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## *EMPIRICAL EVIDENCE FROM THE EU EMISSIONS TRADING SCHEME (EU ETS)*

Sanjay Patnaik

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**How carbon permit markets can lead firms to capture surplus rents –**
Empirical evidence from the EU Emissions Trading Scheme (EU ETS)

*Sanjay Patnaik*

***Abstract***

This paper characterizes a profitable rent-capturing opportunity within the European Union Emissions Trading Scheme (EU ETS), created by an interlinkage between within-EU ETS and outside-EU ETS emissions permits and a concurrent overallocation of within-EU ETS emissions permits to some sectors. I leverage a novel dataset of companies from the iron and steel and refining sectors, covered by the EU ETS, to investigate the extent and characteristics of the exploitation of this opportunity. I find that companies with operations in multiple EU countries were more likely to exploit this opportunity than those in a single country, that exploitation grew over time for all firms, that firms with closer ties to EU ETS market institutions exploited this opportunity more frequently, and that more stringent EU ETS regulations led single-country firms to catch up more quickly to multi-country firms. The paper provides important insights into the intersection of regulation and markets within the context of carbon pricing schemes.

## INTRODUCTION

The threat of climate change due to anthropogenic emissions of greenhouse gases has led policymakers around the world to implement a growing number of carbon pricing schemes to reduce emissions, either through carbon taxes or market-based cap-and-trade programs. In general, market-based approaches for emissions reductions are favored by experts due to their theoretical economic efficiency (e.g., McKibbin and Wilcoxen, 2002; Nordhaus, 1993; Stern, 2008). As a result, we have witnessed a substantial rise in carbon markets around the world, at the subnational, national (United Kingdom Government 2008; Lockwood 2013; Lorenzoni and Benson 2014) and supranational level (Convery 2009; Ellerman, Convery, and De Perthuis 2010).

What is important to note is that carbon markets based on cap-and-trade programs are entirely created by regulators, which makes market design and implementation essential to avoid potential market imperfections (Pinkse and Kolk 2012). Moreover, it is important to examine how firms actually behave in these markets in response to the regulations, to better understand how well such programs work and to identify any inefficiencies that can be corrected by policymakers.

In this paper, I investigate how the linkage between the carbon market in the European Union ETS (EU ETS), the first large-scale multi-national regulatory program for greenhouse gases, with carbon offset credit markets created an opportunity to capture rents in the early years of the EU ETS. Specifically, I characterize the behavior of regulated firms in the exploitation of a profitable opportunity that arose due to the difference in prices between different types of emissions permits.

The EU ETS initially required firms to submit sufficient emissions permits issued by EU regulators to cover all their carbon emissions from within the EU, either through permits freely allocated to them, or by purchasing them from other firms. However, in a later phase, it allowed the use of offset credits purchased from *outside* the EU ETS to be used for compliance. These different permits traded at a lower price than EU emissions permits and at the same time, there was a significant surplus of freely-allocated EU permits in many sectors. This allowed firms to sell their initial allocation of EU emissions permits at higher prices in the market and buy cheaper (but identical in terms of meeting compliance obligations) offset permits from developing and emerging economies to comply with the regulation. One benefit of my study is that the profitable opportunity presented to firms was available to all firms and existed because of externally imposed regulations.

The paper then first examines the extent to which firms exploit this profitable opportunity. I further characterize which firms exploit this opportunity the most, comparing single-country firms against multi-country firms, and firms that have operations with market institutions relevant for the EU ETS (i.e. carbon markets) with firms that do not. I also characterize the temporal behavior of firm exploitation of the arbitrage opportunity. I find that there is significant heterogeneity among firms in the exploitation of the arbitrage opportunity, and that operating structure, regulatory stringency, and embeddedness with important market institutions, are important factors influencing a firm's likelihood to exploit the opportunity.

In Section I, I introduce the EU ETS and describe the setup of the profitable opportunity that leads to our empirical investigation. In Section II, I present the data and empirical methodology used to investigate our research question. In Section III, I present empirical results. Section IV concludes.

## I. THE EU ETS

The EU ETS is currently the largest active transnational cap-and-trade program in the world. Established in 2005, it is a crucial component of the EU's policy to tackle climate change and reduce emissions of GHGs, following the commitments by EU countries under the Kyoto Protocol[1] (Ellerman, Convery, and De Perthuis 2010, European Commission n.d.). It currently consists of four phases: Phase 1 (2005-2007), Phase 2 (2008-2012), Phase 3 (2013-2020) and Phase 4 (2021-2030).[2] During Phases 1 and 2, it covered more than 11,000 installations[3] in several industrial "activities" defined by the EU such as combustion, refining, coke ovens, roasting and sintering, cement and lime, glass, bricks and ceramics, iron and steel, pulp and paper, and a category for firms that opted-in voluntarily (CMD n.d., European Union 2003).

As with every emissions trading program, regulators set an annual total allowance cap (i.e., the total number of emissions permits) for all covered installations in order to achieve the specified emissions goals. The regulators distributed these emissions permits, called EU allowances (EUAs), mostly for free to the affected installations through pre-defined allocation mechanisms before the start of each phase. To comply with the program, firms need to surrender enough allowances to regulators at the end of each year to cover all emissions of their EU ETS plants[4] (European Commission n.d.). If they failed to do so, they were forced to pay substantial fines (European Union 2003).[5] The creation and distribution of EUAs by regulators established a large market for emissions permits, valued at roughly €43 billion in 2008 alone.[6] Several carbon exchanges (i.e., Bluenext in Paris and ICE in London) emerged as main platforms for EUA futures and spot market transactions.

The EU ETS followed a hybrid regulatory approach of centralization and decentralization in Phases 1 and 2 of the EU ETS, which consisted of transnational as well as country-specific elements. This makes the EU ETS an ideal setting for my study for several reasons. First, while the European Commission (EC) supervised the program in Phases 1 and 2, national representatives as well as industrial associations had substantial influence on several critical parts of the regulatory program such as the setting of the national allowance caps and the distribution of EUAs to installations (Ellerman, Convery, and De Perthuis 2010, European Union 2003, Austria Federal Ministry of Agriculture, Forestry, Environment and Water Management 2004). As a result the EU-wide regulatory framework exhibited cross-country differences regarding the implementation of the program (Ellerman, Convery, and De Perthuis 2010, Ellerman and Buchner 2007).

Second, concerns about the international competitiveness of certain industries as well as successful lobbying efforts by firms and industry groups resulted in differential treatment of industries during the allocation process for EUAs (COP 21 2015, Ellerman, Convery, and De Perthuis 2010, European University Institute 2015, Austria Federal Ministry of Agriculture, Forestry, Environment and Water Management 2004). Consequently, some sectors such as steel and iron or bricks and ceramics were provided with a surplus of allowances, while others like refinery or combustion were not, constituting a more rigid or stringent environmental regulations regime for the latter. Sectors allocated an emissions permit surplus faced lower stringency in the EU ETS, while sectors allocated a shortfall in permits experienced higher stringency.

Third, the EU ETS has been promoted as a market-based regulatory program that provides firms with more flexibility for how to comply with carbon emissions regulations. For instance, companies can decide to reduce emissions, buy permits on the market, or pursue a mix of both measures. This stands in contrast to strict per-firm emissions limits under traditional command-and-control regulations, and leaves room for firms to respond to the program more strategically.

The EU policy makers' desire to allow for flexibility in how firms meet their carbon emissions requirements and also facilitate carbon reduction investments in developing countries led to a change in the design of the EU ETS from Phase 1 to Phase 2. While from 2005 to 2007 (Phase 1), EUAs were the only emissions permits that were available for compliance,[7] a preannounced regulatory change in 2008 enabled firms to use external emissions permits (i.e., offset credits) generated *outside* the EU ETS for compliance during Phase 2 of the EU ETS (Ellerman, Convery, and De Perthuis 2010), i.e., Certified Emission Reduction (CER) credits and Emissions Reduction Units (ERUs). CERs were the most important type of offsets (in terms of volume in tons of $CO_2$) and available from 2008 onwards (Ellerman, Convery, and De Perthuis 2010).[8] ERUs started becoming available to firms in 2009.[9] Firms affected by the EU ETS, but also investors from other sectors, were able to purchase these offset credits on the stock exchange in unlimited quantities and surrender them–up to a certain predetermined limits based on plant location (see Figure 1)–to regulators to meet their required level of emissions credits for compliance. These limits were set as a percentage of the original allocations of EUAs for each plant, and they were determined on a national level. Hence, they differed across EU member countries (Ellerman, Convery, and De Perthuis 2010; see overview in Figure 1).

*--- Insert Figure 1 about here ---*

The convergence of two factors turned the introduction of offset credits into an arbitrage opportunity for firms to gain windfall profits from the EU ETS.[10] First, a persistent price spread between the offset credits and EUAs emerged with EUAs trading at a higher price than CERs and ERUs (see Figure

2).[11,12] This price spread allowed firms to "swap" cheaper offset credits to use for compliance and then sell the EUAs received from regulators on the market at a higher price (Ellerman, Convery, and De Perthuis 2010, p. 279).[13] Second, due to the generosity of national regulators during the initial permit allocation and the severe economic crisis that decreased production levels, many firms had a consistent surplus of EUAs (Koch et al. 2014; Neuhoff et al. 2012). Given that there were upper limits set on the allowed reliance on offset credits, the surplus of allowances meant that many firms did not exhaust the allowed number of offset credits (set as a percentage of the number of emissions permits granted to the firm) to meet compliance, as they would have if allowance levels had left them with a substantial shortfall. Instead, they had the opportunity, but not obligation to execute the aforementioned swaps within the offset credit limit during Phase 2.

