Transfer patterns in Phase I of the EU Emissions Trading System: a first reality check based on cluster analysis

Regina A. BETZ[1,2]*, Tobias S. SCHMIDT[3]

[1]School of Management and Law, Zurich University of Applied Sciences, Gertrudstrasse 15, 8401 Winterthur, Switzerland
[2]Centre for Energy and Environmental Markets, UNSW Business School, University of New South Wales, Australia
[3]Department of Humanities, Social and Political Sciences, Energy Politcs Group, Swiss Federal Institute of Technology, ETH Zurich, Haldeneggsteig 4, 8092 Zurich, Switzerland

* Corresponding author contact details: betz@zhaw.ch

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Abstract
In 2005, the world's largest Emissions Trading System (ETS) was introduced in the EU. Economic theory assumes high efficiency of such market-based instruments since companies have the flexibility to trade allowances. However, to date there is a lack of understanding on how companies have participated in the allowance markets. This article uses data on transfers of allowances between 2005 and the end of 2007, published by the EU in the Community Independent Transaction Log (CITL) after a five-year delay. We use cluster analysis to detect patterns in the data and differentiate transfer behaviour. We find that the vast majority of participants (7212 accounts) are rather passive in terms of transfers. Of these, more than half are hardly participating in the market at all, whereas one-third are accounts managed by another account belonging to the parent company. Opposed to that, 143 accounts show more active, but relatively diverse transfer behaviour. We also identify differences in sectoral representations, account types, and primary allocation across the seven clusters. While the passive accounts mostly belong to installations regulated under the EU ETS, the most active accounts are classified as 'non-regulated account type'.

Policy relevance
Our findings have implications for policy makers in the EU as well as other countries that have or are setting up an ETS. The high number of companies not or hardly participating in the allowance market despite being regulated under the EU ETS puts the theoretical praised economic efficiency of this instrument in question. This finding also implies that policy makers should reconsider the entry thresholds for firms into an ETS. At the same time, some of the most active accounts belong to non-regulated firms, such as banks, which calls for better market oversight or potentially restrictions on ETS participation. Finally, we recommend that the timeliness and user-friendliness of CITL should be increased.

Keywords: account types; cluster analysis; Community Independent Transaction Log (CITL) data; emission trading; EU ETS; research agenda

1 Introduction

Market-based approaches to tackle environmental externalities, such as Emissions Trading Systems (ETSs), were first proposed by Coase (1960) and later by Crocker (1966) and Dales (1968). An ETS is a cap-and-trade policy that introduces a ceiling for the amount of GHG emissions (cap) that can be emitted by one or several sectors. In order to emit, firms need emission rights (allowances). While the cap is typically reduced over time, emitters are allowed to transfer these allowances, for example via trading on emission markets. ETSs are particularly lauded for being efficient, as they are able to achieve a given environmental goal at least cost. Economic textbooks generally only assume compli- ance-related transfers of allowances in an ETS. These transfers lead to the efficient outcome in which installations with low abatement costs will reduce emissions and can either be compliant in this way or – in the case where they have over/under-reduced their emissions – by selling/buying the surplus/ shortfall. Those firms with abatement costs higher than the market price of allowances should buy on the market. Such trading behaviour would ensure that the abatement costs are minimized to reach the given target. However, the real world is more complex than typically assumed in textbooks. On the one hand, trading may be motivated by other reasons, and not only driven by compliance. On the other hand, transaction costs or other barriers might discourage firms from trading (Betz et al., 2010; Heindl, 2012). To date, empirical studies on trading behaviour have been rare and mainly relate to US environmental markets such as the Acid Rain Program (Joskow, Schmalensee, & Bailey, 1998) or the RECLAIM programme (Gangadharan, 2000), because US trading schemes have a high degree of trans- parency, and registry data are generally publicly available in real time.

In 2005, the world's largest ETS was introduced in the EU. Although empirical studies on the EU ETS cover many of its aspects (for an overview see Zhang & Wei, 2010), such as the allocation rules applied in different Member States (see, e.g., Betz, Rogge, & Schleich, 2006; Ellerman & Buchner, 2007; Marti- nez & Neuhoff, 2005; Neuhoff, Martinez, & Sato, 2006) or the effects of the ETS on the diffusion or innovation of technology (see, e.g., Hoffmann, 2007; Laurikka & Koljonen, 2006; Rogge, Schneider, & Hoffmann, 2011; Schmidt, Schneider, & Hoffmann, 2012; Schmidt, Schneider, Rogge, Schuetz, & Hoffmann, 2012), research on the trading patterns of firms under the EU ETS is in its infancy. One reason for this is the lack of available data. In contrast to US schemes, the EU Commission releases transfer data about EU allowances only after a five-year delay. The allowances are called European Union Allowances (EUAs), with one EUA being equivalent to the emission right of 1 tCO_2e.[1]

