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Active or passive?
Companies’ use of the EU ETS

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1 Introduction

Since its inception in 2005, the European Union Emissions Trading Scheme (EU ETS) is a pillar of EU climate policy, set up to reach the EU's climate targets in the covered sectors at lowest cost. Through their participation in the EU ETS (either mandatory or voluntary) a large number of businesses across Europe are directly involved in the EU's efforts to deal with climate change, while formulating individual trading decisions and strategies vis à vis the market. The EU ETS has since grown in terms of countries, types of greenhouse gases (GHG) and activities covered by the system, and a considerable number of firms have become active participants in the EU's market for carbon emission allowances (EUAs).

Emissions trading is a form of environmental regulation that acts as an alternative to either a command-and-control policy or a carbon tax. Compared to a command-and-control policy emissions trading is considered to be cost-efficient because it allows achieving a given emissions target (i.e. the cap) at minimum costs to the economy. This assumes that firms engage in the emissions market to comply with the regulatory provisions in a profit-maximizing way. The market price of emission allowances signals scarcity and incentivizes firms to minimize compliance costs. Thus, firms should reduce emissions internally if the associated costs are lower than the market price, and sell any excess allowances on the market. An ETS therefore provides incentives to invest in lowering emissions and to innovate in technologies the cost of which are below the market price (e.g., Hahn and Stavins, 1992). Thus, cost effectiveness of emissions trading presumes that firms engage in the emissions market efficiently by minimizing compliance costs (maximizing profits) through buying and selling allowances assuming minimal or no market frictions such as transaction costs (Hahn and Stavins, 2011, Stavins, 1995).

From a company's perspective, the carbon market is a marketplace for a commodity: a carbon allowance. Firms in the sectors covered by the system might therefore not only use the carbon market for compliance, but also as a tool to generate additional revenues or hedge against market risks (Cludius, 2018; Hintermann et al., 2016; Jaraitė-Kažukauskė and Kažukauskas, 2015; Liu et al., 2017; Pinkse and Kolk, 2007). Indeed, companies appear to differ in their motives to engage with the EU ETS. In particular, several studies for the first trading period (2005–2007) suggest that a substantial share of companies pursued a compliance seeking strategy (see also Jaraitė-Kažukauskė and Kažukauskas, 2015,

p. 585). For example, Ellerman and Trotignon (2009), Ellerman et al. (2010) and Leu et al. (2015) note that companies let a substantial amount of EUAs expire at the end of the first trading period rather than sell them on the market. Betz and Schmidt (2016) find that the vast majority of participants in the EU ETS are passive and that the few active participants are often non-regulated entities such as banks or exchanges. Yet, the efficiency of an ETS typically relies on companies actively participating in the market as sellers and buyers of allowances, and to use the market as efficiently as possible. Otherwise, the price observed on the market does not adequately signal scarcity, eventually resulting in cost-inefficient abatement decisions.

Results from several surveys carried out in the early years of the EU ETS find that especially smaller companies may follow a purely compliance seeking motive. For Ireland, Jaraitė et al. (2010) conclude that in particular smaller companies trade for compliance only and hence refrained from selling any surplus allowances. Similarly, for Sweden, Sandoff and Schaad (2009) find, that smaller firms trade less frequently than larger firms and are less likely to have developed a trading strategy[1].On average though, about 80% of the companies in their sample traded once a year only. Responses from self-assessment items suggest that the vast majority of participating companies pursued a pure compliance-seeking strategy. Martin et al. (2015) interviewed a large number of regulated companied from six ETS countries during the second trading period and find that 30% of those see the EU ETS as a pure compliance exercise and that a large number of companies remain passive on the European carbon market – in particular those companies that could sell allowances, but where the amount that could be sold lies below a certain threshold. The results resemble those found in previous studies based on interviews such as Löschel et al. (2010) and Pinkse & Kolk (2007).

Using data from the first and second trading period, Liu et al. (2017) investigate the performance of regulated companies which the authors measure by the ability of a company to either maximize gains on the market (as sellers) or minimize costs (as buyers). The authors examine the performance by comparing buyers (companies that were allocated less emissions than needed) and sellers (companies that were allocated excess emissions) and within these groups further distinguishing between companies of various emissions levels, energy versus industry sectors, as well as the "trading requirement" (i.e. the level of the shortfall or surplus a company faced). The authors find that companies which were short

1 In addition, for German ETS companies, Heindl (2017) finds non-trading related transaction costs (i.e. costs for monitoring, reporting and verification) relatively larger for smaller firms.

belonged to the industry sector and had a large buying requirement generally performed better than their counterparts. They also find that companies with low emissions generally performed better than those with high emissions.

Several studies analyze factors related with ETS company trading decisions during the first trading period of the EU ETS. Analyzing participation and participation intensity in the EU's carbon market in 2005 and 2006, Zaklan (2013) finds that companies' relative allowance position (i.e. whether the allowances they received for free were sufficient or not to cover their emissions), size, sector affiliation and ownership structure (public vs. private) matter. Also for the first trading period, Jaraitė-Kažukauskė and Kažukauskas (2015) investigate participation in the EU ETS, in particular focusing on transaction costs and transactions between regulated and non-regulated companies. Their multivariate analyses confirm that smaller firms are less likely to participate in the EU ETS (either as sellers or as buyers). In addition, companies from non-energy sectors are generally less likely to participate. Participation is also found to be related to the allocation of allowances and to the location of a company (countries, regions). Finally, their results indicate that companies with multiple installations (and thus presumably lower information and search costs) are less likely to trade with non-regulated companies. Cludius (2018) investigates the drivers for gains and losses made by regulated companies in the first period of the EU ETS which the authors calculated by matching allowance prices to the trading data from the EU ETS. The author finds that the level of under- or over-allocation, the point in time when a company entered the market and the size of a company (both in terms of their emissions and the number of accounts held) were important determinants of the gains and losses made during the first trading period.

Finally, several studies explore the role of non-regulated entities and in particular of companies from the financial sector in greater detail and their impact on the structure of the market (Borghesi and Flori, 2018), carbon price movements (Balietti, 2016; Fan, Liu and Guo, 2016), as well as their importance as trading partners for regulated companies (Cludius and Betz, 2020).

Clearly, companies' trading for compliance only undermines the effectiveness of the EU ETS and lowers market liquidity (Montagnoli and De Vries, 2010 Crossland, Li, and Roca, 2013). In comparison, more active trading strategies are likely to enable learning and lowering trading-related transaction costs such as information and search costs. Companies actively using the EU ETS are also more likely to exploit arbitrage profit opportunities when prices fail to reflect market fundamentals.

In this paper, we aim to empirically explore firms' trading activities in the EU ETS, by assessing their intensity of using the EU ETS. In particular, we investigate active versus passive use of the EU ETS by analyzing companies' transaction volumes, transaction frequency, employment of market intermediaries such as brokers, use of forwards and futures markets, the timing of trading, and – last but not least – to which extent firms transfer allowances internally rather than with other companies or intermediaries. Our multivariate panel econometric analysis employs a unique data set, compiling annual data on trading activity, allocation and verified emissions from the EU transaction log (EUTL) and company characteristics from the ORBIS data base from 2005 to 2015 thus ranging over three trading periods. In particular, we relate companies' trading activities with firm characteristics such as profits, size, or belonging to particular sectors (e.g. energy versus industry sectors) and whether firms are net sellers or net buyers. Our analysis contributes to the existing literature in multiple ways.

First, compared to the previous literature, which focuses on whether companies participate in the EU ETS spot market, or not, or examines only one specific aspect of trading strategy (e.g., use of intermediaries), our analysis provides for a more comprehensive analysis of trading activities.

Second, whereas previous empirical studies primarily referred to the first trading period of the EU ETS (2005–2007), our study joins the few papers (such as Borghesi and Flori 2016; Cludius and Betz, 2020; Liu et al. 2017) which also cover the second trading period (2008–2012), and is the first to combine transaction data and company-specific information for third trading period (2013–2020). Thus, our study provides insights to which extent findings from the early phases of the EU ETS are also valid for later phases.

Finally, while most previous studies employ cross-sectional econometric analyses, we join Jaraitė-Kažukauskė and Kažukauskas (2015) and use panel econometric methods.

The remainder of our paper is organized as follows. Section 2 provides an overview of the EU ETS, in particular on aspects related to trading of allowances. Section 3 describes the methodology including the data set, the dependent and explanatory variables and the econometric methods. Results are presented in Section 4. The final section 5 summarizes and briefly discusses the main findings.

2 Overview of the EU ETS

The EU Emissions Trading Scheme (EU ETS) was introduced in 2005 and is currently in the last year of its third trading period running from 2013 to 2020 (first trading period: 2005–2007; second trading period: 2008–2012). The EU ETS limits (caps) the total amount of emissions that installations of entities covered by the EU ETS are allowed to emit by making available a limited amount of emission allowances. Because allowances can be traded, a market is created. The market price reflects scarcity and provides incentives for entities to lower greenhouse gases emissions efficiently (e.g., Hahn and Stavins, 1992).

The EU ETS has grown in coverage (countries, sectors) and scope (activities, greenhouse gases) from its inception in 2005. Today, the EU ETS covers more than 15,000 stationary installations in electricity generation, as well as energy-intensive industry, such as cement, refineries, iron and steel and chemicals in 31 countries (EU Member States plus Iceland, Liechtenstein and Norway). Since 2012, flights within the EU are also covered by the scheme, making around 500 aircraft operators liable. Together, liable entities emitted ca. 1.7 billion tons of CO_2-equivalent in 2018, representing about 40% of total EU GHG emissions and making the EU ETS the largest emissions market worldwide (EEA, 2018).

The cap governing the EU ETS until 2030 is set in accordance with the EU's 2030 climate and energy targets. This is achieved by making a steadily declining amount of EU allowances (EUAs) available. The Linear Reduction Factor governing the cap was set at 1.74% of average 2008–2012 emissions in the third trading period (2013–2020) and will rise to 2.2% in the fourth trading period (2021–2030) to achieve the target of a 43% reduction of GHG emissions by 2030 compared to 2005.

During the first two trading periods (2005–2007 and 2008–2012) the vast majority of allowances was allocated to participating installations free of charge (100% in first period and 96% in second period, EEA 2020). From 2013 onwards, electricity-generating companies generally have to buy allowances at auction, while companies from the industrial sectors continue to receive a substantial share of their allowances for free (EEA 2018). As a result, roughly 51% of the allowances allocated between 2013 and 2018 were allocated for free (EEA 2020). This free allocation is intended to protect those EU industries susceptible to international competition, thus preventing "carbon leakage". The industrial sectors are further divided into sub-sectors at risk of carbon leakage and non-risk sub-sectors. The sectors and sub-sectors listed on the "carbon leakage list" which is drawn up by the EC continue to receive allowances for free based on benchmarks. For the remaining sectors, free allocation of EUAs declines steadily until 2030, at which point free allocation will cease.

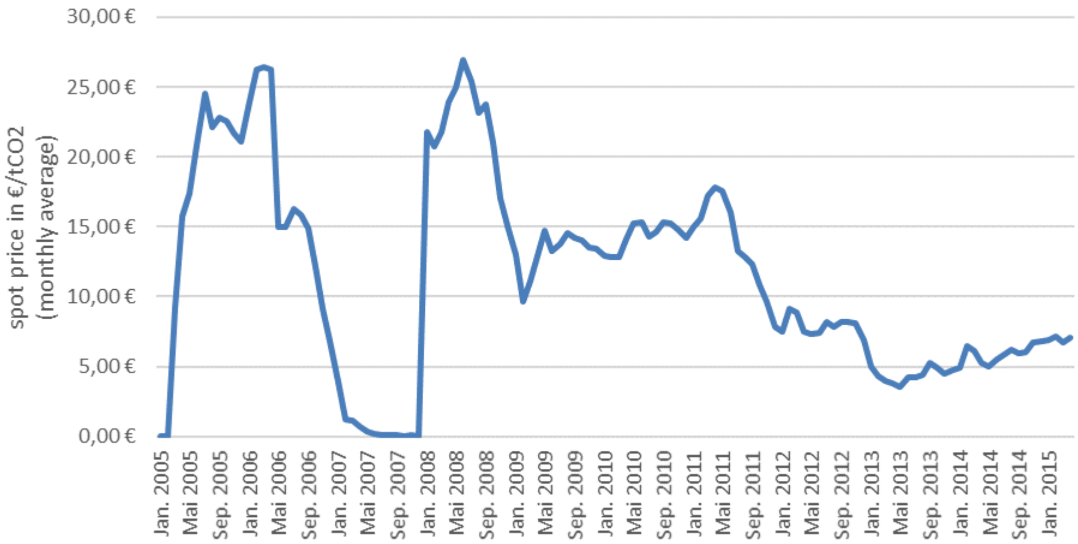
Allocation of free allowances to operators of eligible installations takes place until the last day of February of a given year. Allowances to cover the emissions for a particular year t have to be submitted until 30 April of the next year (t+1). This timing of allocation and surrender of allowances enables entities to "borrow" freely allocated allowances for t+1 to cover emissions in t. Yet, such borrowing is only allowed within trading periods, not between trading periods. Should a liable installation fail to submit the amount required to cover verified emissions of the previous year, it has to pay a penalty and "make good" the amount of allowances it failed to deliver.

In addition to EUAs, liable installations are allowed to use international offset credits, such as Certified Emission Reductions (CERs) and Emission Reduction Units (ERUs). But companies may only use CERs and ERUs up to a pre-specified upper limit. In practice, CERs and ERUs were mainly surrendered during the second trading period, by the end of which the permissible budget was nearly exhausted. From the fourth trading period onwards, companies can no longer use international credits.