*--- Insert Figure 2 about here ---*

To illustrate the profitable opportunity pursued by some firms, the following case provides an insightful example. The Finnish steel and iron producer Rautaruukki, operating three plants in two EU countries (Finland and Sweden) asserted in its 2008 annual report that it exploited the EUA-offset price spread and also sold surplus EUAs (Rautaruukki 2008). Figure 3 shows how Rautaruukki used different emissions permits to capture profits through this strategy. Based on pre-determined allocation schemes, the firm received cost-free EUA allowances, which turned out to be an oversupply of more than 223.6 thousand $CO_2$ tons. Additionally, Rautaruukki's management first engaged in a swap by purchasing cheaper offset credits for compliance and by selling off the corresponding EUAs (more than 197.6 thousand $CO_2$ tons) that were freed up as a consequence. This strategy enabled Rautaruukki to capitalize on an average price spread of €5.3/ton in 2008 between CERs and EUAs. The company decided to also sell the initial surplus of EUAs at the prevailing EUA price. While both transactions allowed the company to reap in about €5 million in extraordinary gains from the EU ETS in 2008, the EUA-CER swap opportunity was the result of an unintended consequence of the regulatory design. Our further analysis will focus on the latter loophole and investigate whether, when and to what extent other companies exploited it.

*--- Insert Figure 3 about here ---*

What looks quite simple in retrospective, i.e., capitalizing on arbitrage opportunities like Rautaruukki did, was quite challenging ex ante as it was a far more complex, dynamic, and uncertain financial and strategic decision. Not only did corporate managers need to recognize the opportunity presented by the price spread between EUAs and the two sorts of offset credits, but they also needed substantial information on the functionality of the EU ETS and on the emissions permit market in the EU in general, to decide to swap EUAs for offset credits and capitalize on the price differential. Specifically, firms would need information on market mechanics and to understand the difference between primary and secondary CER credits as the former carried regulatory approval risk, while the latter did not. In that context, two carbon exchanges that were established in the UK and France took on an important role as crucial information centers related to the EU ETS. In particular, these hubs facilitated the provision of essential explicit information and tacit knowledge on important aspects of the EU ETS carbon market and of the offset credit market (e.g., prices, types of permits, ways to purchase etc.), thereby particularly benefitting those firms that were embedded in the same environment as the carbon markets.

Thus, due to the complicated structure of the offset market and the imperfect linkage of the EU ETS marketplace with the UN regulatory approval process, informational advantages on the EU ETS became important for the ability of firms to identify and pursue profitable opportunities. As a result, many firms did not exploit the price spread to their advantage, even though this opportunity was available to all firms in the EU ETS, transaction costs to obtain the credits were small (Bluenext 2011), and firms that exploited the opportunity could profit from it.

## II. DATA AND METHODS

### Sample: The Iron and Steel Sector in the EU

The main focus of our analysis lies on firms in the iron and steel sector as this industry has multiple unique characteristics that are especially well-suited to test our hypotheses (Demailley and Quirion 2008). First, the iron and steel sector as a whole has consistently received an over-allocation of EUAs from regulators, eliminating the necessity for many firms to reduce emissions or buy permits on the market to comply with the EU ETS. Therefore, this sector is much better suited than other sectors to study how firms are exploiting the existing imperfections in the permit markets to capture profits (during Phase 2 the sector had a surplus in EUA in every year). Second, one of the widely discussed possible implications of cap-and-trade programs is that firms might be willing to relocate factories as a response to the regulatory program. This is particularly relevant in the EU ETS, where the industries were treated differently during the allowance allocation process across EU countries (Ellerman, Convery, and De Perthuis 2010, Austria Federal Ministry of Agriculture, Forestry, Environment and Water Management 2004). However, in the iron and steel sector there is a stable continuity in the location of almost all installations. Due to the high capital investments required for iron and steel plants, it is difficult to relocate whole factories. In addition, most of the firms in our sample and the factories they own have existed for many years and have a tradition of producing iron and steel at those locations. This stability makes it less likely that the strategic relocation of plants by firms in anticipation of the EU ETS might confound the empirical results. The latter point is especially relevant compared to other sectors in the EU ETS, where capital expenditures can be lower. Finally, firms in the iron and steel sector produce for the international market, and most of their decisions are driven by global prices for iron and steel rather than local economic conditions. By focusing on firms only in the iron and steel sector I am able to alleviate confounding influences that might be caused by different economic circumstances in different EU member countries. While this problem cannot be circumvented completely, the focus on iron and steel should mitigate any confounding effects as much as possible (e.g., as compared to firms in the power sector).

In order to test whether regulatory stringency affects the behavior of firms in response to the EU ETS, I also collected data on firms in the refining sector in the EU. Unlike the iron and steel sector, the refining sector faced a significant shortfall of EUAs in 2008, making the EU ETS immediately more salient for managers in that sector. For the total of Phase 2, the sector fared little better, with only a slight surplus of the original allocation of EUAs. This contrast in the stringency of the EU ETS between iron and steel and refining will allow us to test whether the strategic response of firms to the EU ETS evolved differently in these two industries over time. It is important to note, however, that the refining sector was much less stable over the period of the study than iron and steel. As compared to iron and steel, a larger number of firms bought and sold plants from each other, exited and entered the industry or closed down refineries. For that reason, I use the firms in the refining sector only to investigate the impact of regulatory stringency on the exploitation of the price spread particularly over time. All other estimations focus on iron and steel.

### Data

For our analysis, I hand collected a panel dataset (2005–2012) on companies in the iron and steel sector in the EU ETS. As a starting point for constructing the dataset I used the entire population of registered industrial plants in the EU ETS that were classified by the European Commission as part of the iron and steel sector.[14] The focus by the EU ETS on industrial plants rather than firms as a unit of analysis was defined in EU Directive 2003/87/EC and affected how EU ETS data were published. Therefore, EU ETS-related information (e.g., emissions, allowances, compliance status, account holder, etc.) for every installation was available only on the plant level through an EU database (European Environment Agency 2014) and not on the firm level. Moreover, in many cases, information on the owner of a certain installation was not deducible from the available information (for example the account holders of numerous installations listed were natural persons). To create a firm panel, I therefore needed to match every installation manually to its ultimate parent company using the installation's physical address and information from a proprietary database (CMD n.d.), direct company documents as well as data on subsidiaries and ownership patterns from Orbis, OneSource and Amadeus (Amadeus 2011, OneSource 2014, Orbis 2016). Through these steps, I were able to identify the correct owner of every installation and assign the iron and steel plants to their ultimate parent firms.[15] In a similar manner, I then collected information on all other installations from different EU ETS sectors (for example coke ovens, etc.), which were owned by the firms in the sample. Those data were added to the panel to reflect the fact that iron and steel firms also operate plants in multiple sectors.[16] Finally, I gathered all additional relevant firm-level information (e.g., firm size, age, etc.) from direct company sources (such as websites and annual reports), Orbis and OneSource.

I excluded nine small firms from the sample because their EU ETS installations shut down before or during 2008, as well as one small company that ceased production in 2009. I also removed from the sample two firms, whose main activity is unrelated to iron and steel production. Each of these firms just owns one EU ETS iron and steel installation as part of its conglomerate. The final sample includes 85 firms per year in the period from 2005 to 2012. The main focus for the analysis will be on the years 2008 to 2012, as the regulation allowing firms to use offset credits applied during that period. The data for 2005 to 2007 is used to calculate important control variables and to conduct robustness checks. The panel is not fully balanced as one company started operations in 2009 and was then acquired in 2011 by another firm in the sample (I account for that merger in the years 2011 and 2012). In addition, one company shut down at the end of 2011. The final number of firm-year observations for 2008 to 2012 is 421. The distribution of single-country firms and multi-country firms across countries can be found in Table II of the appendix.

I replicated the data collection effort for the oil refining sector by using the entire population of plants that were classified by the European Commission as belonging to the refining sector[17] as a starting point. Similar to the process for iron and steel, I matched each plant manually to its ultimate parent company, added any additional installations those firms owned in different sectors and collected all relevant additional data on those firms (e.g., emissions, allowances, firm characteristics). As the sector was less stable than iron and steel, the identification process for parent companies was more complex as the process involved manually cross-checking hundreds of locations and subsidiaries. The final unbalanced panel for the refining sector includes 61 firms and 299 firm-year observations.

## Variables

### *Dependent variables*

The main dependent variable of interest is a continuous, normalized variable that measures the number of external offset credits submitted in year *t* by firm *i*, divided by the total number of
all emissions permits surrendered in year t by firm *i*:

$$\text{OffsetShare}_{it} = \frac{(\text{Surrendered CER credits} + \text{ERUs})_{it}}{(\text{Surrendered EUAs} + \text{CER credits} + \text{ERUs})_{it}}$$

It therefore measures the extent to which a firm exploited the profitable opportunity by using offset credits. In addition, as a first baseline test in the analysis, I estimate the direct likelihood that firms used CER credits and ERUs for compliance through a binary dependent variable CER (CER is equal to 1 if a firm used CER credits in year t and 0 otherwise), a corresponding binary variable ERU, and a binary variable OFFSET for combined use of offsets.