Some early research based on surveys has shown that the way in which firms make use of the carbon market varies considerably. Engels, Knoll, and Huth (2008) found that some companies ignore the trading scheme, some use it purely for compliance purposes, and others become 'arbitrageurs', making money by generating profits from price volatility. Pinske and Kolk (2007) went a step further by assessing the response of companies not affected by the regulation itself. They found that the financial sector acts as an 'institutional arbitrageur', 'benefiting from other companies' lack of knowledge of emissions trading' (p. 450). Later studies based on surveys in Phase II have supported some of those early findings. Löschel et al. (2010) and Löschel, Brockmann, Heindl, Lutz and Schuma- cher (2011), who surveyed German companies regulated by the ETS, found that only half of those com- panies became active in the market. Anderson et al. (2011) showed that over-allocated firms are more likely to sell allowances than companies that are not over-allocated. Finally, the very first study using Community Independent Transaction Log (CITL) data of surrendered allowances, conducted by Tro- tignon and Delbosc (2008), identified the active players in the market. They discovered that it was mainly companies of the electricity sector located in countries with net deficits of allowances that sur- rendered allowances issued in other Member States, which suggests that they were active. However, installation-specific transaction data were not available at that time, so they were not able to differen- tiate between inter-company and intra-company transfers.

The aim of this article is to go beyond those findings and provide the first insights into the different transaction patterns of all installations in the early years of the EU ETS and, consequently, to derive questions for future research and discuss implications for policy makers. To this end, we use cluster analysis to detect transfer patterns. We use the terms 'transfers' and 'transactions' interchangeably, but note, however, that we do not use the term 'trades', as our database does not indicate whether any money was paid for the transfer of allowances.

This is an explorative article that uses CITL data from 2005 to the end of 2007, first on the account level, and only in a second step aggregated to the parent company level. This differs from the few existing studies, which use the same data set but only consider aggregated data (Jaraitė & Kažukauskas, 2013; Zaklan, 2013). Importantly, this article also differs from the few previous studies using CITL data in that it is the first to also include transfers of non-regulated companies, such as the financial sector, in the analysis. This allows us to assess the whole range of participants and transfer patterns in the EU ETS. The article is structured as follows. In Section 2 we provide a descriptive analysis of the EU ETS, differ- ent account types and transfers, which comprise our data set. In Section 3 the methodology is explained. We present our results in Section 4 and conclude with Section 5, discussing our results and deriving avenues for future research and policy recommendations.

2 Descriptive analysis

In January 2005, the EU launched an EU-wide ETS for GHG emissions, covering around 12,000 instal- lations from the energy industry and other emission-intensive industry sectors across the 25 (now 28) Member States (EEA, 2008).[2] These installations account for nearly 50% of the total CO_2 emissions, and about 40% of all GHG emissions in the EU.[3] The criteria for the inclusion of an installation in the EU ETS were, in most sectors, based on the installed capacity and not on emissions, which resulted in a high number of installations (around 90%) that emitted only a small share of the total emissions covered (around 10%) (Schleich & Betz, 2004).

Almost 99% of EUAs were allocated for free to the covered installations based on various approaches and formulas (Betz et al., 2004). The free allowances were distributed by 28 February each year, leading to an overlap between the time when firms received their allowances for the current year and when they had to surrender their allowances for the previous year (on 30 April each year), allowing firms to 'borrow' from their future allowances to meet current obligations.[4]

In order to record and provide transparency on the issuance, transactions, and surrender of EUAs, national registries were established that are linked with the CITL. Three different types of accounts operate in the EU ETS in Phase I: Operator Holding Accounts (OHAs), for installations regulated under the ETS directive; Person Holding Accounts (PHAs), for entities voluntarily participating in the ETS (e.g. banks, brokers, and exchanges), but which can also be opened by regulated installations in addition to their OHAs; and 'country' accounts used by Member States for administrative functions. Note that one company can hold many OHA accounts as the accounts are held on the basis of installa- tions. RWE AG, for example, has held around 84 OHA accounts in installations from different Euro- pean countries and around 20 PHA accounts in 2005.

This article analyses data from the CITL.[5] The CITL is an electronic accounting system created by the European Commission for tracking ownership of EUAs and other carbon market units. It keeps records of all issuance, allocation, transfer, cancellation, retirement, and surrendering of allowances that take place in the EU ETS registries of each Member State.[6] However, a five-year lag restricts the availability of CITL information to the public and, as a result, transfer data for 2007 was only made publicly available in 2012. Our data set covers all transactions from early 2005, when the first allowances were issued under the EU ETS, to 31 December 2007, and was the largest complete data set available at the time of writing.

Transactions are categorized by type. According to the CITL data, from 2005 to 2007 the EU ETS saw transaction volumes of over 26 billion EUAs in 97,133 transfers. Most of the volume was related to administrative transfers. For example, 6.3 billion EUAs were issued to regulated installations and 6.2 billion were surrendered. By excluding administrative transfers such as allowance issuance, retirement, cancellation, surrender, allocation, and correction,[7] we generate a data set that reflects only 'market transfers' (i.e. non-administrative). In this data set, 6874 OHAs, 729 PHAs, and 58 country accounts transferred a total of 2.9 billion EUAs in 44,434 market transactions between 2005 and 2007. PHA accounts that conducted no market transfers in the period 2005 to 2007 do not appear in the data set. Note that our data set only includes physical transactions of EUAs and does not contain forwards, futures, or other financial contracts.

