leakage sectors x Phase I	0.119	0.108	0.0978
	(0.161)	(0.159)	(0.172)
Leakage sectors x Phase II	0.0725	0.0358	0.00793
	(0.167)	(0.166)	(0.214)
Leakage sectors x ETS x Phase I	-0.00955	0.0378	0.105
	(0.252)	(0.254)	(0.253)
Leakage sectors x ETS x Phase II	0.120	0.121	0.279
	(0.322)	(0.324)	(0.327)
Size (t=0)	-0.0727	-0.0104	0.00508
	(0.0926)	(0.110)	(0.111)
Capital intensity (t=0)		0.146	0.137
		(0.168)	(0.163)
Wages (t=0)		0.314**	0.350***
		(0.131)	(0.123)
Size (t=0) x time trend	0.0331	0.0216	0.0164
	(0.0291)	(0.0347)	(0.0339)
Capital intensity (t=0) x time trend		-0.0491	-0.0440
		(0.0580)	(0.0552)
Wages (t=0) x time trend		-0.0230	-0.0405
		(0.0524)	(0.0449)
2-digit Nace dummies	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes
Rho	-0.685	-0.675	-0.674
Sigma	1.059	1.019	1.011
Lambda	-0.726	-0.688	-0.681
Chi2 test of independence	38.45***	27.82***	23.69***
N censored	4114	3861	3861
N	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 17 – Separate effect for sectors exempted from auctioning (trade >10%)

Intensity (# subs)	ETS	ETS	ETS
ETS	0.139	0.135	0.143
	(0.311)	(0.306)	(0.317)
Phase I	-0.448**	0.409	0.415
	(0.205)	(1.029)	(0.907)
Phase II	-0.648*	1.176	1.203
	(0.343)	(2.054)	(1.809)
ETS x Phase I	-0.295	-0.246	-0.255
	(0.221)	(0.228)	(0.244)
ETS x Phase II	-0.149	-0.165	-0.199
	(0.299)	(0.299)	(0.314)
Leakage sectors	-0.211	-0.167	-0.297
	(0.232)	(0.227)	(0.248)
Leakage sectors x ETS	-0.334	-0.376	-0.323
	(0.352)	(0.351)	(0.354)
Leakage sectors x Phase I	-0.0342	-0.0305	0.0907
	(0.166)	(0.164)	(0.172)
Leakage sectors x Phase II	0.00642	-0.0748	0.140
	(0.189)	(0.184)	(0.221)
Leakage sectors x ETS x Phase I	0.299	0.294	0.243
	(0.274)	(0.277)	(0.282)
Leakage sectors x ETS x Phase II	0.339	0.413	0.348
	(0.351)	(0.352)	(0.345)
Size (t=0)	-0.0916	-0.0307	-0.0222
	(0.0902)	(0.108)	(0.111)
Capital intensity (t=0)		0.138	0.107
		(0.167)	(0.158)
Wages (t=0)		0.291**	0.322***
		(0.124)	(0.118)
Size (t=0) x time trend	0.0420	0.0299	0.0270
	(0.0284)	(0.0333)	(0.0325)
Capital intensity (t=0) x time trend		-0.0492	-0.0335
		(0.0574)	(0.0541)
Wages (t=0) x time trend		-0.0192	-0.0345
		(0.0496)	(0.0435)
2-digit Nace dummies	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes
Rho	-0.668	-0.654	-0.654
Sigma	1.048	1.010	1.002
Lambda	-0.700	-0.660	-0.656
Chi2 test of independence	34.08***	23.21***	19.32***
N censored	4114	3861	3861
N	5097	4827	4827

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Appendix C - Results based on kernel matching