### *Independent variables*

*Trend* is a secular trend component, expressing a change in the use of offset credits over time.

*Multict* is a binary variable that is equal to 1 if a firm operates installations that are covered by the EU ETS in multiple EU member countries, and 0 otherwise. Thus, any firm that has plants covered by the EU ETS in multiple EU countries is denoted as a multi-country firm. Any firm that has EU ETS plants in only one EU member country is classified as a single-country firm.

*TrendXMultict* is an interaction term between the multi-country indicator and the trend component. The coefficient on this variable will measure if there are any differences in the slope of the time trend between single-country firms and multi-country firms.

*CarbonExchange* is an indicator variable equal to 1 if a multi-country firm had an EU ETS plant in a country with a major carbon exchange (either France or the UK) and 0 otherwise. This variable is a measure of the quality of information environment relevant for the EU ETS since carbon exchanges provide critical information such as the prices of allowances, trading volumes and availability of different emissions permits.

### *Control variables*

*Firm size* is the logarithm of the number of employees of a firm in a given year.[18]

*Firm age* is the number of years since the firm was founded at the time of the start of the EU ETS (2005). This variable is included to control for firm-specific experience-related characteristics that might have accrued during the lifetime of a firm and that might influence their likelihood to use cheaper offset credits (e.g., familiarity with the regulatory environment).

*Public* is a binary variable indicating whether a firm is publicly traded or held privately. The majority of firms in iron and steel are held privately as many firms had evolved from family-owned businesses. I include this variable to control for any differences in strategic behavior between public and private companies that arise due to pressures from diverse shareholders.

*Allowances* is the number of EU allowances a firm received from the regulators in a given year and *Emissions* is the number of verified emissions in tons of $CO_2$. Both of these variables are used to calculate multiple control variables as described below.

*EmissionsChangePhase1* captures the percentage change in emissions from the start to the end of Phase 1 of the EU ETS (2005–2007). I include this control variable to account for the possibility that a change in a firm's past emissions might influence its decision to buy offset credits in Phase 2. For example, if a company increased production gradually during Phase 1 (which would at the same time also increase emissions), it might require more permits in Phase 2 and possibly be more likely to buy offset credits.

*EUASurplusPhase1* is binary and equal to 1 if a firm had an EU allowance surplus (relative to its emissions) in Phase 1 of the EU ETS, and it is equal to 0 if it did not. I include this control because a firm's decision to buy offset credits might be influenced by whether it had a shortfall or surplus of EU emissions allowances in the past. While our arguments focus on firms exploiting the profitable opportunities in the EU ETS, it might also be reasonable to expect that firms with a shortfall in EU allowances might be more likely to participate in the offset market in order to use offset credits to compensate for a current or future shortfall (such a shortfall can arise, for example, due to the insufficient number of EUAs received from regulators or due to a substantial increase in emissions).

To control for heterogeneity in the maximum allowed offset limits across countries, I also include three indicator variables *OffsetLimit_Low, OffsetLimit_Medium* and *OffsetLimit_High,* with the variables taking the value 1 if a firm has a plant in a country with a low (<10%), medium (10–14%), and high limit (>14%) on offset credit use, respectively.

## Empirical Methodology

In order to compare the behavior of single-country vs multi-country firms, as well as investigating time-trends in the exploitation of arbitrage opportunities, I utilize the data in years 2008 to 2012 to estimate the following base model (as firms could submit offset credits only since 2008):

$$DV_{it} = \alpha + \beta*Multict_{it} + \gamma*Trend_t + \Omega*X_{it} + \varepsilon_{it} , \qquad (1)$$

where $DV_{it}$ denotes the dependent variable for a given firm *i* in year *t*, $Multict_{it}$ is the multi-country indicator, $Trend_t$ is the secular trend component, $X_{it}$ constitutes the control variables and $\varepsilon_{it}$ is the error term[19]. To test the effect of firms being located in countries with ETS exchanges, the *Multict* indicator will be replaced with *CarbonExchange*. To investigate how the stringency of environmental regulation affects the exploitation of arbitrage opportunities, as well as heterogeneity in this effect between single-country and multi-country firms, I estimate an extended model specified as follows:

$$DV_{it} = \alpha + \beta*Multict_{it} + \gamma*Trend_t + \lambda*TrendXMultict_{it} + \Omega*X_{it} + \varepsilon_{it} , \qquad (2)$$

where $TrendXMultict_{it}$ is the interaction term. I compare estimation results for firms in sectors where the regulation was more (iron and steel) and less (refining) stringent.

The models with the main continuous dependent variable are estimated using a panel tobit regression and those with binary dependent variables using a panel probit regression, both with random effects (since *Multict* is time-invariant, a specification with firm fixed effects cannot be estimated). I employ a panel tobit regression because our primary dependent variable is left-censored (i.e., there are no negative values). OLS estimation would lead to inconsistent estimates (Wooldridge 2010) and the tobit model accommodates the left-censored data to provide consistent and unbiased results. Similarly, using OLS to estimate a model with a binary DV would lead to a mismatch between predicted values (continuous values over a range larger than 0-1) and the observed outcome (restricted to 0 or 1), and undermine the assumption of a normally distributed residual. Hence, I utilize a technique that accounts for the binary nature of the dependent variable. I elected to use a probit model instead of a logistic regression under the assumption that the standard errors are normally distributed. However, during our robustness tests, I also employ a logistic regression model and obtain the same results. Importantly, for both approaches I use a panel design as this allows us to examine how firms identify and take advantage of the opportunities presented by the regulation over time, controlling for unobserved heterogeneity across firms. Our hypotheses predict that firms will increasingly take advantage of the opportunities over time, and that the gap between multi-country firms and single country firms will decrease more over time when the single country firms are in sectors with more stringent regulations. These predictions require panel data to test. I cluster the standard errors by firm and report robust, clustered standard error[20] to account for the potential lack of independence across observations for the same firm, to avoid biasing downward the estimated standard errors.

# III. RESULTS

## Descriptive Statistics and Examination of Baseline Proposition

Detailed descriptive statistics for all variables for the entire panel of firm-year observations for the iron and steel sector are shown in Panel A of Table 1. Panel B displays the descriptive statistics for multi-country and single-country firms in comparison.

*--- Insert Table 1 and Figure 4 about here ---*

Figures 3a and 3b foreshadow our results by plotting the percentage of multi-country and single-country firms that use offset credits over time for iron and steel and refining, respectively. In both sectors, multi-country firms used offsets at significantly higher rates throughout the period from 2008 to 2012. In iron and steel, 50% of multi-country firms used offsets in 2008 and 88% in 2012 vs. 17% in 2008 and 64% in 2012 for single-country firms. In refining, the percentage of multi-country firms using offset credits rose from 67% in 2008 to 100% in 2012 and for single-country firms from 19% in 2008 to 82% in 2012, narrowing the initially large gap between the two groups considerably.

## Main Regression Results

Table 2 reports the results for the iron and steel sector for the base model specified in equation (1) to compare the behavior of single-country vs multi-country firms and understand exploitation time trends. In both specifications for the binary dependent variables CER and ERU, the coefficients on *Trend* and *Multict* are positive and statistically significant at the 99% level, as presented in columns (1) and (2). Column (3) shows the results for the binary variable OFFSET (which measures whether a firm used either type of offset credit), providing similar results. Interpreting these results by calculating marginal effects shows that a change from 0 to 1 for *Multict* results in a 40% higher likelihood to use offset credits (based on column 3) when measured as binary dependent variable (holding other variables constant at their means). Similarly, an increase of *Trend* by 1 (i.e., if one year passes), leads to a 10% higher likelihood (across all firms) to use offset credits (based on column 3).

Estimations for the main dependent variable OffsetShare, as shown in columns (4) and (5) without and with the indicators for country offset limits, also yield positive and statistically significant results for the coefficient on *Trend* (at 99% significance) and on *Multict* (with p-values of 2.5% and 5.1%, respectively). These robust results provide strong support for the claim that the firms' exploitation of this profitable opportunity increased over time across all firms, and they confirm that multi-country firms were more likely to use offset credits to profit from the transnational regulations. Examining the marginal effects reveals that multi-country firms have 13% higher offset share (on average and with other variables constant at their means) than single-country firms (based on column 5). Similarly, the offset share across all firms increases by about 12% every year on average (based on column 5).