According to Figure 1, the peak transfer periods were April, the deadline for the surrender of allow- ances for the previous year; and December, when many forward contracts mature and result in physical transfers of EUAs. Information about OHAs and PHAs is provided by the CITL in other files, separate from the transfers. We extracted registry-specific identification codes[8] for all three data sets and assigned unique IDs to match the accounts between data sets. In this way we generated the very first combined data set (including PHAs), which links the transfer activity of accounts to their sector, emissions profile (verified emissions, allowances distributed, allowances surrendered), compliance, and geographic information.[9]

Due to a lack of identification codes in a number of national registries, we were unable to match the transfer activity of 246 of 6874 OHAs, comprising 0.75% of total market transfers, to their emissions and other characteristics.[10] We thus excluded these accounts, as well as all country accounts and two PHA accounts with missing account names. This resulted in a final data set of 6628 OHAs and 727 PHAs, and 42,955 transfers with a total transfer volume of 2.85 billion EUAs.[11]

Figure 1 Market transfer volumes 2005-2007 (Source: CITL Data, own aggregation)

Sectors were assigned to each account based on NACE codes for 2005. For OHAs, NACE codes were provided by the European Commission. PHAs, however, had to be matched manually to sectors on the basis of information in the CITL PHA data set, i.e. account holder names, email addresses, etc. In order to reduce the number of sectors, three main categories were distinguished. The energy sector includes all accounts of companies whose main activity is in mining, refining, heat, or electricity production (NACE codes CA, DF.23.30, DF23.30, E). The industry sector includes manufacturing (NACE codes CB, DE.21, DF.23.10, DG/DN.36). Finally, 'others' includes everything else, ranging from financial ser- vices to agriculture (NACE codes A, B, DE.22, DN.37, F-O). Figure 2 depicts the 727 active PHAs by sector, revealing that roughly 35% belonged to the financial sector (NACE code J). The fact that 39% belonged to the energy sectors (NACE code E) supports the fact that many of the regulated energy com- panies opened PHAs in addition to their OHAs.

Our main cluster analysis was conducted on the account level and calculates each account's position, and the firm level is only included in the sub-cluster analysis.[12]

The data processing revealed that a number of transactions are missing from the CITL. This became obvious as a few of the PHA accounts appeared to have transferred more allowances than they are recorded to have acquired. Given that in the EU ETS one can only transfer EUAs that are in one's own account, we reckoned that some of the acquisitions had not been recorded in the CITL. Our anticipations were supported by correspondence with relevant EU officials. Although the EU officials did acknowledge the problem and tried to solve it, to date we have been unable to obtain all of the missing transfers. However, given the low number of accounts and low EUA volumes affected, we believe that the omitted data will not significantly reduce the validity of our analysis.[13]