Table 18 – Baseline estimates (matching based on kernel)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.109	-0.128	-0.113	-0.0487	-0.0981	-0.0567
	(0.169)	(0.165)	(0.169)	(0.187)	(0.176)	(0.186)
Phase I	-0.425**	1.166	1.023	-0.188	1.117	1.039
	(0.196)	(0.946)	(0.890)	(0.192)	(0.831)	(0.804)
Phase II	-0.518	2.694	2.403	-0.617*	2.006	1.867
	(0.337)	(1.896)	(1.785)	(0.339)	(1.615)	(1.567)
ETS x Phase I	0.0472	0.0618	0.0457	-0.0507	-0.000168	-0.0370
	(0.138)	(0.139)	(0.141)	(0.174)	(0.174)	(0.180)
ETS x Phase II	-0.0374	-0.00129	-0.0153	0.0253	0.0607	0.000972
	(0.150)	(0.148)	(0.151)	(0.172)	(0.171)	(0.177)
Size (t=0)	-0.0727	-0.0331	-0.0303	-0.0963	-0.0568	-0.0406
	(0.0959)	(0.110)	(0.111)	(0.0978)	(0.103)	(0.105)
Capital intensity (t=0)		0.150	0.109		0.222	0.231
		(0.170)	(0.170)		(0.171)	(0.170)
Wages (t=0)		0.389**	0.394**		0.169	0.140
		(0.197)	(0.194)		(0.112)	(0.122)
Size (t=0) x time trend	0.0475*	0.0429	0.0412	0.0680**	0.0551*	0.0492
	(0.0278)	(0.0296)	(0.0306)	(0.0283)	(0.0285)	(0.0301)
Capital intensity (t=0) x time trend		-0.0398	-0.0194		-0.0742	-0.0767
		(0.0443)	(0.0447)		(0.0482)	(0.0496)
Wages (t=0) x time trend		-0.102	-0.104		-0.0305	-0.0149
		(0.0711)	(0.0680)		(0.0374)	(0.0393)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.717	-0.698	-0.698	-0.627	-0.632	-0.628
Sigma	1.242	1.206	1.203	1.065	1.052	1.040
Lambda	-0.890	-0.841	-0.840	-0.668	-0.665	-0.653
Chi2 test of independence	68.44***	47.05***	45.90***	51.02***	39.60***	36.99***
N censored	169025	150045	150045	172748	153565	153565
N	177024	157644	157644	177024	157644	157644

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 19 – Separate effect for sectors exempted from auctioning (all criteria, matching based on kernel)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.418	-0.352	-0.301	-0.561	-0.571*	-0.488
	(0.349)	(0.347)	(0.368)	(0.354)	(0.344)	(0.326)
Phase I	-0.848***	0.628	0.438	-0.847***	0.410	0.319
	(0.290)	(0.922)	(0.859)	(0.290)	(0.823)	(0.795)
Phase II	-0.878**	2.132	1.747	-0.888**	1.670	1.527
	(0.397)	(1.831)	(1.709)	(0.431)	(1.618)	(1.556)
ETS x Phase I	0.578*	0.599*	0.548	0.451	0.544*	0.481
	(0.328)	(0.336)	(0.352)	(0.339)	(0.317)	(0.321)
ETS x Phase II	0.550	0.571	0.490	0.301	0.273	0.152
	(0.349)	(0.357)	(0.398)	(0.365)	(0.345)	(0.344)
Leakage sectors	-0.359	-0.296	-0.340	-0.745**	-0.693**	-0.716**
	(0.289)	(0.276)	(0.289)	(0.315)	(0.290)	(0.284)
Leakage sectors x ETS	0.357	0.252	0.200	0.535	0.495	0.433
	(0.405)	(0.405)	(0.432)	(0.415)	(0.414)	(0.414)
Leakage sectors x Phase I	0.503*	0.496*	0.536**	0.752***	0.751***	0.789***
	(0.262)	(0.271)	(0.273)	(0.282)	(0.270)	(0.291)
Leakage sectors x Phase II	0.435*	0.385	0.465	0.330	0.285	0.337
	(0.252)	(0.259)	(0.283)	(0.311)	(0.292)	(0.333)
Leakage sectors x ETS x Phase I	-0.649*	-0.659*	-0.609	-0.529	-0.589	-0.547
	(0.361)	(0.368)	(0.384)	(0.385)	(0.369)	(0.383)
Leakage sectors x ETS x Phase II	-0.723*	-0.708*	-0.615	-0.306	-0.229	-0.139
	(0.385)	(0.390)	(0.437)	(0.410)	(0.394)	(0.415)
Size (t=0)	-0.0609	-0.0193	-0.0192	-0.0792	-0.0413	-0.0210
	(0.0932)	(0.108)	(0.109)	(0.0918)	(0.0975)	(0.0976)
Capital intensity (t=0)		0.148	0.111		0.218	0.214
		(0.170)	(0.173)		(0.174)	(0.177)
Wages (t=0)		0.373*	0.372**		0.155	0.137
		(0.192)	(0.188)		(0.107)	(0.116)
Size (t=0) x time trend	0.0464*	0.0415	0.0409	0.0662**	0.0527*	0.0454
	(0.0276)	(0.0294)	(0.0304)	(0.0276)	(0.0280)	(0.0291)
Capital intensity (t=0) x time trend		-0.0388	-0.0207		-0.0728	-0.0691
		(0.0437)	(0.0453)		(0.0477)	(0.0504)
Wages (t=0) x time trend		-0.0915	-0.0909		-0.0270	-0.0168
		(0.0667)	(0.0634)		(0.0362)	(0.0370)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.704	-0.684	-0.686	-0.602	-0.616	-0.611
Sigma	1.228	1.192	1.189	1.043	1.037	1.024
Lambda	-0.865	-0.815	-0.815	-0.628	-0.639	-0.625
Chi2 test of independence	69.04***	44.38***	43.47***	45.78***	36.28***	33.80***
N censored	169025	150045	150045	172748	153565	153565
N	177024	157644	157644	177024	157644	157644