From 2008 on, unused allowances can be "banked" not only within the same trading period, but also into future trading periods. Because the amount of allowances (and credits) available in the market exceeded verified emissions for most of the years in the second and third trading periods, the surplus of EUAs in the market amounted to about 1.65 billion by the end of 2018, corresponding to the emissions of about one year in the EU ETS (EEA 2019).

Figure 1 shows the development of the spot price for EUAs between January 2005 and April 2015, i.e. the time frame covering our empirical analyses. At the end of the first trading period the price was close to zero, because more allowances were available than needed and these allowances expired at the end of the trading period. At the beginning of the second trading period, prices were quite high at around €25, but these fell as emissions declined in the wake of the economic downturn in 2009 and 2010 when, in addition, a huge supply of cheap international credits flooded the market. At the end of the second and the beginning of the third trading period, the price remained very low, in some cases below €5 per ton of CO_2 equivalent. From 2018 onwards (not shown in the figure) EUA prices rose quite steeply to a high of nearly €30, before falling again in the wake of the COVID-19 crisis.

Figure 1: Development of the EUA spot price between 2005 and 2015.



Own illustration based on EEX data

In addition to the operators of liable installations, there are other actors voluntarily participating in the market for EU allowances, such as financial intermediaries. In fact, until at least 2013, banks have been responsible for the largest overall volume traded on the market for EUAs in each year (Cludius and Betz 2020). Along with other financial intermediaries, such as exchanges or brokers, they perform important functions on the market for EUAs, facilitating trading and often acting as the counterparty for future contracts, which are especially important for electricity companies wishing to hedge their future carbon exposure. EUA Futures are usually delivered in December of each year and are mainly traded through the Intercontinental Exchange (ICE), while European Energy Exchange (EEX) is the most important exchange for spot trading of EUAs. Trading of EUAs does not have to happen through exchanges, but can also be directly carried out between two participants ("over-the-counter"). The majority of EUA trades in terms of volume (over 75%) takes place using future contracts settled at the ICE followed by only a minor amount of spot exchanges at the EEX and OTC trades (DEHSt, 2019).

3 Methodology

This section first describes how the data for our empirical analysis was generated, and how this data was translated into dependent and explanatory variables for our empirical analysis. Then, we describe the econometric methods employed in our multivariate analyses.

3.1 Compiling the data

In this study, we use data on allowance transactions under the EU ETS provided by the European Commission in the EU Transaction Log, which we describe in Section 3.1.1. This dataset is augmented by matching additional company data from the ORBIS database, a process detailed in Section 3.1.2. Companies liable under the EU ETS range from those holding one installation in a single country to large multinational companies. In Section 3.1.3 we discuss at which level (installation, operator, subsidiary, company) we carry out the analysis. Sections 3.1.4 and 3.1.5 respectively derive dependent and explanatory variables to be used in the regression analysis.

3.1.1 The Union registry and the EUTL

The Union registry is an electronic database managed by the European Commission that records all transactions of allowances carried out under the EU ETS, including the allocation and surrendering of allowances, but also all transactions taking place between market participants. The European Union Transaction Log (EUTL) checks, records and authorizes all transactions occurring in the Union registry. Via the EUTL, the European Commission publishes data on the transaction of allowances, as well as a selection of further details from the Union registry. This is done with a delay of three years (previously five years) and can be downloaded free of charge.[2]

The EUTL contains additional information for accounts active on the registry. All liable entities covered by the EU ETS are required to open an Operator Holding Account (OHA) for stationary installations or Aircraft Operator Account (AOA) in the Union registry. These accounts receive free allocation (if applicable) and also have to surrender the required amounts to fulfil the entity's compliance obligation.

In addition to these mandatory accounts, Person Holding Accounts (PHAs) and Trading Accounts (TAs) can be opened voluntarily in the Union registry for trading

2 https://ec.europa.eu/clima/ets/.

purposes. TA allow to trade in (almost) real time, whereas transactions from or to a PHA may have delays of up to 26 hours (Art. 39.3 Registry Directive). The majority of these accounts are opened by non-liable companies such as financial intermediaries, as well as liable companies using them for managing compliance and trading activities (Betz and Schmidt 2015, Cludius and Betz 2020). Some PHAs and TAs are held by non-governmental organizations, or private individuals.

Finally, a number of administrative accounts exist that either belong to the EU or individual countries and are used, amongst others, for the issuance, allocation, auctioning or deletion of allowances.

Table 1 and Table 2 show the information available for the accounts in the EUTL. The account type is shown, for example, whether it is an OHA or PHA, the country in which the account was registered, if there is a related installation, the installation ID, the name of the account holder, the company registration number, etc.

Table 1: General account information in the EUTL

General Information							
Account Type	National Administrator	Related Installation/Aircraft Operator ID	Account Holder Name	Account Status	Account Opening Date	Account Closing Date	Company Registration No
Operator Holding Account	Austria	47	AGRANA Stärke GmbH	open	2005-06-16 00:00:00.0		FN 252477 s

Table 2: Contact details of the EUTL accounts

Details on Contact Information						
Type	Name	Main Address Line	Secondary Address Line	Postal Code	City	Country
Account holder	AGRANA Stärke GmbH	Friedrich-Wilhelm-Raiffeisen-Platz 1		1020	Wien	Austria

The EUTL contains information on verified emissions, units surrendered and free allocation on installation level. In addition, information is provided on the location of the installation (address), the activity of the installation, the name and the date of the inclusion in the EU ETS (see Table 3).

Table 3: Information provided by the EUTL on installations

Detailed EU ETS Phase Information - Compliance								
Installation/Aircraft Operator ID	Installation Name/Aircraft Operator Code*	Permit/Plan ID	Permit/Plan Date	Allowance Allocation	Total of Allowances Surrendered**	Total Verified Emissions**	Compliance Code on last 30 April	Account Status
1	Baumit Baustoffe Bad Ischl	IKA119	2005-06-01	38416	278527	278527	A	open
2	Breitenfelder Edelstahl Mitterdorf	ES069	2005-11-23	13776	123705	117319	A	open

The Union registry records all physical movements of allowances in a transaction database. It provides information about the accounts involved (transferring entity, acquiring entity), the type of transaction (allocation, surrender, auction, transaction from installation to another installation etc.), the date of the transaction and also the number of allowances (see Table 4). Trading in futures and forwards is only recorded at the expiration date when the derivative is delivered to the buyer. No prices or payments are shown via the EUTL.

Table 4: Information provided by the EUTL on individual transactions

List of Transactions

Transaction ID	Transaction Type	Transaction Date	Transaction Status	Transferring Registry	Transferring Account Type	Transferring Account Identifier	Transferring Account Holder	Acquiring Registry	Acquiring Account Type	Acquiring Account Identifier	Acquiring Account Holder	Nb of units
EU348866	10-2	2016-04-30 22:47:56.704	Completed	France	100	001DSD76353E Cent Therm Arjowiggins Pap Aa	DALKIA	European Commission	100	EU Allowance deletion	European Commission	24254
EU348855	10-2	2016-04-30 15:09:14.719	Completed	France	100	SIDEFO	SIDEFO	European Commission	100	EU Allowance deletion	European Commission	8794

Until 2012, a decentralized system of national registries existed, which were aggregated and checked in the Community Independent Transaction Log (CITL), the predecessor of the EUTL. In 2012, information was migrated from the individual registries to a single EU-wide registry and the CITL replaced by the EUTL. From this point onwards, a number of rules on the coding and disclosure of information also changed. In this context, all installations received new OHAs, i.e. all banked allowances had to be transferred from the old accounts to the new accounts, which led to a very high level of internal transfers.

For our analyses we have downloaded three data sets from the EUTL:

i) All accounts (liable and voluntary) with associated information like account holders, company registration number and addresses (40,320 accounts, including many that were closed at the end of the second trading period)

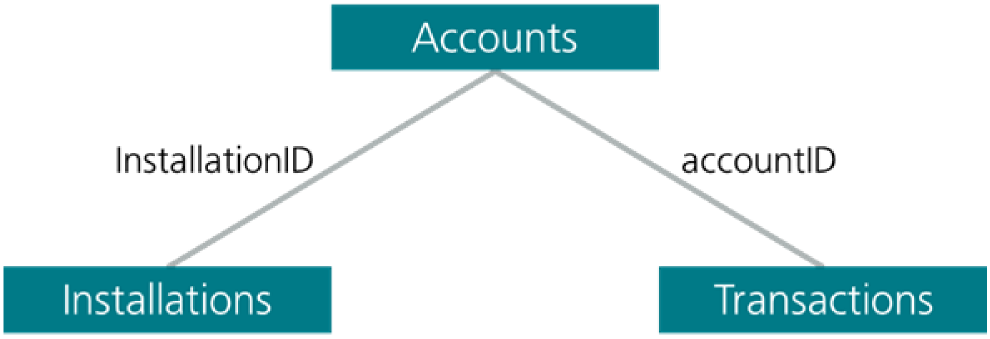
ii) All liable installations with associated information (15,574 installations, including decommissioned installations)

iii) All transactions (incl. administrative transactions) between 2005 and April 2015 which we aggregate to a monthly level (452,187 transactions)

Accounts and installations are related by a unique Installation ID provided by the EUTL[3], which allows the matching of accounts and installations. The matching of transactions to accounts was done using the Account IDs of the transferring and acquiring parties shown in the transaction data set (see Figure 2).

3 Due to institutional changes in the EUTL in 2012, all installations had to be related to a new OHA. In Appendix A, we describe how we construct the matching between former and actual OHA.

Figure 2: Relationship of data from the EUTL registry



The matching of the three different data sets from the EUTL results in a transaction-level data set containing information about the accounts involved in addition to the information on transactions, as well as information on installations.

3.1.2 Matching of EUTL and ORBIS and preparation of the data

In addition to EUTL data containing ETS-related information, we also use financial data on the liable companies from the ORBIS database – a commercial company database operated by Bureau van Dijk. From the ORBIS database, we use financial data on the number of employees, revenues, profit, industry classification (NACE) and home country of a company. To match the EUTL and ORBIS datasets, we relied primarily on the company registration number, which is provided in the EUTL account information (Table 1) and is also available in the ORBIS data.[4]

For our empirical analyses, we focus on transactions in which only OHAs, PHAs and TAs were involved, i.e. all other transactions in which authorities were involved are not considered. That is, all transactions from and to authorities, such as auctions or allocation of allowances, have not been included. However, because allocation or surrender of allowances is a regulatory requirement, which companies cannot influence or freely control, these transactions are not relevant for our research questions and disregarded in our empirical analysis. The total transaction volume (of EUAs, ERUs, CERs,...) included in our original database amounts to 172 billion allowances. Roughly 65% of these transactions are related to regulatory requirements such as the allocation or surrendering of allowances. Therefore, the remaining transaction volume kept for our study amount to about 60 billion allowances.

4 The matching procedure is described in detail in Appendix A.

After the company information from ORBIS was matched to the transaction-level data set described at the end of section 3.1.1, we set up a panel dataset at the level of individual companies for the time frame considered (using the company registration number as an identifier). Because not all transactions were linked to an account with a company registration number, this step resulted in a loss of approximately 10 billion allowances. That is, about 10 billion allowances were purchased by OHAs, PHAs or TAs that did not have a company registration number in the EUTL. However, exclusion of these 10 billion allowances does not necessarily imply that they were eliminated from our empirical analysis. For example, if two PHAs traded with each other, but only the transferor had a company registration number, that transfer would be included in the transfer volume of that company in our data set. But since the buyer did not have a company registration number, this transaction could not be included in the acquisition volume of a specific company. It should be noted that the 10 billion allowances we exclude apply not only to private persons, but also involve transactions between companies that we could not match with the ORBIS data. We believe though, that omitting these transactions will not significantly affect the results of our analysis. Eventually, data on allocations, verified emissions and surrendered EUAs were also aggregated at the company level.

After deleting the accounts that could not be matched with the ORBIS data, 15,014 companies remain in the data set. Since we consider the years 2005 to 2015 and we include information from ORBIS (e.g. on sales, number of employees) for the year 2004 as well, the data set contains 180,168 observations, i.e. 12 entries per company, one for each year. For our multivariate analyses, the data set is significantly smaller, because for many companies, information on the number of employees, sales, profit or sector affiliation was missing.

Figure 3: Data structure and levels of aggregation

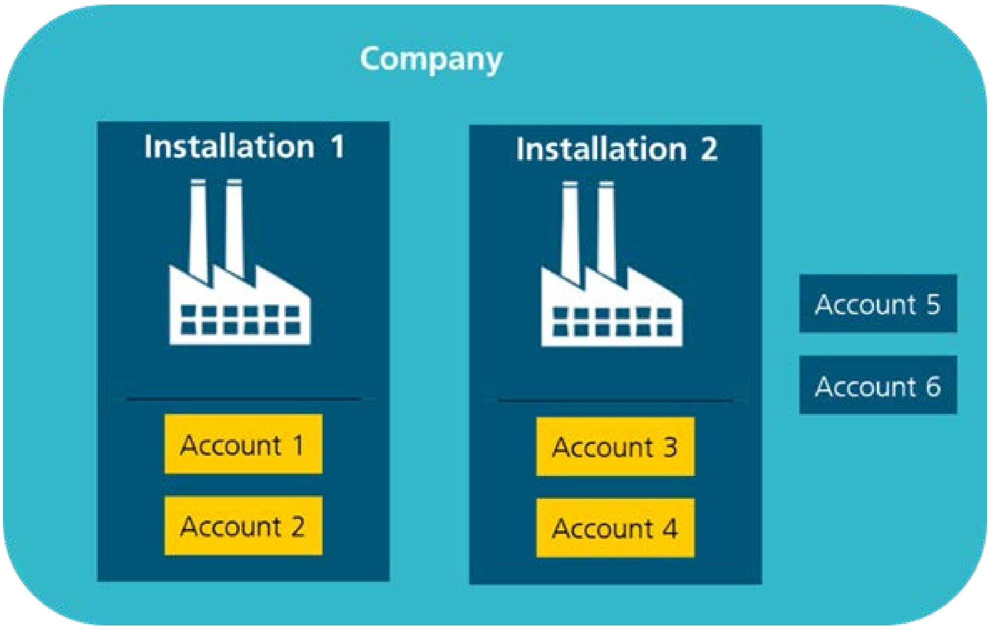


Figure 3 shows the final data structure. The lowest level of aggregation captures individual transactions. Summing up all transactions based on the involved accounts, we obtain the data at the level of accounts (all transactions made by Account 1, for example). To aggregate the data at the level of installations, all accounts assigned to an installation were summed up. In Figure 3, all transactions of installation 1 would then include all transactions made by Account 1 and 2. To obtain the data at the company level, transactions from all installations owned by a company were summed up. In addition, at this level, we also considered transactions by accounts of this company that do not relate to any specific installation such as PHAs or TA, i.e. Accounts 5 and 6 in Figure 3.