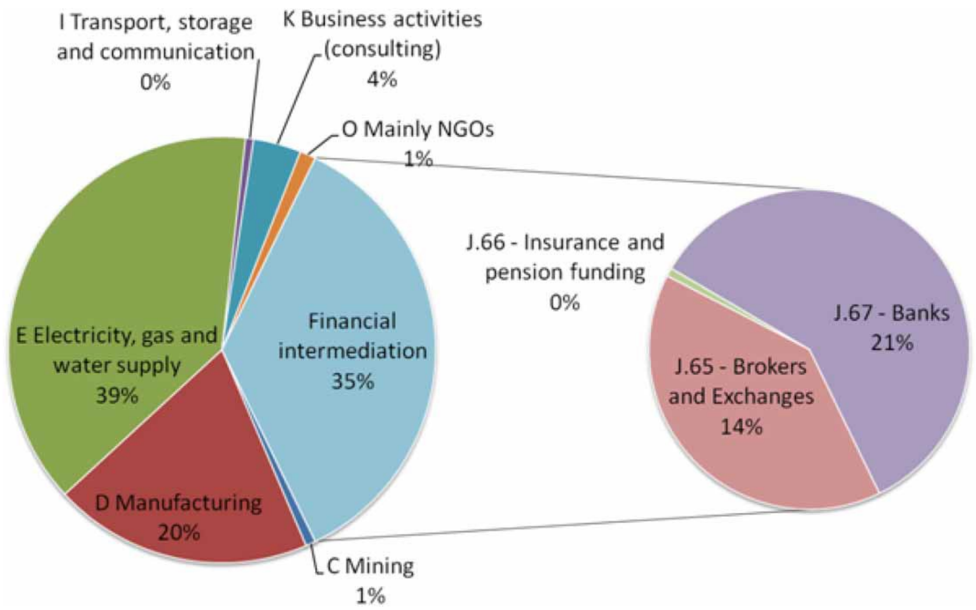

Figure 2 Sectoral shares of active PHAs 2005-2007

3 Methodology

3.1 Main cluster analysis

In order to identify the different transfer patterns of the 7355 accounts we used cluster analysis. Cluster analysis is an explorative multivariate technique that is useful for identifying patterns in large data samples. These patterns are identified by grouping data sets on the basis of 'information found in the data that describes the objects and their relationships' (Pang-Ning et al., 2006, p. 490). The aim is to split data sets into groups (i.e. clusters) that exhibit high internal homogeneity and – at the same time – high external heterogeneity. As a result of a cluster analysis on ETS transfer patterns, accounts (i.e. the objects) in the same cluster share similar transfer properties and differ (significantly) from other clusters regarding these transfer properties. To group the data set, the operator must identify those properties, i.e. the variables along which the data are to be clustered – the so-called *cluster variables* (Hair, Anderson, Tatham, & Black, 2006). In this article we aim to detect diverging transfer patterns, so we define six *transfer variable*s as *cluster variables*[14] for the first analysis and add one additional variable that is used in a sub-cluster analysis (see Section 3.2). Because each of those cluster variables describes an important aspect of the transfer activity of an account, in combination these variables can identify differing transfer patterns. Further variables were also considered as *cluster variables*. However, they did not add new information (tested through correlation analysis) or result in clusters that were not significantly different (tested with analysis of variance – Anova). The six *cluster variables* (of which four are volume-based) and their importance in determining clusters are described as follows:

1. *Total transfer volume*: the sum of EUAs transferred in and out of an account. This variable captures the general transfer activity in terms of size. Accounts that are very active score highly in this variable, so it helps to distinguish active from rather inactive accounts.
2. *Net transfer volume* of transfers: the volume of EUAs transferred into an account minus those transferred out of the account. It describes to what extent accounts were increasing their stock of EUAs and thereby helps to identify accounts that were actively accumulating emission rights. In theory one can expect under-allocated accounts to have a positive net transfer volume and over-allocated accounts to have a negative net transfer volume.
3. *Transfers relative to allocation*: the *total transfer volume* divided by the sum of EUAs allocated over the period 2005 – 2007. This variable normalizes the transfer activity to the size of the account in terms of allocated EUAs. This helps to identify accounts that were highly active compared to their size in terms of emissions. As PHAs did not receive any allocations, we used their *total transfer volume* without dividing it. Note that this variable does not therefore add information on the PHAs.[15] In theory, accounts with mere compliance transactions should receive a low value, whereas accounts opened for trading or management purposes should score very high.
4. *Number of accounts from which EUAs have been transferred into the account*. This variable helps to differentiate accounts that sourced EUAs from many accounts from those that relied on few sources. Accounts scoring high in this variable are either active in acquiring or manage several other accounts.[16] Accounts scoring low are either not very active or managed by other accounts.
5. *Number of accounts to which EUAs have been transferred*. Similarly to the previous variable, this metric captures activity as well as whether accounts have been managed centrally. In combination, one can capture

accounts that receive EUAs from many accounts and pass on to few (e.g. service providers for small firms, which shy away from becoming active on the carbon markets themselves), or vice versa.

6. *Discontinuity of transfers*: defined as each account's variation coefficient of volumes during a three- month period. This helps to differentiate accounts in terms of their temporal activity. One can expect that accounts with a low score transfer continuously throughout the year, while accounts with a high score have spikes in their transfer activities. In other words, while brokers are expected to score low, accounts that are managed by other accounts and accounts that are transferring for compliance score high.

Table 1 provides the descriptive statistics of our data set in terms of the six cluster variables, showing the high variance present in the data set. As the six cluster variables have different orders of magnitude (compare, e.g., the maximum values in Table 1), we normalized each variable via z-scores before applying the cluster analysis in order to avoid weighting issues (Field, 2009).

In order to cluster the accounts along these six variables, we used the standard approach to cluster analysis and proceeded in two steps (Hair et al., 2006). The first step serves to determine the optimal number of clusters. To achieve this we applied Ward's method and performed a hierarchical cluster analysis based on the squared Euclidian distance and the average linkage between groups. We then used the elbow criterion to determine the number of clusters (for more details on determining the optimal cluster number see Tibshirani et al., 2001). The second step allots the individual accounts to each cluster. To this end, we pursued a non-hierarchical K-means cluster analysis (Pang-Ning et al., 2006). In order to check whether the clusters differ in a statistically significant way in terms of the six cluster variables, we performed an Anova and a non-parametric Kruskal–Wallis test for each variable.

Table 1 Descriptive statistics of the cluster variables

	Mean	Std. Dev.	Minimum	Maximum
Total transfer volume	776,279	5,675,220	1	221,464,000
Net transfer volume (in-out)	23,404	999,216	216,537,600	23,255,730
Transfers relative to allocation	549,716	5,511,137	0	221,464,000
No. of accounts transferred from	1.78	7.21	0	212
No. of accounts transferred to	1.65	4.26	0	96
Discontinuity of transfers	2.38	0.63	0.32	3

Note: Negative net transfer volumes are not indicative of errors, as they refer to market transfers only, thus the allocation (reflected by administrative transfers) is not included and accounts transferring excess allowances have a negative net balance. In addition, the mean is not zero because we had to exclude 305 accounts.