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 20 – Separate effect for sectors exempted from auctioning (trade criterion, matching based on kernel)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	0.0455	0.0483	0.112	0.272	0.234	0.313
	(0.244)	(0.238)	(0.247)	(0.292)	(0.274)	(0.290)
Phase I	-0.407*	1.118	0.986	-0.140	1.100	0.960
	(0.211)	(0.936)	(0.880)	(0.204)	(0.780)	(0.773)
Phase II	-0.426	2.665	2.395	-0.395	2.096	1.836
	(0.337)	(1.872)	(1.761)	(0.325)	(1.491)	(1.466)
ETS x Phase I	0.0596	0.0558	-0.00666	-0.159	-0.114	-0.192
	(0.179)	(0.181)	(0.187)	(0.243)	(0.241)	(0.254)
ETS x Phase II	-0.120	-0.0735	-0.182	-0.361	-0.341	-0.479*
	(0.204)	(0.203)	(0.219)	(0.251)	(0.251)	(0.269)
Leakage sectors	-0.340	-0.342	-0.355	-0.243	-0.229	-0.215
	(0.221)	(0.223)	(0.228)	(0.253)	(0.253)	(0.263)
Leakage sectors x ETS	-0.366	-0.407	-0.538	-0.655*	-0.667*	-0.784**
	(0.352)	(0.347)	(0.355)	(0.372)	(0.361)	(0.369)
Leakage sectors x Phase I	0.0774	0.0933	0.0986	0.118	0.108	0.0954
	(0.168)	(0.171)	(0.178)	(0.245)	(0.244)	(0.253)
Leakage sectors x Phase II	-0.0437	-0.0540	-0.0303	-0.127	-0.166	-0.189
	(0.164)	(0.169)	(0.198)	(0.207)	(0.209)	(0.238)
Leakage sectors x ETS x Phase I	-0.0745	-0.0369	0.0885	0.135	0.146	0.266
	(0.269)	(0.270)	(0.275)	(0.340)	(0.341)	(0.338)
Leakage sectors x ETS x Phase II	0.200	0.175	0.430	0.807**	0.838**	1.075***
	(0.291)	(0.287)	(0.311)	(0.324)	(0.327)	(0.337)
Size (t=0)	-0.0455	-0.00692	0.00291	-0.0496	-0.0171	0.00611
	(0.0958)	(0.109)	(0.110)	(0.0945)	(0.0976)	(0.0993)
Capital intensity (t=0)		0.121	0.0732		0.193	0.185
		(0.161)	(0.160)		(0.155)	(0.153)
Wages (t=0)		0.395**	0.401**		0.167	0.137
		(0.198)	(0.194)		(0.109)	(0.119)
Size (t=0) x time trend	0.0413	0.0375	0.0330	0.0544*	0.0433	0.0362
	(0.0282)	(0.0297)	(0.0307)	(0.0279)	(0.0276)	(0.0282)
Capital intensity (t=0) x time trend		-0.0355	-0.0119		-0.0699	-0.0633
		(0.0435)	(0.0439)		(0.0452)	(0.0462)
Wages (t=0) x time trend		-0.102	-0.104		-0.0298	-0.0127
		(0.0716)	(0.0678)		(0.0359)	(0.0382)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.722	-0.700	-0.699	-0.621	-0.627	-0.611
Sigma	1.234	1.197	1.191	1.046	1.035	1.016
Lambda	-0.892	-0.838	-0.833	-0.650	-0.649	-0.621
Chi2 test of independence	60.61***	42.06***	40.30***	45.42***	36.05***	31.24***
N censored	169025	150045	150045	172748	153565	153565
N	177024	157644	157644	177024	157644	157644