3.1.3 Level of analysis

Our matching between EUTL installations and ORBIS companies allows us to establish different levels of analysis depending on the ownership structure provided by ORBIS (see Table 5). The lowest level of analysis is L0, which is equal to analyzing data provided by the EUTL at the installation level. Several installations might belong to same company in the ORBIS database. The company level is denoted by L1. A company may transfer or acquire allowances using the OHA accounts associated with related installations or using additional PHA accounts.

The ORBIS database identifies the national as well as the global owner[5] company. Level L2 refers to the national ownership level. In particular, a company may have multiple subsidiary companies operating one or more installations each. Finally, Level L3 refers to the global ownership level, i.e., a transnational company owner companies in multiple countries participating in the EU ETS.

Table 5: Ownership levels

Ownership Level	**Explanation**
L0	Installations as observed in the EUTL
L1	Company level
L2	National owner
L3	Global owner

Our analysis refers to L1, implicitly assuming that the company operates independently in their decisions regarding the transfer and trade of allowances. To the best of our knowledge, our study is among the first to analyze data at the company level (our level L1). To date, the literature has largely focused on the level of individual installations (Betz and Schmidt, 2015), the level of the national owner (Jaraitė-Kažukauskė and Kažukauskas, 2015) or on the level of the global owner (almost all other papers cited earlier).

The time horizon for our analyses spans from the start of the EU ETS in 2005 to April 2015. Following previous literature (e.g. Cludius and Betz, 2020), we aggregate transactions at the level of a "trading year", which runs from May to April of the following year. For example, the year 2006 in our data runs from May 2006 to April 2007. This approach has the advantage that all transactions carried out to surrender allowances for emissions in a particular calendar year are reflected in the same corresponding trading year. For example, a company may surrender allowances to cover emissions of the year 2006 until the end of April 2007.

3.1.4 Dependent variables

Our empirical analysis employs six indicators reflecting active use of the EU ETS as shown in Table 6.

First, *total transactions* as measured by the amount transacted via purchases or sales per trading year is our first indicator of a company's engagement with the

5 Called "National Ultimate Owner" and "Global Ultimate Owner" in ORBIS.

EU ETS market. Thus, we interpret higher *total transactions* as reflecting a more active use of the EU ETS. Previous studies analyzing companies engagement with the EU ETS have typically considered total transactions or similar (Jaraitė-Kažukauskė and Kažukauskas, 2015; Zaklan, 2013).

Second, *transaction frequency* as measured by the number of transactions a company carries out per year is also used to reflect market engagement. As argued by Jaraitė-Kažukauskė and Kažukauskas (2015), frequent trading increases market experience and provides information gains. In addition, companies trading more frequently may be better placed to exploit price variations over time, or realize gains in liquidity (sell part of allocated EUAs early and purchase EUAs later). Thus, a higher transaction frequency is considered to reflect more active use of the EU ETS. This also includes forwards and futures, each with the transaction on the delivery date. Transactions between the parties to the contract during the life cycle of the future are not registered in the EUTL, only the actual delivery transaction of the allowance.

Third, we consider the number *intermediaries* (e.g. banks or broker firms) used by a company to carry out its trades. The EU ETS involves uncertainties about the fundamentals driving the market (including uncertainty about regulation). Employing brokers and other intermediaries, companies gain access to professional market information (at the costs of a brokerage fee). Similarly, companies may employ intermediaries for directly managing their trading activities, brokering trades with other system participants, using them as partners when entering in forward or future trading or helping them exploit opportunities for generating revenues, such as swapping cheaper international credits (CERs, ERUs) for more expensive EUAs (Cludius and Betz, 2020). We consider companies using intermediaries more intensively to be as more actively. To determine the number of intermediaries used, we identified those trading partners of a regulated entity that belong to the NACE category financial services.

Fourth, by using the derivatives market for *forwards and futures*, companies exert more efforts in understanding the market, may exploit price variations over time, and manage market risks. In particular, to manage risks, electricity companies tend to hedge forward electricity sales (associated with CO_2-emissions in the future) through the derivatives market for EUAs. We therefore consider the use of forward and futures market as reflecting an active use of the EU ETS. Because only actual transactions of allowances are registered in the EU TL, the volume of transactions that were carried out via forward and futures contracts has to be estimated. We define the volume traded in these derivatives markets as those trades of a company that were carried out on the days on which forwards or futures were typically delivered[6]. These days were determined by looking at so-called clearing accounts and their trading activity.

Fifth, we use the share of EUAs traded internally compared to the total trading volume of a company. We generally define *intra-firm trades* as EUAs, which were transferred across installations of the same company (level L1). Trading between OHAs that are linked to the same installation (trading inside an installation) is not taken into account, because such a trade is considered an administrative internal trade, which would not provide information on active participation in the EU ETS.

The EU ETS allows companies' intra-organizational trading to transfer allowances from one subsidiary to another within and across country borders. Of course, from the overarching organizations' perspective such a strategy minimizes compliance costs and contributes to the efficiency of the EU ETS. More generally, companies might have reasons to transfer allowances internally beyond compliance alone, such as the reduction of transaction costs, a lack of trading skills in certain parts of the organization, or a decision-making authority that resides on a corporate level rather than the subsidiary level. Due to the immature state of the EU ETS in its initial phases, the search costs to find market participants to trade with and the information costs to gain knowledge about the functioning of the EU ETS may have been relatively high (Heindl, 2017; Jaraitė-Kažukauskė and Kažukauskas, 2015). Thus, while internal transfers reflect cost-minimizing behaviour, they also lower the trading volume on market.

Sixth, we examine a company's transaction between February and April (*4th quarter trading*). During this fourth quarter of a trading year, companies know the exact amount of EUAs they need to surrender to be in compliance for the previous year. We therefore consider companies with a high share of transactions during the fourth quarter of a trading year to be rather passive users of the EU ETS. Our analysis of 4th quarter trading includes external transfers during this period only. That is, internal company transactions and internal transactions within the same national owner were not taken into account. This is mainly because some companies may use strategic trading accounts and run all their trading for all installa-

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6 Forwards: 30/11 01/12 2005, 30/11 01/12 2006, 30/11 03/12 2007, 28/11 01/12 2008, 30/11 01/12 2009, 30/11 01/12 2010, 30/11 01/12 2011, 30/11 03/12 2012, 29/11 02/12 2013, 28/11 01/12 2014.
Futures: 21-23/12 2005, 18-22/12 2006, 17-19/12 2007, 15-19/12 2008, 14-18/12 2009, 20-23/12 2010, 20-23/12 2011, 17-21/12 2012, 17-20/12 23/12 2013, 16-19/12 22-23/12 2014.

tions via these accounts. In this case, this trading account would deliver the necessary allowances to the individual installations in the last quarter for surrendering, which would lead to a high trading volume of these companies. Without this correction, companies which employ such an internal trading strategy may have erroneously classified as being passive users of the EU ETS.

These six indicators of active use of emissions trading refer to the aggregate volumes of sales and purchases, i.e. our analyses do not distinguish between sales and purchases. Yet, following the literature in related contexts (e.g. Zaklan, 2013; Jaraitė-Kažukauskė and Kažukauskas, 2015; Liu et al., 2016), our analyses distinguish between net buyers and net sellers[7]. Net buyers (net sellers) are defined as companies where in a particular year the amount of free allocation is below (exceeds) verified emissions. For firms which do not trade, we set all variables where the trading volume is in the denominator to zero.

3.1.5 Explanatory variables

Our choice of explanatory variables and control variables (see also Table 6) is guided by the existing literature and availability of data.

First, we account for companies' incentives to actively use the market. To do so, our set or explanatory variables includes the *net position*, which we define as the absolute value of the difference between the amount of allowances allocated for free and verified emissions. Hence, net position takes on nonnegative values, and corresponds to a net deficit for buyers and to a net surplus for sellers. Depending on its net position, a company may be classified as a net seller in one year, and a net buyer in another year.[8]

Companies with a higher *net surplus* need to buy relatively fewer allowances or can sell more allowances on the market to be in compliance. Similarly, companies with a net deficit must purchase allowances (or reduce emissions) to be in compliance. The existing literature finds companies' net surplus to be related with market participation and transaction frequency (e.g. Martin et al., 2015, Jaraitė-Kažukauskė and Kažukauskas, 2015; Zaklan et al., 2013; Cludius, 2018). We

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7 Thus, ignoring potential endogeneity issues.

8 We excluded all observations where verified emissions and allocation were both zero because, for example, these represent installations which ceased to operate but still appear in the EUTL.

therefore expect companies with a higher *net surplus* or with a higher *net deficit* to spur active use of the EU ETS[9].

Second, we include a dummy variable for *carbon leakage*, which is set to 1 if a company belongs to a sector categorized as being at risk of carbon leakage under the EU ETS rules.[10] These companies are more likely to face pressure from import competition, thus providing stronger incentives to pursue a revenue-seeking strategy rather than a compliance-seeking strategy when it comes to emission allowances trading.

Third, *energy* is a dummy variable which takes on the value of 1 if the company belongs to the energy sector (based on NACE codes). In general, since many companies from the energy sector are experienced in trading energy products, they are expected to employ this know-how for profit-seeking strategies in the trading of EU allowances. Furthermore, since electricity generators typically sell electricity via futures markets, they use the futures markets for EUAs to hedge their positions and hence mitigate the financial risks associated with future emissions. Previous studies (Cludius, 2018; Jaraitė-Kažukauskė and Kažukauskas, 2015; Zaklan, 2013) find that sector affiliation is related to EU ETS market participation. Companies from industry sectors are generally less likely to actively participate – with the exception of a number of companies from trade-exposed sectors, such as oil refining (Betz and Schmid, 2016) – and are expected to be less likely to use the EU ETS actively.

Fourth, we use *profitability*, which is calculated as a company's revenues per employee. We assume that a company which enjoys higher per-capita revenues is also more likely to pursue a more active trading strategy.

Fifth, our set of explanatory variables includes the number of *employees*. The existing literature typically finds that smaller companies are less likely to participate in the EU ETS (e.g. Zaklan (2013), Jaraitė-Kažukauskė and Kažukauskas (2015), Jaraitė et al. (2010), Sandoff and Schaad (2009). Similarly, we assume SMEs are less likely to be active users of the EU ETS.

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9 In line with the literature, our definition of net surplus and net deficit does not account for EUAs which were banked from previous years, or borrowed from subsequent years.

10 The carbon leakage list is regularly updated. For our analysis it included a large number of products from different industry sectors, including refineries, iron and steel, metals, aluminum, cement and lime, glass and ceramics, pulp and paper, chemicals as well as the production of food, textiles and machinery.

Table 6: Description of dependent variables and covariates

Label	Description	Data base
Dependent variables		
Total transactions	Transaction volume in tons of EUAs in trading year t.	EUTL
Number of transactions	Number of transactions in trading year t.	EUTL
Intermediaries	Number of intermediaries used in trading year t.	EUTL
Forwards & Futures	Estimated transactions via forwards and futures as a share of total transactions in trading year t (in tons of EUAs).	EUTL
Intra-firm transfers	Transactions between installations of the same firm (level 2) trading year t (in tons of EUAs).	EUTL
4th quarter transactions	Transactions between February and April of year t as a share of total transactions in trading year t.	EUTL
Explanatory variables		
Net position	Allocation minus verified emissions in year t (absolute value in tons of EUAs)	EUTL
Carbon leakage	Dummy =1, if firm belongs to carbon leakage sector.	EUTL
Energy	Dummy = 1, if firm belongs to energy sector according to NACE (rev2) classification (35.00 to 35.30).	ORBIS
Profitability	Calculated as revenues divided by number of employees in year t.	ORBIS
Employees	Number of employees.	ORBIS
Control variables		
Installations	Number of installations	EUTL
Period	Dummy for each trading period (period 1 is the base period).	EUTL
Region 1	Austria (AT), Germany (DE), Lichtenstein (LI)	
Region 2	Belgium (BE), France (FR), Netherlands (NL)	
Region 3	Greece (GR), Cyprus (CY), Spain (ES), Italy (IT), Malta (MT), Portugal (PT),	
Region 4	Estonia (EE), Lithuania (LT), Latvia (LV), Poland (PL)	

Label	Description	Data base
Region 5	Czech Republic (CZ), Hungary (HU), Slovenia (SI), Slovakia (SK)	
Region 6	Denmark (DK), Finland (FI), Iceland (IS), Norway (NO), Sweden (SE)	
Region 7	United Kingdom (UK), Ireland (IE)	
Region 8	Bulgaria (BG), Croatia (HR), Romania (RO)	

To control for intra-firm trading potential we include the *number of installations*. We further captured differences across trading periods by including a separate dummy for the three trading periods (using period 1 as the base period). Similarly, we controlled for region-specific effects by including dummy variable for the regions. Region 1, which consists of the German speaking countries, is used as the base category.