The coefficients for firm size are positive and significant, but in robustness tests I address this potential concern that *Multict* and firm size may be correlated. Across all specifications, the coefficients for firm age are not significant. There is also no significant difference between publicly held and private firms in their likelihood to use offset credits. A previous shortfall or surplus in emissions allowances in Phase 1 of the EU ETS has no significant effect on whether a firm uses offset credits. This finding strengthens our argument that firms buying offset credits do so to capture additional value rather than because they have an allowance shortfall and need the additional credits for compliance. Finally, a change in the level of emissions in Phase 1 has a negative and significant coefficient in several specifications, indicating that an increase in emissions in Phase 1 affected the probability to use offset credits negatively. [21]

*--- Insert Tables 2 and 3 about here ---*

Column (1) in Table 3 shows results that compare the behavior of firms operating in countries with knowledge centers for transnational environmental regulations, namely the UK and France, with countries that do not have operations in these countries. Column (1) shows data for all firms in the iron and steel sector, with the indicator *CarbonExchange* as the main independent variable. The coefficient on *CarbonExchange* is positive and significant (with a p-value of 5.6%), indicating that firms that have operations that are embedded in proximity to and in the same environment as important information hubs—the ones with operations in countries that have a major carbon exchange—are more likely to exploit the profitable opportunity presented by offset credits. The results strengthen for the model with the trend component (column 2). This provides support for the claim that firms operating in countries with market intermediaries relevant for the EU ETS have an advantage over other firms. These estimates suggest that firms with operations in a country with a carbon exchange have an 11% higher offset share on average than firms that do not (holding other variables constant at their means). Columns (3) and (4) in Table 3 show the results for only multi-country firms in the iron and steel sector, indicating that even among multi-country firms, those embedded close to important information centers are more likely to exploit the profitable opportunity presented by offset credits. The results hold for the model with and without the trend component. Those multi-country firms operating in countries with a carbon exchange have about 9% higher offset share than multi-country firms that do not.

In order to rule out the possibility that MNCs operating in countries with a carbon exchange are driving the differences between single-country and multi-country firms and their time trends, I also conduct a robustness check by estimating the base model with a sample that excludes those multi-country firms. The findings are shown in column (1) of Table 5, and the coefficients for *Multict* and *Trend* remain robust.

*--- Insert Tables 4 and 5 about here ---*

Table 4 presents the results of the extended model, as specified in equation (2), and compares results for the iron and steel sector with those for the refining sector, where the regulation was more stringent. Columns (1) and (2) show the findings for iron and steel without and with home country effects, respectively. The coefficients on the interaction term (*TrendXMultict*) are not statistically significant while the coefficients on *Multict* and *Trend* remain robust. Column (3) contains the results for iron and steel for the full sample without the control variables from Phase 1.[22] The findings across all three specifications strongly indicate that multi-country firms in iron and steel were able to maintain their advantage relative to single-country firms over time. In the refining sector, however, the findings are different. Column (4) shows the results without home country effects and Phase 1 controls (for the full sample), column (5) with home country effects and without Phase 1 controls and column (6) with home country effects and with Phase 1 controls (a smaller sample size). In all specifications, the coefficient on the interaction term is negative and significant, indicating that the slope of the time trend was steeper for single-country firms than for multi-country firms (the results for *Multict* and *Trend* also hold). Over time, single-country firms in the refining sector caught up to multi-country firms in their use of offset credits, consistent with the claim that more stringent environmental regulation leads to a greater exploitation of arbitrage opportunities by all firms. These estimates imply that in refining, multi-country firms have on average a 63% higher offset share than single-country firms, but that this difference is reduced every year by 8% (holding other variables constant at their mean).

## Robustness

The following robustness checks will test the robustness of the results that the use of offsets increases across all firms over time and that multi-country firms use offsets more often, for firms in the iron and steel sector. I pursued robustness tests to examine heterogeneity across firms and countries, multiple potential alternative explanations, and alternative empirical specifications.

### *Firm and cross-country heterogeneity*

In order to address potential concerns of unobserved firm heterogeneity, estimating the models using a specification with firm fixed effects would be desirable. However, since the independent variable *Multict* is time-invariant (i.e., firms do not switch between multi-country firms and single-country firm during the period of our study), a firm fixed-effects estimation cannot be employed because the *Multict* indicator would be absorbed by the firm fixed-effects. Instead, I estimate random-effects specifications for both the probit and the tobit models across all different specifications of equations (1) and (2). The significant results for those models provide strong support for our four main results – namely, that that multi-country firms use offsets more often, that the use of offsets increases across all firms over time, that more stringent environmental regulation leads to a greater use of offsets by all firms, and that firms operating in EU ETS knowledge-center countries are more likely to use offsets. Moreover, while I cannot completely eliminate the potential issue of unobserved firm heterogeneity, I have taken several additional steps outlined below to alleviate this concern. Importantly, the fact that firms operating in EU ETS knowledge-center countries are more likely to exploit the arbitrage opportunity also holds among multi-country firms is a strong indication that unobservable differences between multi-country firms and single-country firms are not driving our results for that hypothesis. In addition, the main results hold when including the controls for different levels of offset credit limits as well as when estimating the models with home country effects, alleviating concerns of cross-country heterogeneity.

### *Alternative mechanisms.*

*Managerial quality*

It is possible that multi-country firms might be better managed than single-country firms (Benfratello and Sembenelli 2006, Bloom et al. 2012) and that these differences in managerial skill could drive some of the differences instead. I address this concern empirically in the following way. As Bertrand and Schoar (2003) assert, there is evidence that managerial quality and financial performance are correlated. Therefore, it is reasonable to use measures for past financial performance as a proxy for managerial quality. I collected additional data (where available) on the return on assets (ROA) for the iron and steel firms. The results for estimating equation (1) including lagged $ROA_{t-1}$ as a control are shown in column (2) of Table 5. The coefficient on $ROA_{t-1}$ is not significant and the findings for *Multict* and *Trend* remain robust. This indicates that differences in managerial quality as measured by financial performance do not seem to explain the results, and are in fact not correlated with exploiting the opportunity in this case.[23]

*Multict vs. firm size*

Another potential concern might be the relation between multi-nationality and firm size. I directly control for firm size in all specifications and the correlation coefficient between size and *Multict* is 0.362, which does not indicate a very strong correlation. However, the descriptive statistics suggest that multi-country firms are on average larger than single-country firms and the coefficient on firm size is significant in most specifications of the base model. In order to address this concern empirically, I apply a coarsened exact matching (CEM) algorithm[24] to match multi-country firms to firms from single-country firms, matching based on firm size, firm age and whether a firm is public or not in 2007 as well as the *EmissionsChange* from 2006 to 2007 and *EUASurplus* in year 2006. The CEM algorithm calculates different weights for every observation in the sample that account for the imbalances between single-country firms and multi-country firms by reducing the importance of certain observations. The estimations of the probit and tobit models as specified in equation (1) on the matched sample are shown in columns (3) and (4) of Table 5, respectively. The coefficients for *Multict* and *Trend* remain positive and significant.

*Unobservable transaction costs and the size of potential profits*

There might be some unobservable transaction costs in the allowance market that make the use of offset credits less feasible for some smaller firms, particularly as offset credits can be used only up to a certain percentage of plants' allocation of EUAs. This could be the hiring of a trading expert or specialized consulting firm. It might therefore be possible that only firms for which the expected value of exploiting the price spread is greater than the transaction costs associated with using offset credits would surrender offset credits for compliance. While a previous survey of EU ETS firms conducted by Jaraitė, Convery, and Di Maria (2010) indicates that transaction costs did not prevent firms from trading permits, I also conduct an additional test to directly examine whether the offset limit for each individual firm based on the country-specific percentages of a firm's plants' initial allocation of EUAs (which constrains the magnitude of the profitable opportunity) affects our main findings about the difference between multi-country and single country firms in their use of offset credits. I do so in two ways. For the first test, I constructed a variable that measures the annualized Phase 2 offset limit for every firm *Offset Limit*$_{it}$. Results when including this control are shown in column (5) of Table 5[25] and confirm that the coefficients on *Multict* and *Trend* remain robust. The coefficient on the offset limit variable is not significant, indicating that the magnitude of the profitable opportunity does not seem to affect the decision to use offset credits. For the second test, I estimate the main model with a different dependent variable, which is calculated as a normalized ratio where the numerator is an estimate for the actual number of offsets used and the denominator is the annualized Phase 2 offset limit as described above, defined as follows: $\text{OffsetShareOfLimit}_{it} = \frac{\text{Number of offset credits used}_{it}}{\text{Offset Limit}_{it}}$. The estimation through a tobit model is shown in column (6) of Table 5 and confirms the previous results.

*Reputational effects*

Another possible explanation for the results could be that some firms are not participating due to reputational concerns, because the use of offset credits has been the target of criticism in the news media in the past (Gronewold 2010). To test empirically for this possibility, I constructed a variable that measures how insulated every ultimate parent firm was from reputational risk within the EU ETS during Phase 2. The EU releases information on compliance only on a plant level and not on a firm level, and in multiple cases the publicly released information did not allow identification of the ultimate owner of a plant directly. For every firm, I therefore calculated the percentage of plants for which the ultimate parent firm or a company of the corporate group was directly inferable[26] from the publicly available EU ETS information released by the EU. Results for the estimation including this variable—*Reputational Risk*—are shown in column (7) of Table 5. The findings remain robust to the inclusion of the reputational variable, and the coefficient on the reputation control is not significant.

### *Alternative model specifications*

Estimating additional alternative model specifications confirms the prior results.[27] These include (1) using a logistic panel regression for models with a binary dependent variable, (2) sample restriction (without Arcelor Mittal as the largest outlier) – in Column 1 of Table 5, (3) controlling directly for the presence of production facilities in developing countries, (4) using number of plants as an additional measure of size, and (5) controlling for potential non-linearity of firm size.