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 21 – Separate effect for sectors exempted from auctioning (trade >10%, matching based on kernel)

Intensity (# subs)	Foreign	Foreign	Foreign	Non EU ETS	Non EU ETS	Non EU ETS
ETS	-0.107	-0.0975	-0.0222	-0.110	-0.159	-0.0351
	(0.368)	(0.354)	(0.365)	(0.369)	(0.341)	(0.350)
Phase I	-0.705***	0.754	0.515	-0.583**	0.623	0.437
	(0.217)	(0.902)	(0.817)	(0.257)	(0.738)	(0.703)
Phase II	-0.707**	2.284	1.799	-0.819**	1.604	1.247
	(0.334)	(1.817)	(1.660)	(0.373)	(1.438)	(1.375)
ETS x Phase I	0.291	0.317	0.245	0.00500	0.0856	-0.0223
	(0.265)	(0.267)	(0.278)	(0.314)	(0.307)	(0.319)
ETS x Phase II	0.0850	0.0801	-0.0351	-0.189	-0.167	-0.353
	(0.356)	(0.353)	(0.375)	(0.337)	(0.317)	(0.332)
Leakage sectors	-0.436	-0.383	-0.393	-0.839***	-0.835***	-0.833***
	(0.297)	(0.292)	(0.301)	(0.279)	(0.270)	(0.286)
Leakage sectors x ETS	-0.0712	-0.107	-0.202	-0.0913	-0.0832	-0.225
	(0.407)	(0.401)	(0.418)	(0.396)	(0.377)	(0.378)
Leakage sectors x Phase I	0.410**	0.409*	0.417**	0.525**	0.523**	0.533*
	(0.206)	(0.209)	(0.207)	(0.265)	(0.266)	(0.283)
Leakage sectors x Phase II	0.313	0.248	0.271	0.323	0.304	0.328
	(0.285)	(0.282)	(0.297)	(0.259)	(0.253)	(0.287)
Leakage sectors x ETS x Phase I	-0.343	-0.363	-0.274	-0.0186	-0.0816	0.0389
	(0.311)	(0.312)	(0.322)	(0.366)	(0.364)	(0.370)
Leakage sectors x ETS x Phase II	-0.144	-0.0933	0.0672	0.396	0.420	0.641*
	(0.390)	(0.388)	(0.422)	(0.385)	(0.369)	(0.377)
Size (t=0)	-0.0521	-0.0120	-0.0133	-0.0578	-0.0273	-0.00837
	(0.0969)	(0.110)	(0.112)	(0.0878)	(0.0925)	(0.0918)
Capital intensity (t=0)		0.117	0.0565		0.137	0.0887
		(0.159)	(0.158)		(0.138)	(0.127)
Wages (t=0)		0.373**	0.378**		0.177*	0.175*
		(0.188)	(0.178)		(0.0980)	(0.0993)
Size (t=0) x time trend	0.0441	0.0395	0.0398	0.0631**	0.0503*	0.0448*
	(0.0290)	(0.0305)	(0.0315)	(0.0262)	(0.0265)	(0.0263)
Capital intensity (t=0) x time trend		-0.0354	-0.00609		-0.0655	-0.0397
		(0.0430)	(0.0439)		(0.0431)	(0.0426)
Wages (t=0) x time trend		-0.0944	-0.0966		-0.0305	-0.0276
		(0.0685)	(0.0629)		(0.0342)	(0.0357)
2-digit Nace dummies	Yes	Yes	Yes	Yes	Yes	Yes
2-digit Nace linear trends	No	No	Yes	No	No	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes	Yes	Yes
NUTS1 linear trends	No	No	Yes	No	No	Yes
Rho	-0.704	-0.681	-0.681	-0.604	-0.629	-0.616
Sigma	1.221	1.186	1.181	1.020	1.022	1.003
Lambda	-0.859	-0.808	-0.805	-0.616	-0.643	-0.618
Chi2 test of independence	53.27***	35.66***	33.65***	33.28***	30.48***	26.72***
N censored	169025	150045	150045	172748	153565	153565
N	177024	157644	157644	177024	157644	157644