For the econometric estimations, we use the natural logarithm of *total transactions*, *forwards & futures, 4th quarter transactions, net surplus / net deficit, profitability,* and *employees.*

Table 7 provides an overview of the descriptive statistics of the dependent and explanatory variables described above. Similarly, Tables B2a and B2b in Appendix B show the descriptive statistics separately for net buyers and net sellers.

Table 7: Descriptive statistics

	Mean	Standard deviation	Min	Max	N
Total transactions	323304.10	6016094	0	544000000	95510
Number of transactions	1.95	10.25	0	816	95510
Intermediaries	0.14	0.63	0	41	95510
Forwards & futures	41731.65	1303631	0	146000000	95510
Intra-firm transfers	453422.50	5688301.00	0	297000000	24422
4th quarter trading	1008427.00	10700000.00	0	879000000	21181
Carbon leakage	0.39	0.49	0	1	90687
Energy	0.23	0.42	0	1	95510
Profitability	13.24	133.64	-21.76	13608	52290
Employees	1495.20	12499.16	0	610076	56185
Number of installations	1.78	2.64	1	56	95510

	Mean	Standard deviation	Min	Max	N
Region 1 (AT, DE, LI)	0.16	0.37	0	1	95510
Region 2 (BE, FR, NL)	0.17	0.37	0	1	95510
Region 3 (GR, IT, PT, ES, CY, MT)	0.25	0.43	0	1	95510
Region 4 (EE, LT, LV, PL)	0.10	0.29	0	1	95510
Region 5 (CZ, HU, SI, SK)	0.09	0.28	0	1	95510
Region 6 (DK, FI, IS, NO, SE)	0.10	0.30	0	1	95510
Region 7 (UK, IE)	0.09	0.29	0	1	95510
Region 8 (BG, HR, RO)	0.04	0.20	0	1	95510

3.2 Econometric models

We use panel econometric models to exploit the (unbalanced) panel structure of our data. In particular, we employ different econometric models depending on the nature of the dependent variable.

First, to reflect the count nature of the dependent variables *number of transactions* and *number of intermediaries* we estimate panel Poisson models. Poisson models rely on equidispersion, i.e. the conditional mean is assumed to be equal to the conditional variance. Negative binomial models, for example, do not hinge on this assumption. However, because they involve less restrictive distributional assumptions, we chose Poisson models as our preferred method to estimate the count data models and report findings from estimating negative binomial models in section 4.3 (robustness checks). We estimate the Poisson model via conditional maximum likelihood methods as implemented in Stata.

Second, for *total transactions*, *use of forwards and futures* and *intra-firm transactions*, our models reflect the fact that for a substantial portion of observations, the outcome is zero. More specifically, the share of zeros is about 49% for total transactions, 91% for the use of forwards and futures, and 66% for intra-firm transactions for the final samples available in the respective multivariate analyses. These zeroes reflect companies' decisions not to participate in the market, or not to trade in forwards and futures, for example. In this case, running ordinary least squares models would result in biased parameter estimates. We therefore employ so-called “double hurdle" models. "Double hurdle" models explicitly model the "participation decision", i.e. whether companies decide to participate in the market at all (whether the dependent variable takes on the value of zero or not), and the "intensity decision", i.e., to which extent companies use the market. The participation decision is modelled as a Probit, and the intensity equation as a Tobit Model. Double hurdle models are preferable to standard Tobit models because the latter involve more restrictive distributional assumptions. For example, unlike double hurdle models, Tobit models require the same set of variables entering the participation equation and the intensity equation. In addition, in Tobit models, the sign of the coefficient associated with a particular variable must be the same in both equations. Our specification of the double hurdle model also accounts for endogeneity between both equations. For example, when deciding on whether to use derivatives markets or not, may depend on how many EUAs a firm wants to buy or sell via these markets.

Third, to analyze 4^{th} quarter trading, we use the share of trades during the 4^{th} quarter of a trading year in total transactions. Hence, the dependent variable is a fraction taking on values in the [0,1] range. We therefore employ a fractional logit model (FLM) to estimate these the 4^{th} quarter trading model. The FLM, originally developed by Papke and Wooldridge (1996), is applicable for models where the dependent variable takes on values between zero and one. In particular, the FLM allows the data generating process to differ at both boundaries of the dependent variable (i.e., at 0 and 1)

For all regressions, our preferred models allow for unobserved heterogeneity to be correlated with the explanatory variables and covariates. We therefore use fixed-effects estimators as our preferred estimation method. Fixed-effects estimators involve less restrictive distributional assumptions than random-effects estimators, but for the Poisson Model, they do not allow estimating parameters associated with time-invariant explanatory variables or covariates such as sector or country affiliation. For these reasons, we employ the correlated random-effects estimator (CRE) developed by Mundlak (1978). To control for time-invariant unobserved heterogeneity, the CRE includes the company-specific means of the time-varying variables in the regression equation.[11] Because we are concerned about the effects of unobserved heterogeneity correlated with the explanatory variables, our presentation and interpretation of results will focus on the time-varying effects (i.e., the "within estimators" or fixed-effects results). Section 4.3 reports the findings from estimating the fixed-effects panel econometric models.

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11 Therefore, some authors interpret the Mundlak terms, which pick up the "between variation" to reflect the long run effects, while the time-varying variables, which pick up the "within variation", to reflect the short run effects.

4 Results

We first display and briefly comment on the time path of our dependent variables. Then we present the result of the multivariate analyses.

4.1 Development of dependent variables over time

In the following graphs, we show graphs for the group of net buyers and net sellers respectively and distinguish between energy and non-energy sectors, as well as the most relevant industry sectors (in terms of observations and greenhouse gas emissions within the EU ETS). Again, we use the NACE code (Rev2) to classify companies[12,13]. For scaling reasons, we display *use of forwards and futures* and *intra-firm trading* in relation to verified emissions.

The annual volume transacted per company has generally increased over time (Figure 4). This trend applies to both energy and non-energy firms – and to net buyers as well as net sellers. Energy companies transacted higher volumes than non-energy firms, particularly in the group of net buyers. When looking at net sellers this difference erodes for the first years under consideration. In fact, for a number of dependent variables, we notice a larger difference between energy and non-energy firms in the group of net buyers compared to the group of net sellers. This may be related to the fact that the energy sector is very diverse with a number of large firms and many small utilities. How these firms are divided into net buyers and net sellers influences the shape of the curves.

Regarding individual industry sectors, refineries, metals and cement, lime and gypsum are the sectors accounting for the firms transacting the highest volumes both in the group of net sellers and net buyers. This is not least related to the fact that large firms with higher emissions per firm operate in these sectors compared to other industry sectors. The annual volumes in the group of net sellers is higher than those in the group of net buyers, which reflects the fact that these sectors on average received more allowances than needed to cover their emissions in the analysis time frame (EEA 2020).

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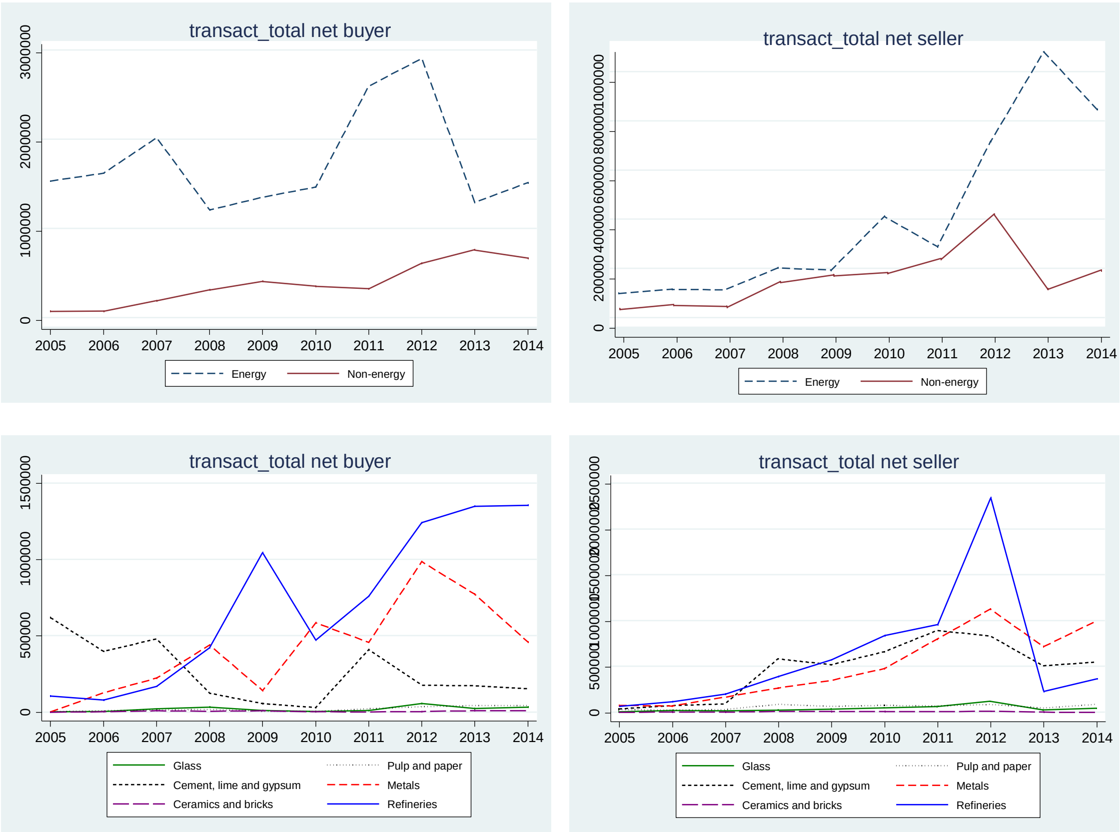
12 The following NACE codes (Rev. 2) were used to classify the sectors: energy: 35.00 to 35.30; cement, lime and gypsum: 23.51 to 23.69; metals (manufacture of basic metals (including casting and non-ferrous metals)) 2410 to 2454; glass: 23.11 to 23.19; refineries: 19.20; pulp and paper: 17.11 to 17.29; ceramics and bricks (manufacture of clay building products): 23.31 to 23.32.

13 See Table B1 in Appendix B for descriptive statistics of sector affiliation by net position.

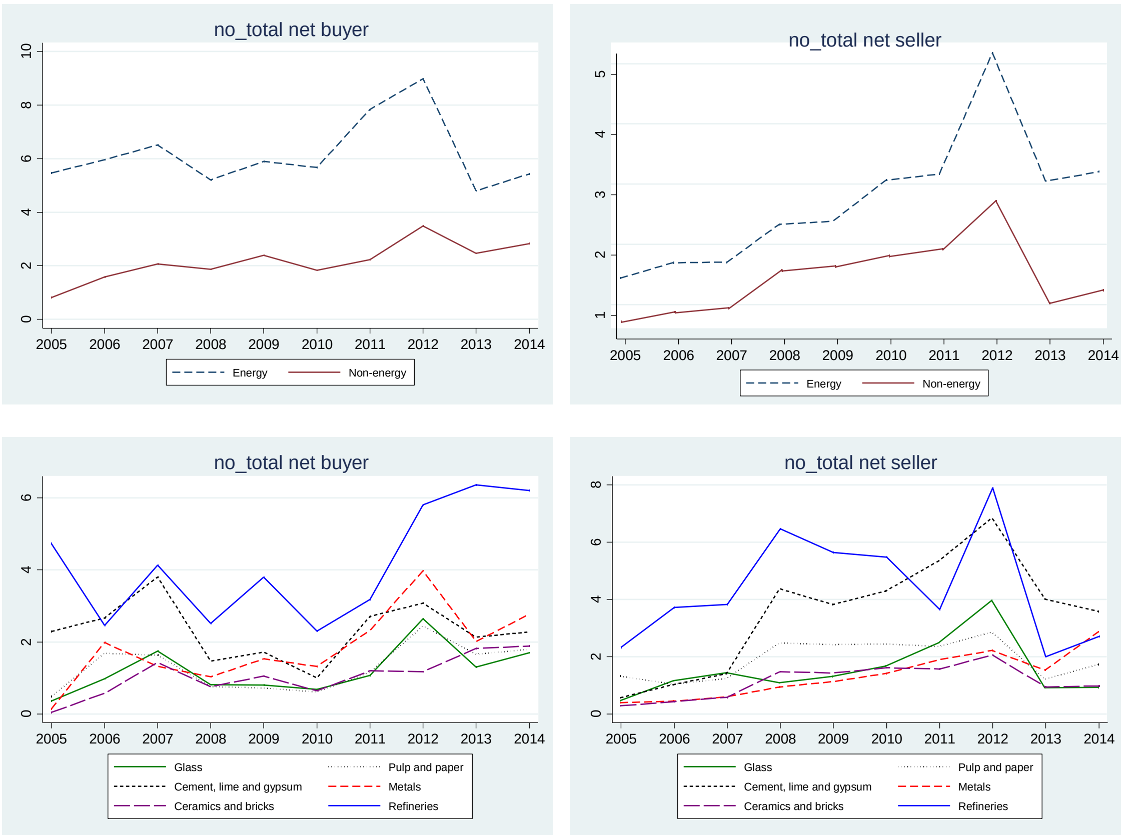
For this and other dependent variables, we observe spikes/breaks in the trading year 2012 or 2013 and thus covering the transition from the second to the third ETS trading period). A number of reasons may explain this break. For example, end-of-period and beginning-of-period effects, such as the fact that borrowing is not allowed in the last year of a trading period or that the setup of the system changed significantly with the start of the third trading period (e.g. a much higher share of allowances auctioned). Furthermore, in the same timeframe, national ETS registries were replaced by an EU-wide registry (cf. Section 3.1.1) with as-associated effects related to data migration.