Similar robustness checks were also implemented for our result that firms operating in EU ETS knowledge-center countries are more likely to use offsets, which are presented in Appendix Table I. Since the findings remain robust for this result as well, I omitted a discussion of Table I due to space constraints.

## IV. CONCLUSION

The early phase of the EU ETS provided significant rent-capturing opportunities for covered firms. The existence of a price spread between EUAs and "offset credits" (CERs and ERUs), coupled with surplus free allocation of EUAs to industries, allowed firms to sell surplus EUAs and buy CERs and ERUs.

I find empirical evidence of an exploitation of these opportunities by certain firms. Firms with operations in multiple EU countries engaged in this opportunity to a greater extent than those with operations in a single country, suggesting that multi-country firms benefited from information and knowledge advantages as well as higher organizational capacity, allowing them to better exploit this opportunity. Further, the stringency of regulations reduces the heterogeneity among firms in exploiting the arbitrage opportunity by incentivizing firms to engage strategically with carbon markets. Finally, I find a significant correlation between the use of the rent-capturing opportunities and the proximity of firms to market institutions, wherein firms with operations in a country hosting a carbon market had a 11% higher offset shares than those that didn't. This suggests that the diffusion of knowledge and information can play a decisive role for environmental regulations based on complex and dynamic market instruments.

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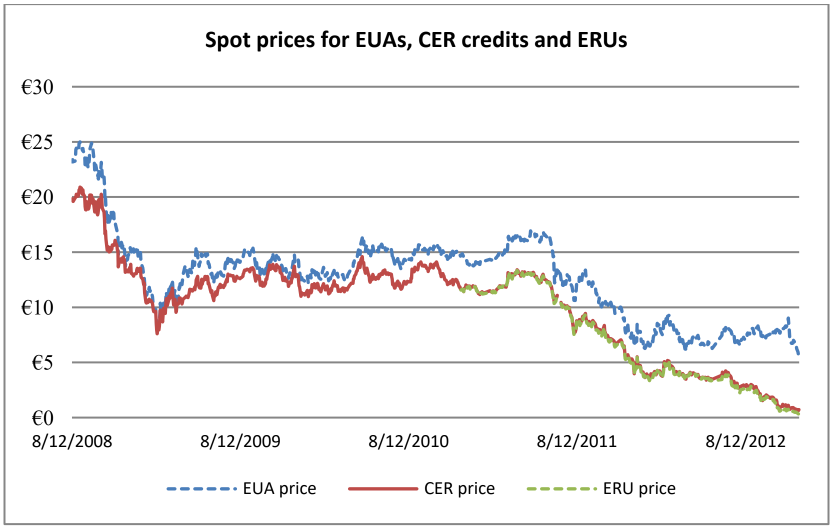
# FIGURES

**FIGURE 1 Spot Market Prices for EU Allowances, Secondary CER Credits and ERUs**




*Note: Price data obtained from* Bluenext (2012)

**FIGURE 2 Rent-capturing Behavior by *Rautaruukki* in 2008** (source: official data)

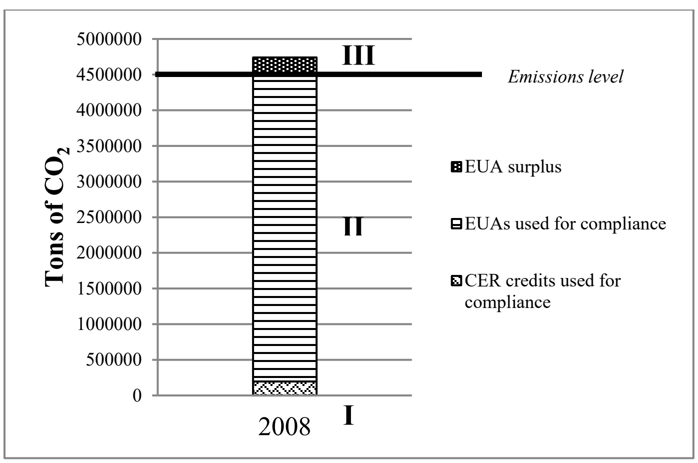
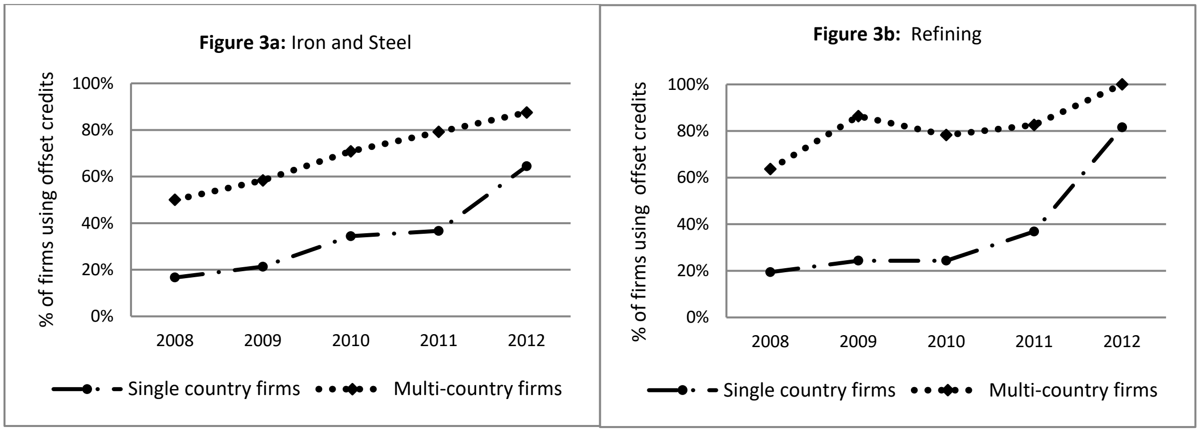


**FIGURE 3 Percentage of Firms that Use Offset Credits to Capture Rents: Iron and Steel vs. Refining**



# TABLES

## TABLE 1 Descriptive Statistics for the Iron and Steel Sector from 2008 to 2012

*Panel A - All firm year observations*

| Variable | Mean | SD | Min | Max | Obs. |
|---|---|---|---|---|---|
| *OffsetShare* | 0.12 | 0.21 | 0 | 1 | 421 |
| *CER* | 0.39 | 0.49 | 0 | 1 | 421 |
| *ERU* | 0.15 | 0.36 | 0 | 1 | 421 |
| *Multict* | 0.29 | 0.45 | 0 | 1 | 421 |
| *Firm size*[a] | 7.95 | 2.02 | 3.37 | 12.66 | 421 |
| *Firm age* | 64 | 51 | 0 | 320 | 421 |
| *Public* | 0.34 | 0.48 | 0 | 1 | 421 |
| *EmissionsChangePhase1* | 0.12 | 0.52 | -0.70 | 4.01 | 409[b] |
| *EUASurplusPhase1* | 0.70 | 0.46 | 0 | 1 | 409[b] |
| *CarbonExchange* | 0.16 | 0.37 | 0 | 1 | 421 |
| *No. of employees* | 16,654 | 39,608 | 29 | 315,867 | 421 |
| *Allowances* | 2,967,693 | $1.09*10^7$ | 3,283 | $8.95*10^7$ | 421 |
| *Emissions* | 1,998,567 | 6,969,270 | 994 | $6.86*10^7$ | 421 |
| *$ROA_{t-1}$*[c] | 2.49 | 9.13 | -75.48 | 27.34 | 338 |
| *Offset Limit*[d] | 396,152 | 1,477,891 | 328 | $1.17*10^7$ | 421 |
| *Reputational Risk*[e] | 0.91 | 0.24 | 0 | 1 | 421 |

*Panel B – Multi-country firms vs. Single-country Firms*

| | *Multi-country firms* | | | | | *Single-country firms* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | SD | Min | Max | Obs. | Mean | SD | Min | Max | Obs. |
| *OffsetShare* | 0.13 | 0.18 | 0 | 0.94 | 120 | 0.11 | 0.22 | 0 | 1 | 301 |
| *CER* | 0.64 | 0.48 | 0 | 1 | 120 | 0.29 | 0.45 | 0 | 1 | 301 |
| *ERU* | 0.30 | 0.46 | 0 | 1 | 120 | 0.10 | 0.30 | 0 | 1 | 301 |
| *Firm size*[a] | 9.54 | 1.50 | 6.87 | 12.66 | 120 | 7.32 | 1.85 | 3.37 | 11.81 | 301 |
| *Firm age* | 70 | 65 | 10 | 320 | 120 | 62 | 45 | 0 | 208 | 301 |
| *Public* | 0.46 | 0.50 | 0 | 1 | 120 | 0.30 | 0.46 | 0 | 1 | 301 |
| *EmissionsChange Phase1* | 0.26 | 0.81 | -0.07 | 4.01 | 120 | 0.06 | 0.31 | -0.70 | 1.60 | 289[b] |
| *EUASurplusPhase1* | 0.88 | 0.33 | 0 | 1 | 120 | 0.62 | 0.49 | 0 | 1 | 289[b] |
| *CarbonExchange* | 0.42 | 0.50 | 0 | 1 | 120 | 0.06 | 0.24 | 0 | 1 | 301 |
| *No. of employees* | 39,355 | 63,409 | 962 | 315,867 | 120 | 7,604 | 17,695 | 29 | 134,000 | 301 |
| *Allowances* | 8.818,160 | $1.90*10^7$ | 117,655 | $8.95*10^7$ | 120 | 635,281 | 2,082,625 | 3,283 | $1.08*10^7$ | 301 |
| *Emissions* | 5,844,038 | $1.20*10^7$ | 64,077 | $6.86*10^7$ | 120 | 465,489 | 1,559,877 | 994 | $8.96*10^6$ | 301 |
| *$ROA_{t-1}$*[c] | 3.89 | 6.57 | -12.4 | 17.19 | 85 | 2.02 | 9.81 | -75.48 | 27.34 | 253 |
| *Offset Limit*[d] | 1,192,721 | 2,572,442 | 15,779 | $1.17*10^7$ | 120 | 78,583 | 279,117 | 328 | $1.96*10^6$ | 301 |
| *Reputational_Risk*[e] | 0.90 | 0.15 | 0.44 | 1 | 120 | 0.92 | 0.26 | 0 | 1 | 301 |