After clustering the accounts along their transfer patterns, four additional *attributes* (which are not related to transfers) were used in order to provide more information on the clusters. Specifically, the following *attribute variables* are considered:

1. *Account type*: 0 represents an OHA and 1 represents a PHA.
2. *Sector affiliation*: 1 indicates that an account belongs to the energy sector, 2 the industry sector, and 3 everything else (but mainly the financial services sector).
3. *Size*: expressed as average verified emissions per year. As the verified emissions are only provided for OHAs, only OHAs can be described in terms of size.

4. *Allocation position* in 2005, 2006, and 2007: i.e. the freely allocated EUAs minus the surrendered EUAs. Positive values indicate an over-allocation, and negative values an under-allocation. As the underlying data are only provided for OHAs, only OHAs can be described in terms of allocation position.

Table A1 in the Appendix provides the descriptive statistics of the four attribute variables.

3.2 Sub-cluster analysis

As our cluster analysis resulted in one very large cluster containing the vast majority of accounts, we aimed to further differentiate this cluster by means of a sub-cluster analysis, i.e. a cluster analysis applied to this dominant cluster only. Applying the same six cluster variables in this sub-cluster analysis did not result in significantly different clusters (tested via Anova). An alternative was there- fore to use a different cluster variable for the sub-cluster analysis. One cluster variable that did not result in statistically significant clusters if applied to the entire sample (and was therefore omitted in the main cluster analysis) is the *share of intra-firm transfers.* This variable can be defined as the total volume of intra-firm transfers (the sum of EUAS transferred in and transferred out of each accounts summed up for all accounts belonging to one firm) in relation to the *total volume of transfers* (see above). In order to construct this variable we differentiated transfers between accounts belonging to the same parent company (called intra-firm transfers) and transfers between accounts not belonging to the parent company (called inter-firm transfers). The parent company level reflects the 'Global Ultimate Owner' and is determined using a dedicated data set published by the European University Institute (Jaraite, Jong, Kažukauskas, Zaklan, & Zeitlberger, 2013), which links OHAs and PHAs via their IDs to IDs in the company database ORBIS. In doing so we can add a new type of information to the analysis, namely the role of the firm level (often firms have more than one single account). This variable helps to differentiate clusters containing accounts managed by other accounts of the parent company from clusters that do not contain managed accounts: accounts with a high intra- firm transfer share are expected to be managed by other accounts of the company. Accounts with a low intra-firm transfer share are either from companies with only one account or from companies that organize emissions trading in a decentralized way.

In the sub-cluster analysis the same approach, i.e. a two-step analysis combining hierarchical and *K*- means clustering, was applied as in the main analysis. Table A2 in the Appendix provides descriptive statistics for the main clusters with respect to the share of intra-firm transfers.

4 Results

4.1 Main clusters

Our analysis resulted in seven clusters. Based on the Kruskal – Wallis tests we can reject the null hypothesis that the clusters do not differ for each of the six transaction variables, at a significance level of $p = 0.99$. Table 2 provides an overview of the seven clusters, their cluster centres (means) with respect to the six transaction variables (the normalized cluster centres can be found in Table A3 in the Appendix). The clusters are ordered by their size, starting with the largest cluster. To simplify the discussion, we chose names that describe a peculiarity of each cluster's transfer pattern.

Table 2 Clusters and their centres regarding the six cluster variables

		Medium Active			Highly Active		Future Clearing
Total transfer volume (1000 EUAs)	290	14,742	18,526	37,776	97,480	78,368	221,464
Net transfer volume (1000 EUAs)	-38	382	7526	1016	332	19,147	0.0
Transfers relative to allocation	97	14,384	12,448	37,776	97,480	78,368	221,464
No. of accounts transferred from	1.11	34.82	11.78	121.55	50.29	37.20	24.00
No. of accounts transferred to	1.25	20.68	6.90	67.00	41.43	30.80	23.00
Discontinuity of transfers	2.40	1.36	1.74	1.03	1.36	1.06	1.74
No. of accounts	7,212	78	41	11	7	5	1
Percent of total accounts	98.06%	1.06%	0.56%	0.15%	0.10%	0.07%	0.01%

Table 2 reveals that the vast majority of accounts (7212 accounts, or more than 98%) can be found in one cluster (*Passive*), which is rather inactive in terms of transactions. The remaining 143 accounts were allocated to six clusters, of which the *Medium Active* cluster comprises a good half of that number and the *Acquiring* cluster another quarter. The four other clusters are very small in terms of account numbers, with *Future Clearing* comprising just one account, namely the clearing house LCH.clearnet.

In terms of two of the four attributes of the accounts in each cluster, Figure 3 shows each cluster's composition in terms of account type and sector affiliation. It becomes obvious that the passive cluster is dominated by OHAs, whereas the active clusters are dominated by PHAs. Industry firms seem to use fewer PHAs, whereas energy firms seem to often use their PHAs for transferring, which seems reasonable given that 39% of PHAs belong to energy companies.

Table 3 presents the descriptive statistics of the remaining two attributes, namely the size and allocation positions of OHAs (both in 1000 tonnes) over the three years of the first phase of the EU ETS. As the *Passive* cluster is mostly made up of OHAs, good data availability is given for both variables (in Table 3, *N* represents the number of accounts covered per variable). The *Medium Active* accounts are mostly PHAs, whereas the *Acquiring* accounts are about 50% OHAs. For the remaining four clusters no data on size or allocation position are available (and are therefore not included in Table 3) as all accounts in these clusters are PHAs.