Figure 4: Average transaction volume per company in energy and selected industry sectors for net buyers and net sellers



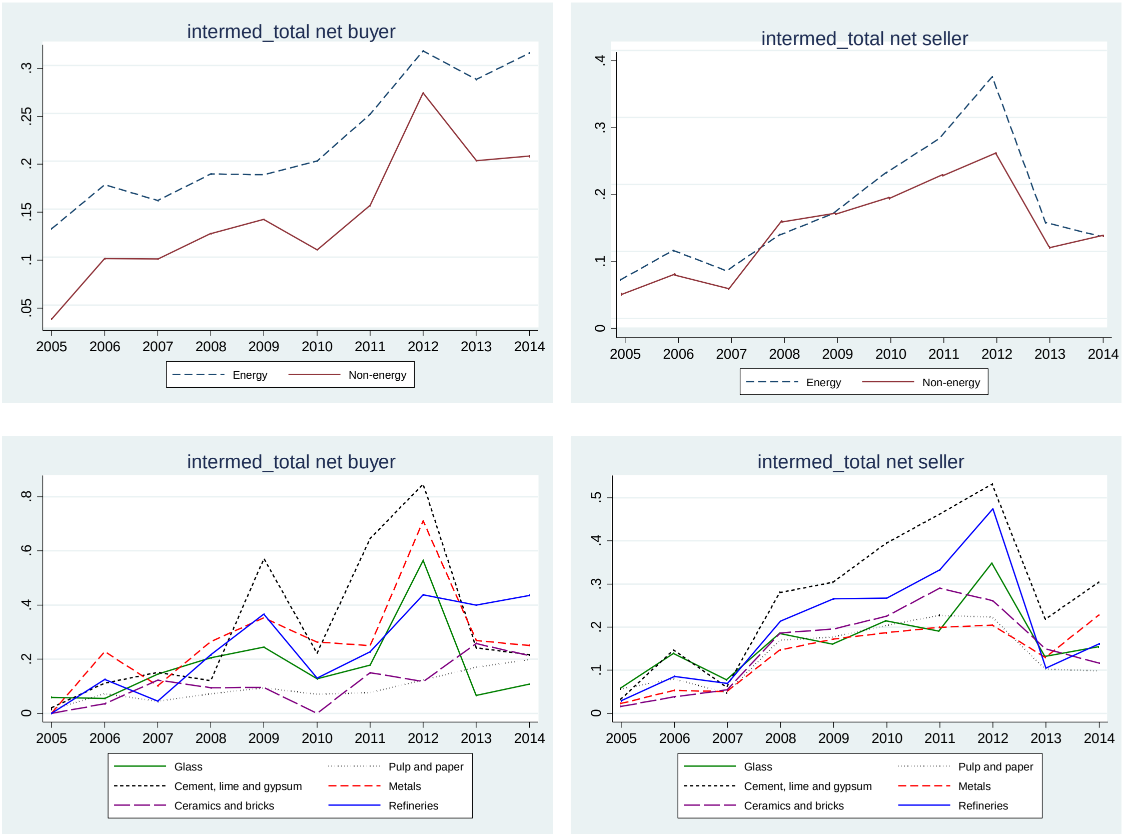
The number of transactions a firm carries out in a year has generally increased over time (Figure 5). This trend applies to both energy and non-energy firms – and to net buyers as well as net sellers. Energy companies transacted more frequently than non-energy firms, both as net buyers and net sellers. Regarding individual industry sectors, refineries are most active in terms of number of transactions, both as net buyers and net sellers. Similar to energy companies, refineries trade their product on globalized markets characterized by a high frequency of trading and volatility, which may explain the relatively higher activity also on the market for emission allowances. The cement, lime and gypsum sector emerges as another active sector in terms of number of transactions. On average, this sector received more freely allocated allowances than needed for compliance in every analysis year with the exception of 2007 (EEA 2020), which may explain this trend. Again, we observe a spike in the trading year 2012.

Figure 5: Average total number of transactions per firm in energy and selected industry sectors for net buyers and net sellers.



When looking at the number of intermediaries used (Figure 6), a diverging picture emerges for net buyers and net sellers. Generally, the amount of intermediaries used per firm increases over time. However, in the group of net sellers, twice as many intermediaries are used per firm than in the group of net buyers. Amongst the net buyers, energy firms are more likely to use an intermediary than non-energy firms. This may be related to their buying EUA futures in order to hedge future electricity sales. Amongst net sellers energy and non-energy firms are equally likely to use intermediaries. When looking at individual industry sectors, again the refinery sector emerges as one of the most active when using intermediaries (in the group of net buyers), this also applies to the glass sector. When looking at the group of net sellers, individual industry sectors show similar trajectories in terms of using intermediaries. The spike in the 2012 trading year is again visible.

Figure 6: Average number of intermediaries used per firm in energy and selected industry sectors for net buyers and net sellers

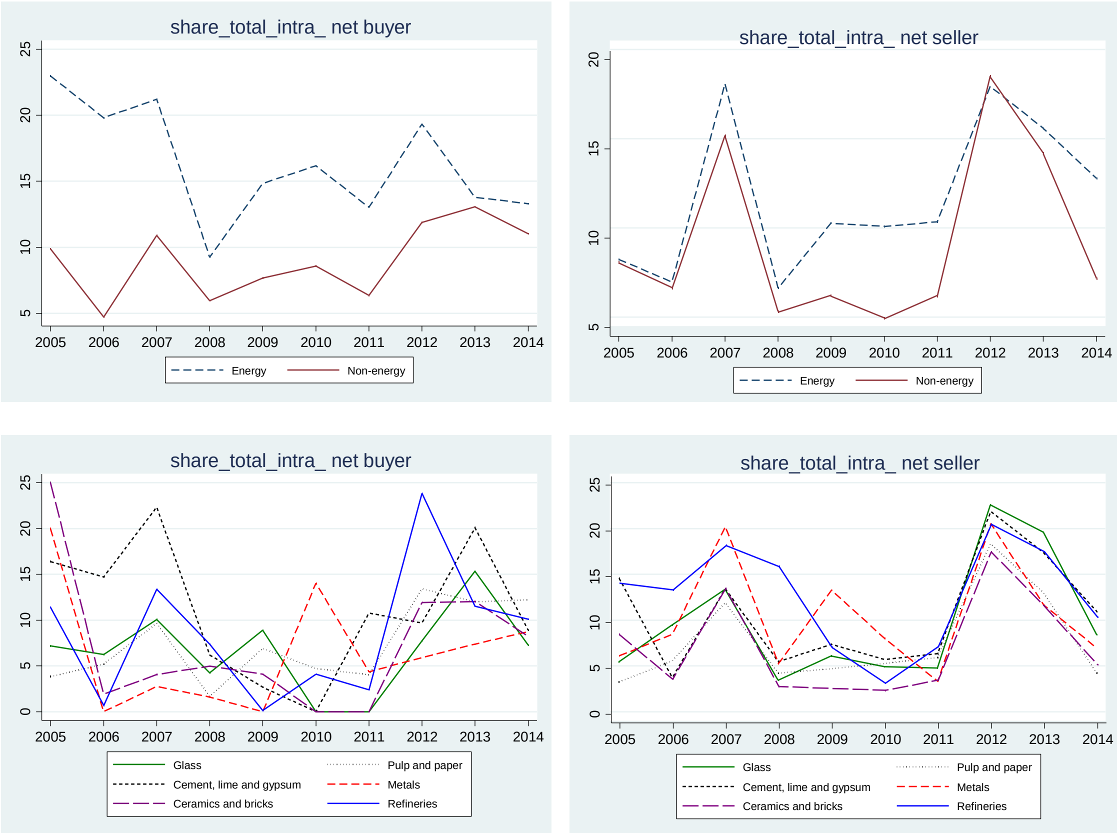


The share of transactions via forwards and futures per firm (Figure 7) does not follow a clear trend over time. In general, energy and non-energy firms exhibit similar shares of transactions via forward and future markets, both for net buyers and net sellers. There is substantial heterogeneity amongst individual industry sectors.

Figure 7: Estimated average transactions via forwards and futures per firm as a share of total transactions in energy and selected industry sectors

The average share of trades within a firm (compared to the overall transaction volume) exhibits a similar pattern for energy and non-energy firms in the group of net sellers (Figure 8). For net buyers, energy firms transacted a larger share internally at the beginning of the EU ETS compared to non-energy firms, while the share of internal trades converges between energy and non-energy firms over time. The individual industry sectors generally show similar trajectories, while the heterogeneity is larger for net buyers than net sellers. We again observe a spike in the majority of curves in 2012.

Figure 8: Estimated average share of trades within firms for net buyers and net sellers



Finally, we observe that energy firms carry out a larger share of their transactions between February and April (just before the point in time when permits have to be surrendered) than non-energy firms, both in the group of net buyers and net sellers (Figure 9). Looking at individual industry sectors, the refinery sector again sticks out in the group of net buyers. In the group of net sellers, the trajectories are more similar between individual industry sectors. In general, the amount of transactions carried out between February and April increases over time and exhibits the same spike in the years 2011, 2012 or 2013 (dependent on the curve under consideration).

Figure 9: Average transactions per firm between February and April as a share of total transactions (*4th quarter trading*) for net buyers and net sellers

4.2 Results of multivariate analysis

In this section, we present the findings for our preferred model specifications in Table 8, Table 9, Table 10, Table 11, and Table 12. Robust standard errors are reported in parentheses below the parameter estimates.

Total transactions

Table 8 presents the findings from estimating a double hurdle model, where the first hurdle captures participation, i.e., whether a company engages in transactions of EUAs in a particular period or not. For those companies that engage in this market, the second hurdle captures the intensity of transaction, i.e. the transaction volume. Table 8 implies that companies with a higher *net position*, companies from the *energy sector*, companies with higher *profitability*, more *employees*, and more *installations*, are more likely to engage in transactions under the EU ETS (i.e. to pass the participation hurdle) and to also transact larger amounts (i.e.

higher intensity). Calculating the average marginal effects for net buyers [net sellers], we find that an increase in the net deficit [net surplus] by one percent increases the probability to engage in transactions by about 2.7 [5.2] percentage points. Similarly, belonging to the *energy* sector (rather than the non-carbon leakage industry sector) increases the probability to engage in transactions by 7.8 [6.1] percentage points for net buyers [net sellers].

The coefficients presented in Table 8 reflect the marginal effect (or discrete probability effects for dummies) conditional on the having decided to participate in allowance transactions. That is, for companies engaging in transactions, an increase in the net deficit [net surplus] by 1 percent, increases the volume of EUA transactions by about 0.53 [0.56] percent for net buyers [net sellers]. Belonging to the *energy* sector (rather than the non-carbon leakage industry sector] increases the total transaction volume by about 100 [65] percent for net buyers [net sellers].

Companies included in the *carbon leakage* list are found to increase the probability to engage in allowance transactions and to increase the total trading volume for net buyers and net sellers. However, we find no evidence that for *carbon leakage* companies, which are net buyers, the probability to engage in transactions differs from non-leakage industry companies.

For net buyers and net sellers, the probability of engaging in allowance transactions and transaction intensity were higher in trading period 2 compared to period 1 and period 3. For net buyers, the probability of passing the participation hurdle and transaction intensity in period 3 was higher than in period 1, but lower than in period 2. In most regions, transaction participation and intensity were typically weaker than in the German-speaking base region. Only in the Nordic Countries was the probability engaging in allowance transactions higher than in the base region. Finally, the coefficient associated with the Mills' ratio is statistically significant for net buyers and net sellers, suggesting that estimating the participation and intensity equation separately would have resulted in biased parameter estimates.

Table 8: Multivariate results for *total transactions* (CRE double hurdle models)

	Total transactions			
	Net buyers		***Net sellers***	
	Participation	***Intensity***	***Participation***	***Intensity***
Net position	0.0769***	0.5336***	0.1557***	0.5624***
	(0.009)	(0.028)	(0.009)	(0.023)
Carbon leakage	-0.0040	0.4352***	0.1259***	0.4276***
	(0.027)	(0.046)	(0.020)	(0.036)
Energy	0.2184***	0.9758***	0.1780***	0.6457***
	(0.037)	(0.074)	(0.028)	(0.047)
Profitability	0.0573**	0.1358***	0.0300	0.1303***
	(0.028)	(0.049)	(0.022)	(0.034)
Employees	0.0781***	0.2086***	0.0212	0.0748**
	(0.030)	(0.056)	(0.021)	(0.035)
Installations	0.0226***	0.0541***	0.0394***	0.0819***
	(0.004)	(0.005)	(0.004)	(0.005)
Period 2	0.1912***	0.7156***	0.5952***	1.3662***
	(0.036)	(0.070)	(0.020)	(0.076)
Period 3	-0.4539***	-0.7962***	0.0115	0.2071***
	(0.034)	(0.123)	(0.026)	(0.046)
Region 2 (BE, FR, NL)	-0.1090***	-0.5413***	-0.1983***	-0.4132***
	(0.041)	(0.084)	(0.032)	(0.058)
Region 3 (GR, IT, PT, ES, CY, MT)	0.0148	-0.1512***	-0.0122	-0.2806***
	(0.034)	(0.057)	(0.029)	(0.046)
Region 4 (EE, LT, LV, PL)	-0.3249***	-0.8100***	-0.3732***	-0.3847***
	(0.058)	(0.124)	(0.037)	(0.072)
Region 5 (CZ, HU, SI, SK)	-0.0785*	-0.5647***	-0.0351	-0.2351***
	(0.045)	(0.078)	(0.033)	(0.052)

	Total transactions			
	Net buyers		**Net sellers**	
	Participation	**Intensity**	**Participation**	**Intensity**
Region 6 (DK, FI, IS, NO, SE)	0.3285***	-0.1418	0.0829**	-0.5201***
	(0.046)	(0.103)	(0.036)	(0.055)
Region 7 (UK, IE)	-0.0236	-0.0996	-0.0702*	-0.5355***
	(0.045)	(0.071)	(0.038)	(0.058)
Region 8 (BG, HR, RO)	-0.0126	0.0004	-0.2307***	-0.0596
	(0.059)	(0.100)	(0.048)	(0.081)
Mill's ratio		3.1657***		2.1594***
		(0.397)		(0.215)
Mean net position	0.0440***	0.4323***	0.1176***	0.5738***
	(0.010)	(0.020)	(0.010)	(0.021)
Mean profitability	-0.0283	0.0563	-0.1080***	-0.0429
	(0.030)	(0.051)	(0.023)	(0.038)
Mean employees	-0.0715**	0.0469	-0.0667***	0.0017
	(0.030)	(0.055)	(0.022)	(0.035)
Constant	-0.9967***	-2.9255***	-2.5431***	-3.7353***
	(0.069)	(0.544)	(0.060)	(0.481)
N	**13388**	**13388**	**25680**	**25680**

* $p < 0.10$; ** $p < 0.05$, *** $p < 0.01$.