Heckman maximum likelihood sample selection model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Appendix D - Selection bias correction based on Semekyna and Wooldridge (2010)

Table 22 – Baseline estimates (based on Semekyna and Wooldridge, 2010)

Intensity (# subs)	OLS	Semekyna and Wooldridge (2010)	OLS	Semekyna and Wooldridge (2010)
	Foreign	Foreign	Non EU ETS	Non EU ETS
ETS	-0.201	-0.163	-0.246	-0.163
	(0.161)	(0.147)	(0.159)	(0.152)
Phase I	0.442	1.995**	0.582	2.142*
	(0.858)	(0.939)	(0.844)	(1.158)
Phase II	1.342	1.906	1.239	2.385
	(1.716)	(1.738)	(1.672)	(1.873)
ETS x Phase I	0.0791	0.0544	0.0658	0.0637
	(0.131)	(0.132)	(0.150)	(0.149)
ETS x Phase II	-0.0693	-0.0412	0.0158	0.0184
	(0.130)	(0.130)	(0.150)	(0.161)
Size (t=0)	0.280***	-0.295**	0.191**	-0.0630
	(0.0927)	(0.137)	(0.0898)	(0.127)
Capital intensity (t=0)	0.0889	-0.0695	0.130	0.0848
	(0.152)	(0.124)	(0.138)	(0.129)
Wages (t=0)	0.493***	0.454***	0.290**	0.216
	(0.165)	(0.155)	(0.136)	(0.137)
Size (t=0) x time trend	0.0222	0.0934*	0.0385	0.0783
	(0.0268)	(0.0495)	(0.0263)	(0.0527)
Capital intensity (t=0) x time trend	0.0295	0.0349	-0.0156	-0.0155
	(0.0463)	(0.0442)	(0.0436)	(0.0408)
Wages (t=0) x time trend	-0.103**	-0.116**	-0.0534	-0.0415
	(0.0463)	(0.0469)	(0.0375)	(0.0392)
Mills' ratio		3.811***		2.676***
		(0.717)		(0.965)
Mills' ratio x t=1		2.773***		1.636*
		(0.546)		(0.860)
Mills' ratio x t=2		3.113***		1.606**
		(0.667)		(0.802)
2-digit Nace dummies	Yes	Yes	Yes	Yes
2-digit Nace linear trends	Yes	Yes	Yes	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes
NUTS1 linear trends	Yes	Yes	Yes	Yes
F test significance Mills' ratio and interact		12.79***		5.149***
R sq	0.252	0.308	0.280	0.302
N	1208	1208	800	800

Pooled OLS model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 23 – Separate effect for sectors exempted from auctioning (all criteria - based on Semekyna and Wooldridge, 2010)