Table 3 Comparison of accounts' size and allocation position (OHAs only)

	Passive			Medium Active			Acquiring		
	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*
Size (ktCO_2e)	220	1013	6604	1189	1832	3	5333	5118	21
Allocation position (1000 EUAs)									
2005	16	218	6604	266	460	3	-2413	1904	21
2006	10	241	6604	-553	991	3	-2757	2157	21
2007	8	245	6604	-218	483	3	-2556	1923	21

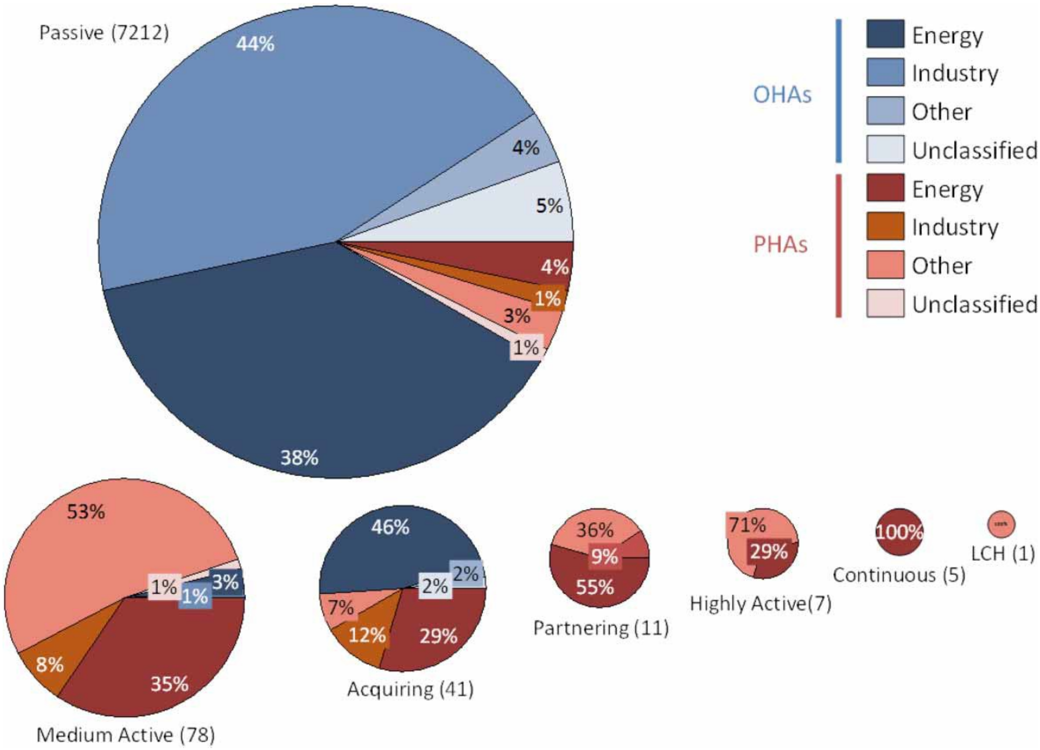

Figure 3 Clusters' composition in terms of account type and sector affiliation

4.2 Description of each cluster in terms of transaction patterns and attributes

While the previous sub-section has shown that our analysis identifies seven different clusters and that the majority of accounts belong to only one of those clusters, we now turn to the description of each cluster in terms of both its transfer patterns and its attributes. Table 4 lists a (random) selection of names of account holders (OHAs and PHAs) in the different clusters.

The transfer patterns of the largest cluster illustrate that, compared to the other clusters, the accounts of this cluster are rather inactive – hence the name *Passive*. The centres of the total transfer volume, net transfers, and transfers relative to allocation are close to zero. At the same time, the numbers of accounts transferred from as well as transferred to are close to 1 (0 is the lowest value possible). Furthermore, regarding the temporal pattern of trading, the *Passive* account holders are very inactive. They reveal the highest discontinuity; i.e. they traded the least continuously, typically only at the end of each trading period. In summary, accounts in this cluster have made use of emissions trading only to a limited extent. Turning to the attributes, the results show that 92% of the accounts in the *Passive* cluster are OHAs, belonging mainly to the energy (38%) and industry (44%) sectors. The accounts are rather small on average (220,000 tonnes of verified emissions), but the variation is relatively high. Their allocation position seems relatively balanced over the three years, also with a relatively high standard deviation (Std. Dev.). For more details on the passive cluster, please refer to the results of the sub-cluster analysis (Section 4.3).