Transaction frequency

Table 9 reports in column two (for net buyers) and in column three (for net sellers) the findings from estimating a Poisson count data model capturing the number of transactions. The results reported in Table 9 for *transaction frequency* suggest that a higher *net position* is associated with more transactions. For net buyers and net sellers, companies in a *carbon leakage* or the *energy* sector trade more frequently. Results of Wald tests provide evidence that companies in the energy sector trade more frequently than companies from "leakage sectors". In addition, more profitable and larger firms (as measured by the number of *employees*) trade more often, but the coefficients are statistically significant for net buyers only. Companies with more installations are also found to trade more often. The coefficients of the dummies for the trading periods suggest that for net buyers and net sellers the average number of transactions has increased in period 2 and period 3 compared to period 1. Results of a Wald test further suggest that transaction frequency was higher in period 2 than in period 3 for net sellers. For net buyers, we found no statistically significant evidence for a difference in transaction frequency between period 2 and period 3. The findings for the regional dummies generally provide no evidence for differences in transaction frequency. Only the Nordic countries (region 6) in the panel of net buyers were found to trade more than the German speaking countries (base region 1).

For most explanatory variables, the size effects are rather substantial. For example, the point estimate associated with *energy* suggest that the mean number of transactions by net buyers in the energy sector is about 66 percent (= exp(0.5072) = 1.66) higher than in industry sectors which are not subject to carbon leakage.

The findings for the Mundlak terms suggest that employing a pure random-effects estimator would lead to biased and inconsistent parameter estimates.[14]

Use of intermediaries

The third and fourth column of Table 9 present the findings from estimating a Poisson count data model capturing the number of intermediaries used by companies. Qualitatively, the findings for the *use of intermediaries* are quite similar to those for *transaction frequency*. Companies with a higher *net position,* or companies belonging to a *carbon leakage* or to the *energy* sector use more intermediaries. *Profitability* and *employees* are positively related with the use of intermediaries, but only *profitability* for net sellers turns out to be statistically significant. Companies with more installations also use more intermediaries. Wald-tests imply that the use of intermediaries has increased for net buyers and net sellers in trading periods 2 and 3 compared to period 1. Net sellers also tend to use fewer intermediaries in period 3 compared to period 2, but for net buyers there appears to be no difference between periods 2 and 3. Unlike for *transaction frequency*, results for the region dummies suggest substantial heterogeneity in the *use of intermediaries* across regions. Except for region 5, most regions tend to use fewer intermediaries than the German-speaking region.

14 Formally, the test is similar to a Hausman test and tests whether all parameters associated with the Mundlak terms are jointly equal to zero.

Table 9: Multivariate results for *transaction frequency* and *use of intermediaries* (CRE Poisson models)

	Transaction frequency (number of transactions)		***Use of intermediaries (number of intermediaries)***	
	Net buyers	***Net sellers***	***Net buyers***	***Net sellers***
Net position	0.0416**	0.1390***	0.0356**	0.1345***
	(0.019)	(0.015)	(0.016)	(0.019)
Carbon leakage	0.1475***	0.1624***	0.1927**	0.1900***
	(0.049)	(0.050)	(0.091)	(0.073)
Energy	0.5072***	0.3304***	0.3923***	0.2518**
	(0.082)	(0.072)	(0.128)	(0.103)
Profitability	0.2035***	0.0372	0.1106	0.0921**
	(0.075)	(0.065)	(0.169)	(0.042)
Employees	0.2960***	0.0615	0.2824	0.0030
	(0.089)	(0.040)	(0.186)	(0.049)
Installations	0.1529***	0.1742***	0.0200**	0.0174*
	(0.012)	(0.014)	(0.010)	(0.010)
Period 2	0.3845***	0.6404***	0.5446***	1.1575***
	(0.092)	(0.046)	(0.103)	(0.055)
Period 3	0.3319***	0.4166***	0.5874***	0.9399***
	(0.107)	(0.064)	(0.104)	(0.083)
Region 2 (BE, FR, NL)	-0.0671	0.0704	-0.6220***	-0.4695*
	(0.123)	(0.207)	(0.196)	(0.280)
Region 3 (GR, IT, PT, ES, CY, MT)	0.0111	0.0352	-0.5579***	-0.0947
	(0.062)	(0.084)	(0.117)	(0.123)
Region 4 (EE, LT, LV, PL)	-0.1214	-0.1759**	-0.2251	-0.3707***
	(0.100)	(0.087)	(0.159)	(0.125)
Region 5 (CZ, HU, SI, SK)	-0.0373	-0.0252	0.7674***	0.3272***
	(0.079)	(0.078)	(0.111)	(0.108)
Region 6 (DK, FI, IS, NO, SE)	0.4143***	0.0577	-0.8252***	-0.7835***
	(0.107)	(0.119)	(0.206)	(0.155)

	Transaction frequency (number of transactions)		*Use of intermediaries (number of intermediaries)*	
	Net buyers	***Net sellers***	***Net buyers***	***Net sellers***
Region 7 (UK, IE)	-0.0594	-0.1523*	-0.7456***	-0.9551***
	(0.111)	(0.085)	(0.172)	(0.145)
Region 8 (BG, HR, RO)	0.0815	0.0220	0.2945*	-0.1678
	(0.101)	(0.114)	(0.154)	(0.168)
Mean net position	0.1129***	0.1366***	0.0951***	0.1418***
	(0.026)	(0.025)	(0.030)	(0.033)
Mean profitability	-0.0034	0.0510	0.0287	-0.1424**
	(0.078)	(0.066)	(0.141)	(0.056)
Mean employees	-0.1236	0.0426	-0.1373	0.0665
	(0.090)	(0.056)	(0.135)	(0.060)
Constant	-2.7905***	-3.5578***	-4.3378***	-5.2693***
	(0.149)	(0.140)	(0.233)	(0.208)
N	**10979**	**24077**	**10979**	**24077**

* $p < 0.10$; ** $p < 0.05$, *** $p < 0.01$.

Use of forwards and futures

The findings from estimating a double hurdle model capturing companies' use of forwards and futures are presented in Table 10. The participation equation describes engagement in those derivatives markets. The intensity equation captures the volume of forwards and futures for those companies that engage in derivative markets. Table 10 implies that companies with a higher *net position* are more likely to engage in the forwards and futures markets and to also use these derivatives markets more intensively. Calculating the average marginal effects for net buyers [net sellers], we find that in increase in the net deficit [net surplus] increases the probability of engaging in the derivatives market by about 1.0 [0.7] percentage points. The coefficients presented in Table 10 suggest, for example, that for companies engaging in derivatives markets, an increase in the net deficit [net surplus] by 1 percent, increases the volume of EUAs traded in the derivatives market by about .66 [0.22] percent for net buyers [net sellers]. For net sellers, we find companies of sectors included in the *carbon leakage* list to be positively related with engaging in the derivatives market and to use this market more intensely compared to the base category of companies belonging to the non-carbon leakage industry sectors. Net sellers and net buyers belonging to the *energy* sector are more likely to engage in derivatives markets and also to use these markets more intensively than companies from the base sector. Belonging to the *energy* sector (rather than the non-carbon leakage industry sector) increases the probability to engage in the derivatives market by about 3 [4] percentage points for net buyers [net sellers]. Next, more profitable net buyers and net sellers are more likely to engage in the market for forwards and futures, and also to use these markets more extensively – yet for net buyers the coefficient in the intensity equation is just shy of being statistically significant at conventional levels. Similarly, larger companies (as measured by the number of *employees*) and companies with more installations are more likely to engage in the derivatives markets, and also to employ them more intensively, but for net sellers, the coefficient associated with *employees* is not statistically significant. Likewise, for net sellers the coefficient associated with *installations* is not significant in the intensity equation.

For net buyers and net sellers, engaging in and using of derivative markets was stronger in trading period 2 compared to periods 1 and 3, and weaker in trading period 3 than in period 1. In all regions, participation and intensity were weaker than in the German-speaking base region. The coefficient associated with the Mills' ratio is statistically significant, suggesting that estimating the participation and intensity equations separately would have resulted in biased parameter estimates. Finally, most of the 'Mundlak terms' turn out to be statistically significant, providing evidence in favor of the fixed effects estimator.

Table 10. Multivariate results for *use of forwards and futures* (CRE double hurdle models)

	Use of forwards and futures			
	Net buyers		***Net sellers***	
	Participation	***Intensity***	***Participation***	***Intensity***
Net position	0.0770***	0.6553***	0.0497***	0.2153**
	(0.016)	(0.105)	(0.014)	(0.084)
Carbon leakage	-0.0228	0.2525	0.1802***	0.2794*
	(0.045)	(0.175)	(0.032)	(0.160)
Energy	0.2405***	2.7028***	0.3344***	0.7091**
	(0.054)	(0.474)	(0.041)	(0.326)
Profitability	0.0958**	0.2506	0.0595*	0.1831*
	(0.045)	(0.163)	(0.034)	(0.110)

	Use of forwards and futures			
	Net buyers		**Net sellers**	
	Participation	**Intensity**	**Participation**	**Intensity**
Employees	0.1046**	0.8932***	0.0083	0.0099
	(0.050)	(0.187)	(0.035)	(0.100)
Installations	0.0092**	0.0386***	0.0096***	0.0057
	(0.004)	(0.015)	(0.004)	(0.012)
Period 2	0.3011***	2.7284***	0.5633***	1.7191***
	(0.055)	(0.447)	(0.033)	(0.642)
Period 3	-0.1565***	-0.6175**	-0.2138***	-0.8882***
	(0.055)	(0.272)	(0.050)	(0.238)
Region 2 (BE, FR, NL)	-0.2996***	-2.2635***	-0.1759***	-0.9721***
	(0.060)	(0.495)	(0.044)	(0.265)
Region 3 (GR, IT, PT, ES, CY, MT)	-0.5460***	-3.6706***	-0.2233***	-0.9786***
	(0.053)	(0.662)	(0.041)	(0.220)
Region 4 (EE, LT, LV, PL)	-0.4191***	-2.9678***	-0.5052***	-0.7456
	(0.089)	(0.590)	(0.055)	(0.556)
Region 5 (CZ, HU, SI, SK)	-0.4487***	-2.3680***	-0.3454***	-0.8323*
	(0.074)	(0.632)	(0.049)	(0.439)
Region 6 (DK, FI, IS, NO, SE)	-0.1195*	-0.3812**	-0.1492***	-0.6553***
	(0.062)	(0.181)	(0.050)	(0.180)
Region 7 (UK, IE)	-0.3687***	-1.9104***	-0.3339***	-1.4255***
	(0.065)	(0.459)	(0.053)	(0.440)
Region 8 (BG, HR, RO)	-0.6544***	-4.0631***	-1.0829***	-1.2069
	(0.114)	(0.970)	(0.099)	(1.046)
Mill's ratio		8.8391***		2.7136**
		(1.764)		(1.363)
Mean net position	0.0698***	0.7551***	0.1816***	0.8119***
	(0.017)	(0.111)	(0.017)	(0.179)
Mean profitability	-0.0568	0.5595***	-0.0601*	0.2135*

	Use of forwards and futures			
	Net buyers		Net sellers	
	Participation	Intensity	Participation	Intensity
	(0.048)	(0.163)	(0.036)	(0.115)
Mean employees	-0.0160	0.2104	0.0194	0.2920***
	(0.050)	(0.167)	(0.035)	(0.106)
Constant	-3.1815***	-27.0766***	-4.0174***	-7.6147
	(0.109)	(5.896)	(0.092)	(5.293)
N	**13428**	**13428**	**25680**	**25680**

* $p < 0.10$; ** $p < 0.05$, *** $p < 0.01$.

Intra-firm transfers

Table 11 reports the findings from estimating a double hurdle model capturing *intra-firm trading*. The results suggest that companies with a larger *net position* are more likely to transfer EUAs internally (participation equation), and to transfer more EUAs internally (intensity equation), yet only the findings for net seller are statistically significant. Compared to the base sector, belonging to a carbon leakage sector is statistically significantly related with internal transfers for net buyers, but not for net sellers. Net buyers of sectors on the *carbon leakage* list are less likely to trade internally, but to trade more intensively once they participate. *Energy* is positively related with participation, but does not appear to affect intensity of internal trading. We find more profitable companies to be more likely to trade internally and to trade more intensively, yet only the findings for net sellers turn out to be statistically significant at conventional levels. Company size as measured by the numbers of *employees* is positively related with participation and intensity for net buyers and net sellers, but not statistically significant for net sellers. As expected, net sellers and net buyers with more installations are more likely to trade internally and also to trade higher volumes of EUA internally, but for net sellers the coefficient in the intensity equation is just shy of being statistically significant. In period 2, net buyers and net sellers were more likely to trade internally than in period 1 and in period 3. In period 3, net buyers and net sellers were less likely to participate in internal trading than in period 1 and 2. We also find heterogeneity in the probability to trade internally and in internal transaction volume across regions. Except for companies located in the Nordic Countries, companies located in other regions were less likely to trade internally than companies located in the German-speaking countries.