*Notes: Numbers shown are rounded.*

*[a] Log (number of employees).*

*[b] The number of observations for these control variables for Phase 1 is lower as 12 firm-year observations did not have any emissions during those years.*

*[c] Return on Assets in year t-1: this variable is used in one robustness check as a proxy for managerial quality.*

*[d] Offset limit control: annualized Phase 2 regulatory limits on the use of offset credits; this variable is used in an additional robustness check.*

*[e] Reputational risk variable: continuous variable from 0 to 1, with 1 being the most vulnerable in terms of reputational risk; variable is used in robustness check to account for differences in reputational risk.*

**TABLE 2 Effect of Multi-country Firm and Trend on the Use of Offset Credits in Iron and Steel**

| Sample | *Iron and Steel firms* | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Estimation | *Probit* | *Probit* | *Probit* | *Tobit* | *Tobit* |
| Dependent Variable | CER[a] | ERU[a] | OFFSET[a] | OffsetShare[b] | OffsetShare[b] |
| *Multict* | 1.100** | 0.985** | 1.565** | 0.112* | 0.130+ |
| | (0.378) | (0.370) | (0.537) | (0.050) | (0.067) |
| *Trend* | 0.287** | 0.557** | 0.428** | 0.120** | 0.120** |
| | (0.076) | (0.110) | (0.084) | (0.014) | (0.014) |
| Firm size[c] | 0.174+ | 0.191* | 0.180* | 0.027+ | 0.025+ |
| | (0.099) | (0.090) | (0.086) | (0.014) | (0.014) |
| Firm age[d] | 0.002 | -0.004 | -0.0001 | 0.0001 | 0.0002 |
| | (0.003) | (0.003) | (0.003) | (0.0004) | (0.0004) |
| Public[e] | -0.016 | 0.248 | -0.031 | 0.037 | 0.018 |
| | (0.377) | (0.313) | (0.333) | (0.050) | (0.051) |
| EmissionsChangePhase1[f] | -0.472 | -0.414* | -0.456** | -0.082+ | -0.082+ |
| | (0.337) | (0.169) | (0.171) | (0.048) | (0.047) |
| EUASurplusPhase1[g] | -0.104 | -0.444 | -0.155 | -0.021 | -0.026 |
| | (0.330) | (0.308) | (0.288) | (0.050) | (0.051) |
| OffsetLimit_Low[h] | - | - | -0.505 | - | -0.029 |
| | | | (0.500) | | (0.061) |
| OffsetLimit_Medium[h] | - | - | -0.409 | - | 0.130 |
| | | | (0.514) | | (0.065) |
| OffsetLimit_High[h] | - | - | -0.511 | - | -0.050 |
| | | | (0.490) | | (0.065) |
| Const. | -3.020** | -4.587** | -2.613** | -0.677** | -0.638** |
| | (0.766) | (0.707) | (0.790) | (0.117) | (0.130) |
| Prob. > $Chi^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wald $Chi^2$ | 42.17 | 48.47 | 51.24 | 82.78 | 84.17 |
| Pseudo $R^2$ | 0.113 | 0.196 | 0.175 | 0.215 | 0.219 |
| # of observations | 409 | 327[i] | 409 | 409 | 409 |

*Notes: Standard errors are shown in parentheses ((1)-(3) robust standard errors clustered by firm; (4)-(5) standard errors using observed information matrix). +p<0.1; *p<0.05; **p<0.01. Numbers shown are rounded.*

[a] *Binary variable CER is 1 if a firm used CER credits in a given year and 0 otherwise. Binary variable ERU is 1 if a firm used ERUs in a given year and 0 otherwise. Binary variable OFFSET is 1 if a firm used any offset credits in a given year and 0 otherwise. Results for binary dependent variables are obtained through a panel probit estimation with random effects.*

[b] *OffsetShare is a continuous variable, measuring the number of offset credits submitted by a firm in a given year as share of the total number of emissions permits surrendered to regulators (the variable can therefore only take positive values). Results for OffsetShare are obtained through a left-censored panel tobit estimation with random effects.*

[c] *Log (number of employees).*

[d] *Age in number of years since founding of the company until the year 2005 when the EU ETS started.*

[e] *Indicator variable for whether a firm is publicly traded or held privately.*

[f] *The percentage change in emissions from 2005 to 2007 (Phase 1 of the EU ETS).*

[g] *Indicator variable for whether a firm had a surplus or a shortfall of EUAs in Phase 1 of the EU ETS.*

[h] *OffsetLimit_Low, OffsetLimit_Medium and OffsetLimit_High are indicator variables capturing whether a firm had plants in countries that have a low, medium or high limit for the use of offset credits, respectively.*

[i] *ERUs were only used from 2009 onwards, so this model excludes observations from 2008.*

**TABLE 3 Effect of *CarbonExchange* on the Use of Offset Credits among Multi-country Firms in Iron and Steel**

| Sample | All firms in Iron and Steel | | Multi-country firms in Iron and Steel | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Estimation | *Tobit* | *Tobit* | *Tobit* | *Tobit* |
| Dep. Variable | OffsetShare[a] | OffsetShare[a] | OffsetShare[a] | OffsetShare[a] |
| *CarbonExchange*[b] | 0.111+ | 0.115* | 0.097* | 0.093* |
| | (0.058) | (0.054) | (0.049) | (0.042) |
| *Trend* | | 0.119** | | 0.080** |
| | | (0.014) | | (0.014) |
| Firm size | 0.032* | 0.034** | 0.011 | 0.012 |
| | (0.013) | (0.013) | (0.020) | (0.017) |
| Firm age | 0.0001 | 0.0001 | 0.000 | 0.000 |
| | (0.0004) | (0.0004) | (0.0004) | (0.0003) |
| Public | 0.021 | 0.019 | 0.022 | 0.015 |
| | (0.052) | (0.049) | (0.058) | (0.051) |
| EmissionsChangePhase1 | -0.061 | -0.065 | -0.100* | -0.104* |
| | (0.049) | (0.047) | (0.047) | (0.044) |
| EUASurplusPhase1 | -0.008 | -0.014 | -0.140 | -0.139 |
| | (0.053) | (0.049) | (0.102) | (0.089) |
| Const. | -0.343** | -0.712** | 0.065 | -0.182 |
| | (0.104) | (0.114) | (0.171) | (0.156) |
| Prob. > $Chi^2$ | 0.004 | 0.000 | 0.117 | 0.000 |
| Wald $Chi^2$ | 19.10 | 83.81 | 10.20 | 43.58 |
| Pseudo $R^2$ | 0.099 | 0.26 | 0.191 | 0.741 |
| # of observations | 409 | 409 | 120 | 120 |

*Notes: Standard errors (using observed information matrix) are shown in parentheses.*
*+p<0.1; *p<0.05; **p<0.01. Numbers shown are rounded.*
[a] *Results for OffsetShare are obtained through a left-censored panel probit estimation with random effects.*
[b] *CarbonExchange is an indicator variable equal to 1 if a firm has a plant in a country with a major carbon exchange and 0 otherwise.*