Intensity (# subs)	OLS	Semekyna and Wooldridge (2010)	OLS	Semekyna and Wooldridge (2010)
	Foreign	Foreign	Non EU ETS	Non EU ETS
ETS	-0.101	-0.442	0.0222	-0.266
	(0.306)	(0.303)	(0.292)	(0.337)
Phase I	0.135	1.192	0.362	0.863
	(0.884)	(0.979)	(0.840)	(1.153)
Phase II	0.949	1.081	1.358	1.969
	(1.754)	(1.767)	(1.660)	(1.796)
ETS x Phase I	0.295	0.536**	0.181	0.446
	(0.268)	(0.261)	(0.294)	(0.315)
ETS x Phase II	0.205	0.495*	-0.0833	0.179
	(0.263)	(0.257)	(0.315)	(0.338)
Leakage sectors	-0.280	-0.531**	-0.0994	-0.358
	(0.267)	(0.257)	(0.276)	(0.281)
Leakage sectors x ETS	-0.178	0.295	-0.416	0.0429
	(0.372)	(0.361)	(0.371)	(0.431)
Leakage sectors x Phase I	0.267	0.601**	0.367	0.703**
	(0.230)	(0.243)	(0.260)	(0.282)
Leakage sectors x Phase II	0.255	0.594**	0.0339	0.323
	(0.233)	(0.234)	(0.341)	(0.359)
Leakage sectors x ETS x Phase I	-0.273	-0.597*	-0.119	-0.422
	(0.317)	(0.310)	(0.341)	(0.361)
Leakage sectors x ETS x Phase II	-0.337	-0.666**	0.164	-0.145
	(0.312)	(0.308)	(0.373)	(0.427)
Size (t=0)	0.284***	-0.292**	0.218***	-0.0230
	(0.0919)	(0.132)	(0.0840)	(0.123)
Capital intensity (t=0)	0.0641	-0.0918	0.105	0.0683
	(0.156)	(0.127)	(0.151)	(0.140)
Wages (t=0)	0.477***	0.439***	0.304**	0.225*
	(0.162)	(0.151)	(0.136)	(0.136)
Size (t=0) x time trend	0.0192	0.0961**	0.0293	0.0651
	(0.0266)	(0.0465)	(0.0249)	(0.0502)
Capital intensity (t=0) x time trend	0.0336	0.0418	-0.0111	-0.0135
	(0.0468)	(0.0444)	(0.0452)	(0.0422)
Wages (t=0) x time trend	-0.0974**	-0.109**	-0.0587	-0.0447
	(0.0451)	(0.0450)	(0.0362)	(0.0378)
Mills' ratio		3.770***		2.462***
		(0.707)		(0.929)
Mills' ratio x t=1		2.797***		1.864**
		(0.551)		(0.865)
Mills' ratio x t=2		3.051***		1.580**
		(0.652)		(0.800)
2-digit Nace dummies	Yes	Yes	Yes	Yes
2-digit Nace linear trends	Yes	Yes	Yes	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes
NUTS1 linear trends	Yes	Yes	Yes	Yes
F test significance Mills' ratio and interact		12.48***		3.518**
R sq	0.266	0.321	0.292	0.312
N	1208	1208	800	800

Pooled OLS model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 24 – Separate effect for sectors exempted from auctioning (trade criterion - based on Semekyna and Wooldridge, 2010)

Intensity (# subs)	OLS	Semekyna and Wooldridge (2010)	OLS	Semekyna and Wooldridge (2010)
	Foreign	Foreign	Non EU ETS	Non EU ETS
ETS	0.0832	0.129	0.190	0.300
	(0.231)	(0.215)	(0.257)	(0.253)
Phase I	0.507	2.076**	0.741	2.089*
	(0.853)	(0.923)	(0.799)	(1.071)
Phase II	1.526	2.075	1.573	2.560
	(1.704)	(1.731)	(1.555)	(1.677)
ETS x Phase I	0.00979	-0.0511	-0.136	-0.206
	(0.178)	(0.177)	(0.223)	(0.226)
ETS x Phase II	-0.284	-0.245	-0.497**	-0.502*
	(0.193)	(0.190)	(0.242)	(0.257)
Leakage sectors	-0.140	-0.332*	-0.00396	-0.160
	(0.200)	(0.200)	(0.215)	(0.210)
Leakage sectors x ETS	-0.610*	-0.617**	-0.836**	-0.912***
	(0.325)	(0.294)	(0.336)	(0.324)
Leakage sectors x Phase I	0.0808	0.174	-0.0659	-0.0506
	(0.165)	(0.168)	(0.185)	(0.199)
Leakage sectors x Phase II	-0.0260	-0.0959	-0.181	-0.144
	(0.174)	(0.182)	(0.215)	(0.221)
Leakage sectors x ETS x Phase I	0.103	0.172	0.374	0.528*
	(0.249)	(0.243)	(0.280)	(0.286)
Leakage sectors x ETS x Phase II	0.475*	0.506*	1.034***	1.103***
	(0.285)	(0.283)	(0.319)	(0.323)
Size (t=0)	0.322***	-0.212	0.241***	0.0377
	(0.0911)	(0.132)	(0.0817)	(0.122)
Capital intensity (t=0)	0.0791	-0.0703	0.128	0.109
	(0.145)	(0.122)	(0.127)	(0.127)
Wages (t=0)	0.492***	0.465***	0.278**	0.222*
	(0.158)	(0.148)	(0.123)	(0.125)
Size (t=0) x time trend	0.00986	0.0647	0.0203	0.0397
	(0.0275)	(0.0493)	(0.0249)	(0.0478)
Capital intensity (t=0) x time trend	0.0313	0.0313	-0.0164	-0.0242
	(0.0464)	(0.0449)	(0.0431)	(0.0426)
Wages (t=0) x time trend	-0.102**	-0.118***	-0.0494	-0.0441
	(0.0446)	(0.0452)	(0.0337)	(0.0360)
Mills' ratio		3.649***		2.294***
		(0.691)		(0.830)
Mills' ratio x t=1		2.696***		1.553*
		(0.535)		(0.808)
Mills' ratio x t=2		3.186***		1.675**
		(0.679)		(0.799)
2-digit Nace dummies	Yes	Yes	Yes	Yes
2-digit Nace linear trends	Yes	Yes	Yes	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes
NUTS1 linear trends	Yes	Yes	Yes	Yes
F test significance Mills' ratio and interact		12.37***		4.130***
R sq	0.268	0.323	0.304	0.322
N	1208	1208	800	800