Table 11. Multivariate results for *intra-firm transfers* (CRE double hurdle models)

	Intra-firm transfers			
	Net buyers		***Net sellers***	
	Participation	***Intensity***	***Participation***	***Intensity***
Net position	0.0240	0.0205	0.0905***	0.1162**
	(0.016)	(0.057)	(0.016)	(0.057)
Carbon leakage	-0.1159**	0.7529***	0.0427	0.0585
	(0.052)	(0.176)	(0.040)	(0.125)
Energy	0.1972***	-0.0131	0.1718***	0.0666
	(0.060)	(0.191)	(0.051)	(0.168)
Profitability	0.0803	0.2221	0.1951***	0.2373*
	(0.054)	(0.167)	(0.046)	(0.140)
Employees	0.2470***	0.7631***	0.0518	0.1303
	(0.059)	(0.194)	(0.044)	(0.133)
Installations	0.0400***	0.0299**	0.0643***	0.0317
	(0.005)	(0.013)	(0.004)	(0.020)
Period 2	0.2585***	0.4814**	0.3826***	0.6821***
	(0.064)	(0.187)	(0.038)	(0.176)
Period 3	-0.1872***	-0.1071	-0.0998**	0.2520
	(0.062)	(0.216)	(0.049)	(0.162)
Region 2 (BE, FR, NL)	-0.2925***	0.4753*	-0.6812***	0.3243
	(0.072)	(0.265)	(0.059)	(0.246)
Region 3 (GR, IT, PT, ES, CY, MT)	-0.0534	0.2405	-0.3082***	0.2255
	(0.060)	(0.173)	(0.050)	(0.172)
Region 4 (EE, LT, LV, PL)	-0.3054***	0.1836	-0.4676***	-0.1774
	(0.102)	(0.330)	(0.066)	(0.231)
Region 5 (CZ, HU, SI, SK)	-0.0378	0.3819	-0.2954***	0.4210**
	(0.100)	(0.305)	(0.063)	(0.192)

	Intra-firm transfers			
	Net buyers		***Net sellers***	
	Participation	***Intensity***	***Participation***	***Intensity***
Region 6 (DK, FI, IS, NO, SE)	0.7185***	-1.6514***	0.1320**	-0.8088***
	(0.069)	(0.298)	(0.053)	(0.156)
Region 7 (UK, IE)	-0.3587***	0.2202	-0.2292***	-0.4778***
	(0.074)	(0.270)	(0.060)	(0.182)
Region 8 (BG, HR, RO)	-0.0221	1.3151***	-0.5394***	-0.6933**
	(0.131)	(0.412)	(0.094)	(0.306)
Mill's ratio		-0.8634		-0.2089
		(0.701)		(0.551)
Mean net position	0.0661***	0.5693***	0.0652***	0.6314***
	(0.019)	(0.057)	(0.019)	(0.061)
Mean profitability	-0.0243	0.1109	-0.2496***	0.0687
	(0.059)	(0.180)	(0.049)	(0.151)
Mean employees	-0.1884***	-0.4976***	-0.0265	0.2209
	(0.060)	(0.185)	(0.045)	(0.136)
Constant	-1.9433***	2.4937*	-2.4010***	-0.6401
	(0.135)	(1.405)	(0.116)	(1.339)
N	**4763**	**4763**	**8191**	**8191**

* $p < 0.10$; ** $p < 0.05$, *** $p < 0.01$.

4^{th} *quarter trading*

The findings from employing a fractional logit model to estimate *4th quarter trading* are reported in Table 12. They imply that a larger *net position* of allowances increases the share of allowances companies trade during the 4th quarter of the trading year. *Carbon leakage* and *energy* are positively related with *4th quarter trading* for net sellers and net buyers, but for net sellers *energy* is not statistically significant. In comparison, *profitability* and *employees* are negatively related with *4th quarter trading*, but the coefficients are – except for employees for net sellers – just shy of being statistically significant at conventional levels. The number of installations does not appear to be related with 4th quarter trades. Compared to trading period 1, the share of *4th quarter trading* was larger in periods 2 and 3 for net sellers and net buyers. Results of Wald tests suggest that *4th quarter trading* shares were higher in period 2 than in period 3 for net buyers, but lower in period 2 than in period 3 for net sellers. Finally, country-specific findings suggest that companies from most regions exhibit higher *4th quarter trading* shares than the base region of German-speaking countries for net buyers, but the coefficient is statistically significant for four regions only. For net sellers, the country-dummy is also statistically significant for four regions, but the sign is negative in three of those cases. Thus, country-specific patterns of *4th quarter trading* appear to differ across countries, and between net buyers and net sellers.

Table 12. Multivariate results for share of *4th quarter trading* (CRE fractional logit models)

	4th quarter trading	
	Net buyers	***Net sellers***
Net position	0.0938***	0.1743***
	(0.023)	(0.025)
Carbon leakage	0.2825***	0.1603***
	(0.090)	(0.059)
Energy	0.4597***	0.0427
	(0.113)	(0.082)
Profitability	-0.0102	-0.0714
	(0.073)	(0.050)
Employees	-0.0440	-0.1404**
	(0.096)	(0.065)
Installations	0.0022	0.0036
	(0.007)	(0.006)
Period 2	0.6453***	1.3498***
	(0.101)	(0.068)
Period 3	0.4081***	1.4965***
	(0.107)	(0.083)
Region 2 (BE, FR, NL)	-0.0829	-0.2686***
	(0.145)	(0.093)
Region 3 (GR, IT, PT, ES, CY, MT)	0.1617	0.0942
	(0.110)	(0.077)
Region 4 (EE, LT, LV, PL)	0.3871**	-0.0080

	4th quarter trading	
	Net buyers	***Net sellers***
	(0.154)	(0.105)
Region 5 (CZ, HU, SI, SK)	0.2334	-0.0359
	(0.149)	(0.094)
Region 6 (DK, FI, IS, NO, SE)	0.5942***	-0.2574**
	(0.138)	(0.105)
Region 7 (UK, IE)	0.2381*	-0.2425**
	(0.145)	(0.108)
Region 8 (BG, HR, RO)	0.5278***	0.2935**
	(0.198)	(0.119)
Mean net position	0.0185	0.0660**
	(0.028)	(0.028)
Mean profitability	0.0494	-0.0085
	(0.081)	(0.056)
Mean employees	0.1013	0.0867
	(0.098)	(0.066)
Constant	-4.7204***	-5.4106***
	(0.210)	(0.157)
N	**10979**	**24077**

4.3 Robustness checks

To assess the robustness of findings presented in in Section 4.2 we conducted a series of robustness checks, distinguishing between distributional assumptions and model specifications.

Distributional assumptions

Rather than employing CRE Poisson models to estimate the regression equations for *total transactions* and *use of intermediaries*, we also estimate those via CRE negative binomial models. Compared to the Poisson model, the conditional probability function of the negative binomial model includes an additional term reflecting unobserved heterogeneity, which is assumed to follow a gamma distribution. Thus, unlike standard Poisson models, negative binomial models do not assume equidispersion. For both, the *total transactions* and *use of intermediaries* equation, the findings of the CRE negative binomial model are virtually identical to those reported in Table 9 for net sellers. For net buyers, the coefficients associated with net surplus are somewhat larger (in absolute terms) for the negative binomial model compared to the Poisson model, but the remaining results are very similar. We also estimated Poisson fixed effects models. As expected, the findings for the time-varying variables are almost identical to those presented in Table 9.[15]

Model specification

We further tested the robustness of our findings for several alternative specifications of the model. First, our results remain virtually the same if we use (before profit taxes) rather than revenues per employees to reflect profitability. Because in principle, revenues from selling allowances may affect profits, hence causing an endogeneity problem. We therefore estimated our preferred models using lagged values for *profitability*. Results of running this model are almost the same as those presented in section 4.2. Our preferred specification included dummies for the three trading period. To allow for a more fine-grained representation of temporal effects, we estimated our preferred models using yearly dummies instead of trading period dummies. The results for the explanatory variables and other covariates are very similar to those reported in section 4.2. Finally, we used ten categorical dummy variables to capture net surplus of allowances to mitigate effects of "outliers" at both ends of the distribution of *net surplus*. The findings for the other explanatory variables and the covariates are virtually identical to those presented in section 4.2 for our preferred specification.

Thus, in sum, our findings appear robust to alternative distributional assumptions and model specification.

5 Conclusions

Table 13 summarizes the findings of our empirical analysis of factors related with six indicators reflecting companies' engagement with the EU ETS between 2005 and 2014. They generally suggests that a higher *net position*, i.e. a net deficit of a net seller and a net surplus for a net seller, are typically associated with a more active use of the EU ETS. Thus, for most indicators, economic incentives such as financial gains from trading appear to explain companies' engagement in the

15 All findings which are not shown in the report to save space, are available from the main author upon request.

EU ETS. This finding is in line with previous literature analyzing companies' trading behavior for earlier trading periods (e.g., Cludius, 2018; Jaraitė-Kažukauskė and Kažukauskas, Zaklan, 2013). Similarly, companies belonging to sectors which appear on the *carbon leakage* list tend to be more likely to be active users of the EU ETS (with the exception of the findings for *4th quarter trading*), generalizing the results by Betz and Schmid (2016) for the refinery sector. Thus, companies which face higher competitive pressure appear to employ the EU ETS more actively.

Similar to previous studies (e.g., Cludius, 2018; Jaraitė-Kažukauskė and Kažukauskas, 2015; Zaklan, 2013), we generally find companies belonging to the energy sector to be more actively engaged with the EU ETS than companies from industry sectors. Typically, more profitable and larger companies (as measured by their number of employees) are more active users of the EU ETS. These findings are also in line with the extant literature (e.g. Jaraitė et al., 2010; Jaraitė-Kažukauskė and Kažukauskas, 2015, Sandoff and Schaad; 2009; Zaklan, 2013). Thus, findings from the early phases of the EU ETS appear to also hold for the more recent phases. In sum, our results for sector affiliation, profitability and company size suggest that companies' absorptive capacity, i.e., "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990:128) helps explain their level of engagement with the EU ETS. In this sense, our results are similar to Delmas et al. (2011), Delmas and Pekovic (2015) and Olsthoorn et al. (2017), who find that a higher absorptive capacity is positively related with companies' proactive environmental strategy and energy efficiency technology adoption. In this sense, improving companies' absorptive capacity is expected to improve the efficiency of the EU ETS in general, leading to more adequate price signals and cost-efficient abatement decisions.

Table 13. Summary of results of multivariate analyses

	Total transactions		***Transaction frequency***		***Use of intermediaries***		***Use of forwards and futures***		***Intra-firm transfers***		***4th quarter trading***	
	Net buyers	***Net sellers***	***Net buyers***	***Net sellers***	***Net buyers***	***Net sellers***	***Net buyers***	***Net sellers***	***Net buyers***	***Net sellers***	***Net buyers***	***Net sellers***
Net surplus	+	+	+	+	+	+	+	+	0	+	+	+
Carbon leakage	+	+	+	+	+	+	0	+	/	0	+	+
Energy	+	+	+	+	+	+	+	+	+	+	+	0
Profitability	+	+	+	0	0	+	+	+	0	+	0	0
Employees	+	+	+	0	0	0	+	0	+	0	0	-
Installations	+	+	+	+	+	+	+	+	+	+	0	0
Period 2	+	+	+	+	+	+	+	+	+	+	+	+
Period 3	-	/	+	+	+	+	-	-	-	-	+	+

+ coefficient positive and statistically significant; - coefficient negative and statistically significant; 0 coefficient not statistically significant; / coefficients significant but of different sign in participation and intensity equation of double hurdle models; for double hurdle model, a '+' ['-'] was assigned if coefficient was positive [negative] in both equations, or if it was statistically significant in one equation, and not statistically significant in the other equation.

Our results further imply that over time, companies used the EU ETS more actively. For most indicators, we find the use of the EU ETS to be more intensive in trading period 2 compared to trading period 1. Yet for most indicators, activity has declined in period 3 compared to period 2, and for some indicators also compared to period 1.Finally, our findings also suggest heterogeneity in companies' use of the EU ETS across countries.

In sum, most of our empirical findings on the factors related with companies' use of the EU ETS are in line with the extant literature, yet for a much broader set of indicators and for a longer time period. Previous literature had focused on total transaction and on intra-firm transfers, typically for the first trading period.

References

Balietti, A. (2016): Trader types and volatility of emission allowance prices. Evidence from EU ETS Phase I. Energy Policy 98, pp. 607–620.

Betz, R.A.; Schmidt, T.S. (2016): Transfer patterns in Phase I of the EU Emissions Trading System: a first reality check based on cluster analysis. Climate Policy, 16(4), pp. 474–495.

Borghesi, S.; Flori, A. (2016): EU ETS Facets in the Net: How Account Types Influence the Structure of the System. 2016.008 Note di Lavoro. http://www.feem.it/userfiles/attach/20162171024194NDL2016–008.pdf.

Branger, F.; Olivier, L; Quirion, P. (2015): The European Union Emissions Trading Scheme: should we throw the flagship out with the bathwater? Wiley Interdisciplinary Reviews: Climate Change, 6(1), pp. 9–16.

Brouwers, R; Schoubben, F.; Van Hulle, C.; van Uytbergen, S. (2016): The initial impact of EU ETS verification events on stock prices. Energy Policy, 94, pp. 138–149.