Table 4 Examples of account holders' names

	Medium Active	Acquiring	Partnering	Highly Active	Continuous
OHAs	*Energy (only)*: • DALKIA • DONG Energy Power • National Grid Gas plc	*Energy*: • E.ON UK plc • Electrabel • RWE Power AG *Industry*: • TATA Steel UK Ltd	None	None	None
PHAs	*Energy*: • BHP Billiton Marketing • ENEL Trade • GDF Suez *Industry:* • Cargill International • ThyssenKrupp AG • Wienerberger AG *Financial services:* • JPMorgan Chase • KfW • The Royal Bank of Scotland	*Energy*: • DONG Energy Power • RWE Power AG • Endesa Generacion SA *Industry*: • ThyssenKrupp AG • CIMENTS CALCIA • Trading • TATA Steel UK *Financial services*: UBS Limited	*Energy*: • BP Gas Marketing • E.ON Energy Trading SE *Financial services*: • Fortis Bank SA • Carbon Capital Markets	*Energy*: • Garth Edward (of Shell) • EDF Trading Limited • RWE Supply & Trading GmbH *Financial Services*: • Barclays Bank PLC • Caisse des Dépôts et Consignations	*Energy*: • EDF Energy plc • Nuon Power • RWE Npower plc • RWE Supply & Trading Netherlands B.V. • SSE Energy Supply Limited

The *Medium Active* cluster is composed of 78 accounts. Compared to the other clusters, the cluster centre reveals low to medium values regarding almost all six cluster variables. Only the discontinuity of transfers is relatively low, meaning the account has transferred emission rights relatively regularly. In terms of attributes, the accounts belong to all three sectors covered (mainly energy and services). As the vast majority (96%) of the accounts are PHAs, the meaningfulness of the further attributes is limited. The three OHAs in this cluster are larger on average than the passive OHAs and, while over-allocated on average in 2005, they were under-allocated in 2006 and 2007.

The *Acquiring* cluster is made up of 41 accounts and exhibits, compared to the other clusters, a medium value for the total transfer volume and transfers relative to allocations. At the same time it demonstrates the second-highest net transfers. The numbers of accounts EUAs were transferred from and transferred to are both the second lowest, and the dispersion of transfers is also relatively high, indicating rather unsteady transfers. A good half (21 of 41) of the accounts are OHAs, and almost completely belong to the energy sector. The PHAs are mostly owned by energy firms. The OHAs are larger in terms of verified emissions than those in the *Medium Active* cluster and at the same time much more under-allocated on average (see Table 3). This explains why those accounts exhibit positive net transfer values, because they had to cover their shortfall of emissions. The PHAs also belong mainly to energy, partly to industry, with just a few to the services sector.

The 11 accounts in the *Partnering* cluster show higher total transfer volumes than the previously described clusters. The number of different accounts transferred from is the highest among all clusters, as is the number of different accounts transferred to (hence the name). At the same time, the dispersion is very low, indicating very continuous transfers. All 11 accounts are PHAs, and most belong to the energy and services sectors.

The *Highly Active* cluster comprises seven accounts, which show a very high total transfer volume and near zero net transfers. Because EUAs are worthless at the end of Phase I, holders of PHAs will aim to empty their accounts by the end of Phase I. OHAs will need EUAs by the end of April 2008 for compliance in 2007. The number of accounts transferred from and transferred to are second highest amongst all clusters. The relatively low dispersion indicates continuous transfer activity in and out. All accounts are PHAs, most of which are affiliated with the services (71%) or energy (29%) sectors.

Although most variables of the *Continuous* cluster show medium to high values, the dispersion of transfers is very low, indicating very continuous transfer activity. All five accounts are PHAs and exclusively members of the energy sector. The continuity could hint to forward backing of electricity sales (hedging).

Finally, the cluster *Future Clearing* is made up of one account (PHA) only, which belongs to the UK- based company LCH.clearnet, a clearing house serving major international exchanges. The trading volume is by far the highest, whereas the number of accounts transferred to and transferred from as well as the dispersion of transfers are rather medium. Furthermore, this cluster has zero net transfer volume, which is the only value that makes sense for a clearing house.

4.3 Zooming into the *Passive* cluster

As our main analysis resulted in one very large cluster, the *Passive* cluster, the sub-cluster analysis was performed to further understand differences within this cluster (see Section 3.2). The sub-cluster analysis on the basis of the share of intra-firm trades variable resulted in three (statistically significantly different) clusters (cluster centres are given in Table 5).

Table 5 Sub-clusters and their centres regarding the sub-cluster variable

	Passive – Truly Passive	Passive – Managed	Passive – Managing
Share intra-firm transfers	1%	99%	48%
No. of accounts	4119	2559	534
Percent of *Passive* accounts	57%	36%	7%
Percent of total accounts	56%	35%	7%

The results of the sub-cluster analysis show that the passive accounts differ strongly regarding their intra-firm transfer patterns. The largest sub-cluster (*Truly Passive*) covers 57% of the passive cluster and comprises accounts that virtually do not transfer accounts within the boundaries of the firm. These are firms that hardly participated in the market at all and thus are called *Truly Passive*. The second largest sub-cluster (*Managed*) comprises 35% of the *Passive* accounts and shows an opposing intra-firm transfer share: virtually all of the few transfers take place within the boundaries of the firm. This can be interpreted in the following way. These accounts are managed by other accounts;

i.e. they transfer their EUAs to the managing account (which then engages in trading or other transfer activities), and receive the necessary number of EUAs to be surrendered back before April each year. The remaining 534 accounts (allotted to the *Managing* sub-cluster) show an approximately 50% share of intra-firm transfers. These accounts could act as the managing accounts for other accounts but on a rather low transfer activity level given that they belong to the *Passive* cluster. To better understand which accounts can be found in the three sub-clusters, we also analysed the account attributes (as in Section 4.2), as summarized in Figure 4 and Table 6. In the following we will briefly describe each of the sub-clusters.