**TABLE 4 Comparison of Dynamic Firm Behavior in Iron and Steel Sector vs. Refining Sector**

| Sample | Iron and Steel firms | | | Refining firms | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3)[a] | (4)[b] | (5)[b] | (6) |
| Estimation | *Tobit* | *Tobit* | *Tobit* | *Tobit* | *Tobit* | *Tobit* |
| Dep. Variable | OffsetShare[c] | OffsetShare[c] | OffsetShare[c] | OffsetShare[c] | OffsetShare[c] | OffsetShare[c] |
| *Multict* | 0.260* | 0.274* | 0.234+ | 0.484** | 0.388* | 0.626** |
| | (0.113) | (0.128) | (0.131) | (0.147) | (0.159) | (0.163) |
| *Trend* | 0.135** | 0.137** | 0.134** | 0.162** | 0.168** | 0.152** |
| | (0.018) | (0.018) | (0.018) | (0.020) | (0.020) | (0.018) |
| *TrendXMultict* | -0.041 | -0.043 | -0.038 | -0.090** | -0.096** | -0.084** |
| | (0.029) | (0.028) | (0.029) | (0.028) | (0.028) | (0.024) |
| Firm size | 0.025+ | 0.022 | 0.016 | 0.022 | 0.047* | 0.051* |
| | (0.014) | (0.018) | (0.018) | (0.017) | (0.019) | (0.020) |
| Firm age | 0.0002 | 0.0005 | 0.0005 | -0.001 | -0.0005 | -0.0006 |
| | (0.0004) | (0.0005) | (0.0005) | (0.001) | (0.001) | (0.001) |
| Public | 0.018 | -0.073 | -0.070 | -0.160* | -0.172** | -0.100+ |
| | (0.052) | (0.082) | (0.084) | (0.062) | (0.059) | (0.060) |
| EmissionsChange Phase1 | -0.080+ | -0.057 | - | - | - | 0.018 |
| | (0.047) | (0.055) | | | | (0.013) |
| EUASurplusPhase1 | -0.027 | -0.033 | - | - | - | 0.161* |
| | (0.051) | (0.066) | | | | (0.065) |
| OffsetLimit_Low | -0.027 | 0.037 | 0.080 | -0.093 | -0.068 | -0.220 |
| | (0.061) | (0.080) | (0.079) | (0.073) | (0.119) | (0.107) |
| OffsetLimit_Medium | 0.016 | -0.055 | -0.094 | -0.090 | 0.077 | -0.154 |
| | (0.065) | (0.088) | (0.088) | (0.087) | (0.112) | (0.113) |
| OffsetLimit_High | -0.049 | -0.093 | -0.122 | 0.060 | -0.051 | -0.177+ |
| | (0.065) | (0.142) | (0.142) | (0.078) | (0.086) | (0.085) |
| Home country FE | N | Y | Y | N | Y | Y |
| Const. | -0.693** | -0.641** | -0.625* | -0.558** | -0.815** | -0.958** |
| | (0.137) | (0.243) | (0.249) | (0.157) | (0.248) | (0.235) |
| Prob. > $Chi^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wald $Chi^2$ | 83.54 | 95.70 | 94.39 | 93.54 | 150.54 | 126.53 |
| Pseudo $R^2$ | 0.224 | 0.277 | 0.252 | 0.333 | 0.511 | 0.671 |
| *N* | 409 | 409 | 421 | 299 | 299 | 250 |

*Notes: Standard errors (using observed information matrix) are shown in parentheses. +p<0.1; *p<0.05; **p<0.01. Numbers shown are rounded.*

[a] *This specification is estimated without the controls for Phase 1 of the EU ETS for the purposes of comparing the results with refining in columns (4) and (5) as those Phase 1 variables were not available for many of the observations in refining.*

[b] *This specification is estimated without the controls for Phase 1 of the EU as those Phase 1 variables were not available for many of the observations in refining.*

[c] *Results for OffsetShare are obtained through a left-censored panel tobit estimation with random effects.*

**TABLE 5 Robustness Checks for the Use of Offset Credits in the Iron and Steel Sector: Multi-country vs. Single-country Firms**

| Sample | Restricted Multi-country: Iron and Steel | Iron and Steel firms | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) Restricted sample | (2) Return on Assets Control | (3) Matched Sample | (4) Matched Sample | (5) Offset Limit Control | (6) DV: Offsets used/Offset Limit | (7) Reputational Risk Control |
| Estimation | *Tobit* | *Tobit* | *Probit* | *Tobit* | *Tobit* | *Tobit* | *Tobit* |
| Dep. Variable | OffsetShare[a] | OffsetShare[a] | OFFSET[b] | OffsetShare[a] | OffsetShare[a] | Offset/Limit[c] | OffsetShare[a] |
| *Multict* | 0.181* | 0.188* | 1.490** | 0.111+ | 0.164* | 0.608+ | 0.132* |
| | (0.088) | (0.082) | (0.446) | (0.065) | (0.065) | (0.325) | (0.065) |
| *Trend* | 0.130** | 0.147** | 0.283** | 0.097** | 0.119** | 0.575** | 0.121** |
| | (0.017) | (0.019) | (0.061) | (0.015) | (0.014) | (0.071) | (0.014) |
| Firm size | 0.031+ | 0.026 | 0.304** | 0.035* | - | 0.149* | 0.025+ |
| | (0.016) | (0.018) | (0.096) | (0.016) | | (0.067) | (0.013) |
| Firm age | 0.0003 | 0.0006 | 0.004 | 0.0002 | 0.0002 | 0.0007 | 0.0003 |
| | (0.0006) | (0.0006) | (0.003) | (0.0006) | (0.0004) | (0.002) | (0.0004) |
| Public | 0.002 | -0.015 | -0.709* | -0.038 | 0.047 | -0.045 | 0.029 |
| | (0.067) | (0.071) | (0.312) | (0.052) | (0.049) | (0.252) | (0.051) |
| EmissionsChange Phase1 | -0.070 | -0.075 | -0.328 | -0.079 | -0.068 | -0.506* | -0.095* |
| | (0.054) | (0.055) | (0.244) | (0.049) | (0.047) | (0.237) | (0.048) |
| EUASurplusPhase1 | -0.019 | 0.020 | -0.131 | -0.064 | -0.012 | -0.319 | -0.050 |
| | (0.057) | (0.063) | (0.328) | (0.059) | (0.051) | (0.249) | (0.052) |
| OffsetLimit_Low | -0.189+ | -0.056 | -0.436 | -0.017 | -0.032 | -0.110 | -0.022 |
| | (0.114) | (0.076) | (0.382) | (0.058) | (0.063) | (0.295) | (0.059) |
| OffsetLimit_Medium | -0.137 | -0.016 | -0.360 | 0.018 | 0.008 | 0.226 | 0.018 |
| | (0.111) | (0.078) | (0.423) | (0.067) | (0.066) | (0.317) | (0.063) |
| OffsetLimit_High | -0.196+ | -0.086 | -0.738+ | -0.051 | -0.072 | -0.430 | -0.036 |
| | (0.112) | (0.083) | (0.433) | (0.066) | (0.067) | (0.317) | (0.064) |
| Return on Assets$_{t-1}$ | - | -0.0004 | - | - | - | - | - |
| | | (0.003) | | | | | |
| Offset Limit[e] | - | - | - | - | 0.0001 | - | - |
| | | | | | (0.0001) | | |
| Reputational risk[f] | - | - | - | - | - | - | 0.145 |
| | | | | | | | (0.095) |
| Const. | -0.589 | -0.739** | -3.182** | -0.583** | -0.452** | -3.016** | -0.772** |
| | (0.176) | (0.153) | (0.927) | (0.167) | (0.088) | (0.632) | (0.158) |
| Prob. > Chi$^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wald Chi$^2$ | 64.02 | 77.29 | 40.52 | 51.09 | 83.11 | 85.41 | 85.87 |
| Pseudo R$^2$ | 0.188 | 0.245 | 0.126 | 0.172 | 0.214 | 0.093 | 0.224 |
| # of obs. | 359 | 328 | 304 | 304 | 409 | 409 | 409 |

*Notes: Standard errors are shown in parentheses ((3) robust standard errors; (1)-(2) and (4)-(7) standard errors using observed information matrix). +p<0.1; *p<0.05; **p<0.01. Numbers shown are rounded.* [a]*Results for OffsetShare are obtained through a left-censored panel tobit estimation with random effects.*

[b] *Results for binary variable OFFSET are obtained through a panel probit estimation with random effects.*

[c] *Ratio of number of offset credits used by firm in a given year, divided by the annualized Phase 2 offset limit for each firm in year t. The model is estimated through a left-censored panel tobit estimation with random effects.*

[e] *Offset limit control: annualized Phase 2 offset limit in year t; variable scaled by $10^4$ for presentation purposes.*

[f] *Reputational risk variable: continuous variable from 0 to 1, with 1 being the most vulnerable in terms of reputational risk.*

# APPENDIX

## TABLE I: Robustness Checks for the Use of Offset Credits in the Iron and Steel Sector: Carbon Exchange

| Sample | Iron and Steel firms | | | |
|---|---|---|---|---|
| | (1) Return on Assets Control | (2) Offset Limit Control | (3) DV: Offsets used/Offset Limit | (4) Reputational Risk Control |
| Estimation | *Tobit* | *Tobit* | *Tobit* | *Tobit* |
| Dep. Variable | OffsetShare[a] | OffsetShare[a] | Offset/Limit[b] | OffsetShare[a] |
| *CarbonExchange* | 0.156* | 0.135* | 0.466+ | 0.126* |
| | (0.070) | (0.057) | (0.277) | (0.053) |
| *Trend* | 0.147** | 0.118** | 0.573** | 0.120** |
| | (0.019) | (0.014) | (0.072) | (0.014) |
| Firm size | 0.031* | - | 0.209** | 0.034** |
| | (0.016) | | (0.064) | (0.012) |
| Firm age | 0.0005 | 0.0000 | -0.0007 | 0.0001 |
| | (0.0006) | (0.0004) | (0.002) | (0.0004) |
| Public | 0.010 | 0.074 | 0.058 | 0.025 |
| | (0.062) | (0.046) | (0.248) | (0.048) |
| EmissionsChange | -0.047 | -0.040 | -0.435+ | -0.078+ |
| Phase1 | (0.054) | (0.046) | (0.241) | (0.047) |
| EUASurplusPhase1 | -0.024 | 0.016 | -0.208 | -0.039 |
| | (0.062) | (0.050) | (0.251) | (0.051) |
| Return on Assets$_{t-1}$ | 0.000 | - | - | - |
| | (0.003) | | | |
| Offset Limit[c] | - | 0.0001 | - | - |
| | | (0.0001) | | |
| Reputational risk[d] | - | - | - | 0.154 |
| | | | | (0.094) |
| Const. | -0.829** | -0.482** | -3.604** | -0.845** |
| | (0.140) | (0.069) | (0.581) | (0.142) |
| Prob. > Chi$^2$ | 0.000 | 0.000 | 0.000 | 0.000 |
| Wald Chi$^2$ | 77.01 | 80.63 | 76.24 | 86.06 |
| Pseudo R$^2$ | 0.239 | 0.199 | 0.084 | 0.220 |
| # of obs. | 328 | 409 | 409 | 409 |