Cludius, J. (2016): The EUTL Transfer Dataset – Description and Insights. SML Working Paper(9).

Cludius, J. (2018): Winners and Losers of EU Emissions Trading. Insights from the EUTL Transfer Dataset. Economics of Energy & Environmental Policy 7(2).

Cludius, J.; Betz, R. (2020): The Role of Banks in EU Emissions Trading. The Energy Journal, http://dx.doi.org10.5547/01956574.41.2.jclu.

Cohen, W.M.; Levinthal, D.A. (1990): Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly 35, pp. 128–152.

Creti, A.; Jouvet, P.-A.; Mignon, V. (2012) : Carbon price drivers: Phase I versus Phase II equilibrium? Energy Economics, 34(1), pp. 327–334.

Crossland, J.; Li, B.; Roca, E. (2013): Is the European Union Emissions Trading Scheme (EU ETS) informationally efficient? Evidence from momentum-based trading strategies. Applied Energy, 109, pp. 10–23.

Delmas, M.A.; Hoffmann, V.H.; Kuss, M. (2011): Under the tip of the iceberg: absorptive capacity, environmental strategy, and competitive advantage. Bus. Soc. Rev. 50, pp. 116–154. http://dx.doi.org/10.1177/0007650310394400.

Delmas, M.A.; Pekovic, S. (2015): Resource Efficiency Strategies and Market Conditions. Long Range Planning 48, pp. 80–94. doi:10.1016/j.lrp.2013.08.014.

Deutsche Emissionshandelsstelle (DEHSt) (2019): Auktionierung: Deutsche Versteigerungen von Emissionsberechtigungen, Periodischer Bericht: Jahresbericht 2018.

European Environment Agency (EEA) (2020): EU Emissions Trading System (ETS) data viewer; https://www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.

European Environment Agency (EEA) (2019): The EU Emissions Trading System: trends and projections; https://www.eea.europa.eu/publications/the-eu-emissions-trading-system.

European Environment Agency (EEA) (2018): Trends and Projections in the EU ETS in 2018; https://www.eea.europa.eu/publications/trends-and-projections-in-the.

Ellerman, A.D.; Buchner, B. (2007): The European Union emissions trading scheme: origins, allocation, and early results. Review of Environmental Economics and Policy, 1(1), pp. 66–87.

Ellerman, A.D.; Convery F.J.; de Perthuis, C. (2010): Pricing carbon: the European Union emissions trading scheme. Cambridge University Press, Cambridge.

Ellerman, A.D.; Trotignon, R. (2009): Cross-border trading and borrowing in the EU ETS. Energy Journal 30, pp. 53–77.

European Commission (2016): The EU Emissions Trading System (EU ETS). https://ec.europa.eu/clima/sites/clima/files/factsheet_ets_en.pdf.

European Environment Agency (EEA) (2018): Trends and projections in the EU ETS in 2018, EEA Report No. 14/2018, https://www.eea.europa.eu/publications/trends-and-projections-in-the.

European Environment Agency (EEA) (2019): The EU Emissions Trading System in 2019: trends and projections, EEA Report No. 9/2019, https://www.eea.europa.eu/publications/the-eu-emissions-trading-system.

Fan, Y.; Liu, Y.-Peng; Guo, J.-F. (2016): How to explain carbon price using market micro-behaviour? Applied Economics 48(51), pp. 4992–5007.

Frunza, M.-C.; Guegan, D.; Lassoudiere, A. (2011): Missing trader fraud on the emissions market, Journal of Financial Crime 18(2), pp. 183–194.

Hahn, R.W.; Stavins, R.N. (1992): Economic incentives for environmental protection: integrating theory and practice. The American Economic Review 82(2), pp. 464–468.

Hahn, R.W.; Stavins, R.N. (2011): The effect of allowance allocations on cap-and-trade system performance. Journal of Law and Economics 54, pp. 267–294.

Heindl, P. (2017): The impact of administrative transaction costs in the EU emissions trading system. Climate Policy 17(3), pp. 314–329. doi: 10.1080/14693062.2015.1110108

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

Hintermann, B.; Peterson, S.; Rickels, W. (2016): Price and Market Behavior in Phase II of the EU ETS: A Review of the Literature. Review of Environmental Economics and Policy, 10(1), pp. 108–128.

Hoffmann, V.H. (2007): EU ETS and investment decisions: The case of the German electricity industry. European Management Journal, 25(6), pp. 464–474.

Jaraitė, J.; Convery, F.J.; Di Maria, C. (2010): Transaction costs for firms in the EU ETS: lessons from Ireland. Climate Policy 10, pp. 190–215. DOI: 10.3763/cpol.2009.0659.

Jaraitė-Kažukauskė, J.; Kažukauskas, A. (2015): Do Transaction Costs Influence Firm Trading Behaviour in the European Emissions Trading System? Environmental and Resource Economics, 62(3), pp. 583–613.

Kolk, A.; Pinkse, J. (2005): Business responses to climate change: identifying emergent strategies. California Management Review, 47(3), pp. 6–20.

Laing, T.; Sato, M.; Grubb, M.; Comberti, C. (2014): The effects and side-effects of the EU emissions trading scheme. Wiley Interdisciplinary Reviews: Climate Change, 5(4), pp. 509–519.

Leu T.; Betz R.; Cludius J. (2015): Trading costs in the first phase of the EU ETS: Estimation and explanations – Evidence from CITL data, CREST Working Paper 2015/'9.

Liu, Y.-P; Guo; J.-F.; Fan, Y. (2017): A big data study on emitting companies' performance in the first two phases of the European Union Emission Trading Scheme. Journal of Cleaner Production. 142(2), pp. 1028–1043.

Löschel, A.; Heindl, P.; Alexeeva-Talebi, V., Lo, V.; Detken, A. (2010): KfW/ZEW CO 2 Panel: Vermeiden oder kaufen? – Deutsche Unternehmen im Emissionshandel. Zeitschrift für Energiewirtschaft, 34(1), pp. 39–46.

Martin, R.; Muûls, M.; Wagner, U.J. (2015): Trading Behavior in the EU ETS. In M. Gronwald, and B. Hintermann (Eds.), Emissions Trading as a Policy Instrument: Evaluation and Prospects, pp. 213–238. Cambridge, MA: MIT Press.

Martin, R.; Muûls, M.; Wagner, U.J. (2016): The Impact of the European Union Emissions Trading Scheme on Regulated Firms: What Is the Evidence after Ten Years? Review of Environmental Economics and Policy 10(1), pp. 129–148.

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

Mundlak, Y. (1978): On the pooling of time series and cross section data. Econometrica 46, pp. 69–85.

Oberndorfer, U. (2009): EU emission allowances and the stock market: evidence from the electricity industry. Ecological Economics 68(4), pp. 1116–1126.

Olsthoorn, M.; Schleich, J.; Hirzel, S. (2017): Adoption of Energy Efficiency Measures for Non-residential Buildings: Technological and Organizational Heterogeneity in the Trade, Commerce and Services Sector. Ecological Economics 136, pp. 240–254. http://dx.doi.org/10.1016/j.ecolecon.2017.02.022.

Pinkse, J.; Kolk, A. (2007): Multinational corporations and emissions trading: Strategic responses to new institutional constraints. European Management Journal 25(6), pp. 441–452.

Pinkse, J.; Kolk, A. (2009): International business and global climate change. London: Routledge.

Papke, L.E.; Wooldridge, J.M. (1996): Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. Journal of Applied Econometrics, 11 (6), pp. 619–632.

Pontoglio S. (2010): An early assessment of the influence on eco-innovation of the EU emissions trading scheme: evidence from the Italian paper industry. In: Mazzanti M, Montini A, editors. Environmental efficiency. Innovation and economic performances: Routledge, pp. 81–91.

Rogge, K.S.; Schneider, M.; Hoffmann, V.H. (2011): The innovation impact of the EU Emission Trading System – Findings of company case studies in the German power sector. Ecological Economics, 70(3), pp. 513–523.

Rogge, K.; Schleich, J.; Haussmann, P.; Roser, A., Reitze, F. (2011): The role of the regulatory framework for innovation activities: The EU ETS and the German paper industry. International Journal of Technology Policy and Management 11 (3/4), pp. 250–273.

Sandoff, A.; Schaad, G. (2009): Does EU ETS lead to emission reductions through trade? The case of the Swedish emissions trading sector participants. Energy Policy 37, pp. 3967–3977

Sijm, J.; Neuhoff, K.; Chen, Y. (2006): CO_2 cost pass-through and windfall profits in the power sector. Climate Policy 6(1), pp. 49–72.

Stavins, R. (1995): Transaction costs and tradeable permits. Journal of Environmenatl Economics and Management 29, pp. 133–148.

Zaklan, A. (2013): Why Do Emitters Trade Carbon Permits? Firm-Level Evidence from the European Emission Trading Scheme. EUI Working Paper RSCAS(19).

Appendix A: Construction of Database

A1 Matching of former and current OHA

In 2012, the EUTL was reorganized leading to creation of new account types. Consequently, each installation needed to be associated with a new operator holding account (OHA). As the EUTL only reports up-to-date information and not historical changes, the database only provides the current OHA related to an installation but not the OHA before the regime switch. We therefore, need to infer old OHA using information provided. To do so, we proceed in several, subsequent steps:

(1) Matching account name to installation name and accept matches if they are unique.

(2) Matching on the account address to installation address and accept matches if they are unique.

(3) Matching on allocation information: In this stage we use information on allocated and surrendered provided for installations and search for the corresponding transaction with the same amount allowances and an administrative account of the respective registry involved. Again, only unique matches are accepted. We start with allocation followed by surrendering transfers.

Overall, out of the existing 13'001 former OHA we match 12894 to the existing accounts.

A2 Matching of EUTL accounts and ORBIS companies

Accounts are obliged to report a VAT registration number within the EUTL. This can either be a national or European VAT number. The ORBIS database also uses these VAT numbers, so that in theory a matching between the two databases based on the VAT number is possible. However, due to different formatting as well as reporting errors, a direct matching is not possible in praxis. We therefore use fuzzy matching based on the VAT number, the name of the account, and the address of the account contact. These variables are used in automatic ORBIS batch search using the account data as criteria for the ORBIS company. Batch search returns a number of possible matches together with the matching score. We then do the selection of the final match by hand inspecting the quality of the matches of the single fields.

Appendix B: Descriptive statistics

Table B1: Means of sector dummies

	All	Net deficit	Net surplus
energy	0.228	0.287	0.209
cement & lime	0.031	0.026	0.032
metal	0.046	0.037	0.048
pulp & paper	0.076	0.090	0.072
glass	0.028	0.038	0.025
bricks	0.093	0.049	0.108
refinieries	0.011	0.016	0.009
Number of observations	95510	23033	72477

Note: The mean for a particular sector dummy corresponds to the share of observations of this sector in the sample. So, 22.8 percent of all observations belong to companies in the energy sector

Table B2a: Descriptive statistics – net buyers

	Mean	Std. dev.	Min	Max	N
Total transactions	684303.20	9250894.00	0	508000000	23033
Number of transactions	2.80	11.57	0	350	23033
Intermediaries	0.15	0.58	0	17	23033
Forwards & futures	83900.56	2032566.00	0	146000000	23033
Intra-firm transfers	936109.70	9012945.00	0	297000000	7519
4th quarter trading	469521.90	2624643.00	0	62100000	4949
Carbon leakage	0.34	0.47	0	1	21926
Energy	0.29	0.45	0	1	23033
Profitability	23.08	220.90	-0.17	13608	13350
Employees	1804.00	15889.73	0	610076	14282
Number of installations	2.17	3.49	1	56	23033
Region 1 (AT, DE, LI)	0.19	0.39	0	1	23033
Region 2 (BE, FR, NL)	0.16	0.37	0	1	23033
Region 3 (GR, IT, PT, ES, CY, MT)	0.25	0.44	0	1	23033

	Mean	Std. dev.	Min	Max	N
Region 4 (EE, LT, LV, PL)	0.09	0.29	0	1	23033
Region 5 (CZ, HU, SI, SK)	0.07	0.25	0	1	23033
Region 6 (DK, FI, IS, NO, SE)	0.12	0.33	0	1	23033
Region 7 (UK, IE)	0.09	0.29	0	1	23033
Region 8 (BG, HR, RO)	0.03	0.16	0	1	23033

Table B2b: Descriptive statistics – net sellers

	Mean	Std. dev.	Min	Max	N
Total transactions	208579.60	4521631.00	0	544000000	72477
Number of transactions	1.68	9.78	0	816	72477
Intermediaries	0.14	0.64	0	41	72477
Forwards & futures	28330.48	962243.00	0	134000000	72477
Intra-firm transfers	238707.60	3235541.00	0	215000000	16903
4th quarter trading	242302.60	2805199.00	0	208000000	12239
Carbon leakage	0.41	0.49	0	1	68761
Energy	0.21	0.41	0	1	72477
Profitability	9.86	84.90	-21.76	5542	38940
Employees	1389.96	11107.82	0	439400	41903
Number of installations	1.66	2.29	1	56	72477
Region 1 (AT, DE, LI)	0.16	0.36	0	1	72477
Region 2 (BE, FR, NL)	0.17	0.38	0	1	72477
Region 3 (GR, IT, PT, ES, CY, MT)	0.25	0.43	0	1	72477
Region 4 (EE, LT, LV, PL)	0.10	0.30	0	1	72477
Region 5 (CZ, HU, SI, SK)	0.09	0.29	0	1	72477
Region 6 (DK, FI, IS, NO, SE)	0.09	0.29	0	1	72477
Region 7 (UK, IE)	0.09	0.29	0	1	72477
Region 8 (BG, HR, RO)	0.05	0.21	0	1	72477

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