Pooled OLS model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 25 – Separate effect for sectors exempted from auctioning (trade >10% - based on Semekyna and Wooldridge, 2010)

Intensity (# subs)	OLS	Semekyna and Wooldridge (2010)	OLS	Semekyna and Wooldridge (2010)
	Foreign	Foreign	Non EU ETS	Non EU ETS
ETS	0.0832	0.129	0.190	0.300
	(0.231)	(0.215)	(0.257)	(0.253)
Phase I	0.507	2.076**	0.741	2.089*
	(0.853)	(0.923)	(0.799)	(1.071)
Phase II	1.526	2.075	1.573	2.560
	(1.704)	(1.731)	(1.555)	(1.677)
ETS x Phase I	0.00979	-0.0511	-0.136	-0.206
	(0.178)	(0.177)	(0.223)	(0.226)
ETS x Phase II	-0.284	-0.245	-0.497**	-0.502*
	(0.193)	(0.190)	(0.242)	(0.257)
Leakage sectors	-0.140	-0.332*	-0.00396	-0.160
	(0.200)	(0.200)	(0.215)	(0.210)
Leakage sectors x ETS	-0.610*	-0.617**	-0.836**	-0.912***
	(0.325)	(0.294)	(0.336)	(0.324)
Leakage sectors x Phase I	0.0808	0.174	-0.0659	-0.0506
	(0.165)	(0.168)	(0.185)	(0.199)
Leakage sectors x Phase II	-0.0260	-0.0959	-0.181	-0.144
	(0.174)	(0.182)	(0.215)	(0.221)
Leakage sectors x ETS x Phase I	0.103	0.172	0.374	0.528*
	(0.249)	(0.243)	(0.280)	(0.286)
Leakage sectors x ETS x Phase II	0.475*	0.506*	1.034***	1.103***
	(0.285)	(0.283)	(0.319)	(0.323)
Size (t=0)	0.322***	-0.212	0.241***	0.0377
	(0.0911)	(0.132)	(0.0817)	(0.122)
Capital intensity (t=0)	0.0791	-0.0703	0.128	0.109
	(0.145)	(0.122)	(0.127)	(0.127)
Wages (t=0)	0.492***	0.465***	0.278**	0.222*
	(0.158)	(0.148)	(0.123)	(0.125)
Size (t=0) x time trend	0.00986	0.0647	0.0203	0.0397
	(0.0275)	(0.0493)	(0.0249)	(0.0478)
Capital intensity (t=0) x time trend	0.0313	0.0313	-0.0164	-0.0242
	(0.0464)	(0.0449)	(0.0431)	(0.0426)
Wages (t=0) x time trend	-0.102**	-0.118***	-0.0494	-0.0441
	(0.0446)	(0.0452)	(0.0337)	(0.0360)
Mills' ratio		3.649***		2.294***
		(0.691)		(0.830)
Mills' ratio x t=1		2.696***		1.553*
		(0.535)		(0.808)
Mills' ratio x t=2		3.186***		1.675**
		(0.679)		(0.799)
2-digit Nace dummies	Yes	Yes	Yes	Yes
2-digit Nace linear trends	Yes	Yes	Yes	Yes
NUTS1 dummies	Yes	Yes	Yes	Yes
NUTS1 linear trends	Yes	Yes	Yes	Yes
F test significance Mills' ratio and interact		12.37***		4.130***
R sq	0.268	0.323	0.304	0.322
N	1208	1208	800	800

Pooled OLS model. Standard errors clustered by firm in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.