*Notes: Standard errors (using observed information matrix) are shown in parentheses. +p<0.1; *p<0.05; **p<0.01. Numbers shown are rounded. [a]Results for OffsetShare are obtained through a left-censored panel tobit estimation with random effects.*

*[b] Ratio of number of offset credits used by firm in a given year, divided by the annualized Phase 2 offset limit for each firm in year t. The model is estimated through a left-censored panel tobit estimation with random effects.*

*[c] Offset limit control: annualized Phase 2 offset limit in year t; variable scaled by $10^4$ for presentation purposes.*

*[d] Reputational risk variable: continuous variable from 0 to 1, with 1 being the most vulnerable in terms of reputational risk.*

**TABLE II: Location of Plants by Country of Single-country Firms and Multi-country Firms (Iron and Steel)**

| Country | Number of single-country firms with production locations in that country | Number of multi-country firms with production locations in that country |
|---|---|---|
| Austria | 2 | 1 |
| Belgium | 0 | 6 |
| Czech Republic | 5 | 2 |
| Denmark | 0 | 1 |
| Finland | 0 | 3 |
| France | 2 | 8 |
| Germany | 5 | 11 |
| Greece | 3 | 0 |
| Hungary | 1 | 2 |
| Italy | 21 | 7 |
| Latvia | 1 | 0 |
| Luxembourg | 0 | 1 |
| Netherlands | 1 | 1 |
| Norway[a] | 0 | 2 |
| Poland | 2 | 3 |
| Portugal | 0 | 1 |
| Romania | 0 | 3 |
| Slovakia | 2 | 1 |
| Slovenia | 2 | 0 |
| Spain | 8 | 6 |
| Sweden | 4 | 6 |
| UK | 2 | 3 |

Notes: [a] While Norway is not an EU member, it opted into the EU ETS voluntarily.

# Endnotes

[1] The Kyoto protocol is an international environmental agreement established in 1997, aimed at reducing the emissions of anthropogenic greenhouse gases into the atmosphere.

[2] Phase 1 was largely designed as a pilot period that would allow regulators and affected firms to gain experience with emissions trading, a policy instrument that few stakeholders in the EU had prior exposure to (Ellerman, Convery, and De Perthuis 2010). While our analysis uses some data from Phase 1, it focuses on Phase 2 because that period was the first commitment period.

[3] Installations in the EU ETS are individual factories/production plants.

[4] One emissions permit gives a firm the right to emit one ton of a certain pollutant (in this context $CO_2$). $CO_2$ or carbon dioxide is one of the most important greenhouse gases. For more information on $CO_2$ as a greenhouse gas, please see US EPA (2022) and for more information on climate change, please see US EPA (2023).

[5] The penalties ranged from €40/ton of $CO_2$ in Phase 1 to €100/ton in Phase 2 (European Union 2003).

[6] Numbers are derived using data from CMD (n.d.) and Bluenext (2012). The information on the prices for EU allowances and CER credits was obtained directly from Bluenext (2012), which was a major market exchange for CER credits during Phase 2.

[7] Understanding and using the EUAs for compliance required managers to gather little additional information on the EU ETS since all firms received EUAs from regulators.

[8] CERs were generated by emissions-reduction projects in developing countries and were issued after a complex regulatory approval process administered by the United Nations (UNFCCC n.d.a, n.d.b). CERs that had not yet received UN approval (primary credits) were sold through forward contracts at a discount since there was a risk that they might not receive regulatory approval. However, any CER credits that were approved by the UN (secondary CER credits) were equivalent to EUAs for compliance and were traded on EU carbon exchanges just like EUAs. In this paper, the discussion and measurement of offset credits always refers to the secondary CERs and ERUs, and excludes the riskier primary CERs.

[9] ERUs were also generated through emissions reduction projects, but mostly within industries in the EU that were not covered by the EU ETS and certain non-EU countries such as Australia, Japan, New Zealand, Russia and the Ukraine (Ellerman, Convery, and De Perthuis 2010, UNFCCC n.d.c, n.d.d.). These credits could be issued and verified in many cases directly by the host country of the emissions reduction project.

[10] The principle for these offset credits had already been defined by the United Nations in the Kyoto Protocol and the EU decided to accept those credits into its system.

[11] Prior work that has examined the reasons behind the CER-EUA spread provides ambiguous insights, but suggests it was likely the result of a combination of factors: the national regulatory limits on the use of offset credits which established a theoretical upper limit on demand, continuous intervention by EU regulators in the regulatory program and some uncertainty about possible future regulatory changes for Phase 3 of the EU ETS as well as how those changes would affect the supply and demand for EUAs and offsets (Ellerman, Convery, and De Perthuis 2010; Mansanet Bataller et al. 2010; Nazifi 2013). In order to investigate this topic further, I conducted informal interviews and conversations with EU regulators, market participants, carbon traders, regulatory experts and industry representatives, which suggest that the regulatory percentage limits on offset use likely contributed mostly to the price differentials.

[12] Similar to the price spread that emerged between EUAs and CER credits, ERU credits have also persistently traded at a discount relative to EUAs, providing similar opportunities to profit from trades (the spot prices for ERU credits closely tracked prices for secondary CER credits).

[13] Like CER credits, firms could swap out EUAs for cheaper ERU credits from 2009/2010 onwards (using ERUs would count towards the offset credit limits set by national regulators—likely the main reason that they also cost less than EUAs).

[14] The exact definition of this sector as outlined in the EU directive is as follows: "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" (European Union 2003: 11). Iron and steel is one of ten industrial "activities" that the EU ETS covered in Phases 1 and 2, as defined by the EU Commission (CMD n.d., European Union 2003).

[15] I excluded three small subsidiary firms from the sample that were owned jointly by larger parent firms.

[16] Alchemia (a Polish steel firm), for example, operates one plant labeled as iron and steel by the EU, but also owns several installations covered by the EU ETS that belong to the combustion sector.

[17] The exact definition of this sector as outlined in the EU directive is: "Mineral oil refineries" (European Union 2003, p. 11).

[18] If the number of employees was not available for a specific year, I extrapolated the number from a different year by using average employee change rates in the industry or the average number of employees for a specific company. The numbers are scaled for estimation purposes. I use the number of employees in our main specification, because employee data could be found for all companies in our sample, which was not the case for other commonly used measures of firm size. Using employees therefore allows me to test our hypotheses on the complete population of iron and steel and refining firms.

[19] The inclusion of the trend component precludes using year effects at the same time. However, an alternative estimation with only the *Multict* variable and year effects instead of the trend component yields robust results (omitted here).

[20] I am unable to cluster standard errors in the tobit model as this is not possible in Stata.

[21] Further model specifications (omitted here) that control for the surplus/shortfall in EUAs and the change in level of emissions in year t-1 instead of in phase 1 confirm the robustness of our results.

[22] This specification is estimated to better juxtapose it to the refining sector where there was no data on these two control variables for many observations (as firms entered the industry later or did not have emissions or allowances in Phase 1).

[23] A more direct way to control for managerial quality is through the use of manager fixed effects for those firms where a change in management occurred during the period 2008 to 2012 (without managerial changes, manager fixed effects would be equivalent to firm fixed effects and absorb the *Multict* indicator). To explore this possibility, I manually collected additional data on the managerial leadership team for each firm in iron and steel from a variety of databases on executive leadership, company sites, news reports, and firm documents. However, a large majority of firms did not have a change in executive leadership between 2008 and 2012, which makes it infeasible to estimate a specification with manager fixed effects.

[24] CEM matching is a matching method that has been shown to exhibit superior statistical qualities compared to other commonly used matching techniques such as propensity score matching (Iacus, King, and Porro 2012). CEM outperforms other matching techniques along the following dimensions: "reducing the imbalance" between treatment and control groups, and "model dependence, estimation error, bias, variance and mean square error" (Iacus, King, and Porro 2012, p. 2). Moreover, matching does not rely on the specification of a particular functional form like other techniques (Todd 2008). It can therefore be a more suitable method for analyzing observational data that were not generated through a randomized trial.

[25] In this specification I drop the standard firm size control, because the potential rent variable and firm size are highly correlated, which would lead to multicollinearity.

[26] Inferable in this context means that either the name of the installation or the name of the account holder contains information about t
he ultimate parent firm or a company of the corporate group that owns an installation.

[27] Results are omitted here, but they are available upon request from the corresponding author.

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