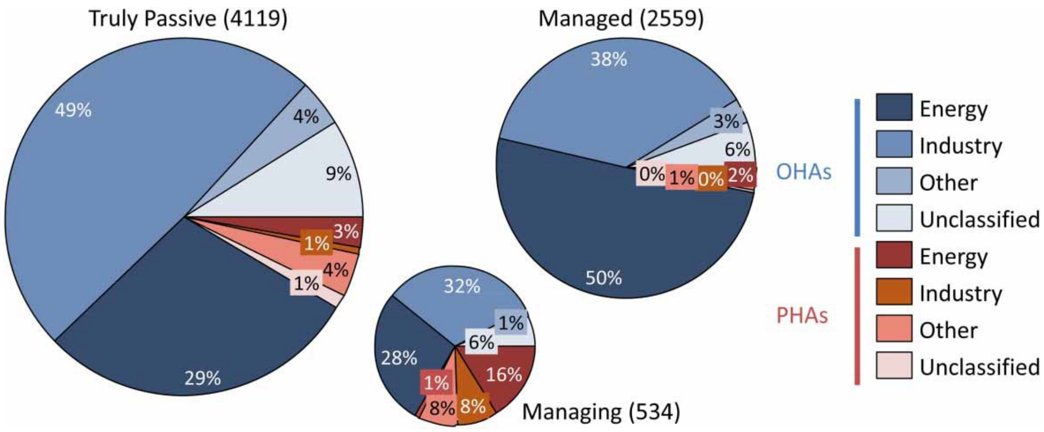

Figure 4 The *Passive* sub-clusters' composition in terms of account type and sector affiliation

Table 6 Descriptive statistics of *Passive* sub-clusters' OHAs

	Truly Passive			Managed			Managing		
	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*	Mean	Std. dev.	*N*
Size (ktCO_2e)	154	703	3766	313	1356	2481	275	929	357
Allocation position (1000 EUAs)									
2005	22	183	3766	8	265	2481	18	197	357
2006	16	184	3766	5	311	2481	24	217	357
2007	14	188	3766	2	314	2481	2	245	357

The *Truly Passive* accounts represent more than 90% of OHAs, of which the large majority belong to industry firms. Energy OHAs are the second-biggest group of accounts. In terms of emissions, the OHAs are rather small (on average 154,000 tonnes) and show a mixed allocation position over time.

The *Managed* sub-cluster is also dominated by OHAs. While energy sector firms make up half of the cluster, industry holds 40% of the accounts. In terms of size, the verified emissions of OHAs are about twice as high as those in the truly passive sub-cluster. In terms of allocation position, the picture is again mixed.

The *Managing* accounts are less dominated by OHAs (which make up two-thirds of the cluster) than the other two sub-clusters. These OHAs are mainly industry (32%) and energy (28%) accounts, whereas the one-third comprising PHAs are made up of energy (16%), industry (8%) and other (8%) accounts. In terms of size, the managing OHAs have slightly lower verified emissions on average than the *Managed* OHAs. An additional analysis revealed that accounts in the *Managing* sub-cluster have significantly higher transfers relative to the allocation of emission rights than the other two clusters, underlining their more active role within the *Passive* cluster.

5 Discussion and conclusion

The aim of this article is to deliver the first insights regarding the transfer activities of account holders in the first phase of the EU ETS. The recommendations for future research are divided into two parts. The first part contains recommendations for policy makers and the second lists interesting research questions for the private sector.

5.1 Recommendations for policy makers

Our analysis has revealed that downloading and processing data from the CITL is unnecessarily bur- densome. Furthermore, data quality could be improved in order to avoid the negative balances we observed in a few accounts. We therefore urge European decision makers to ensure that data are pro- vided with a high degree of quality. In addition, we recommend real-time availability of transfer data, similar to US emissions trading schemes. To reduce the work of researchers it would be valuable if the data reflected identifiers for installations and PHAs that indicate the company to which they belong, their sectoral classification (e.g. NACE), and a direct link to their transfers.

Turning now to the key results of our analysis, they show that the vast majority of accounts were rela- tively inactive during the first three years of the EU ETS. However, several accounts show high activity levels with different transfer behaviour. These are mostly PHAs, partly of firms that are regulated by the ETS (energy and industry sector) and therefore also have OHAs, partly firms belonging to other sectors, and the majority of firms belongs to the financial services sector. Based on the findings of our explora- tive data analysis we propose the following topics to be worthwhile of being addressed in future research in order to derive more in-depth advice for policy makers on regulatory design and market monitoring (see summary in Table 7).

Table 7 Summary of topics for future research and relevant policy implications

Research topic	High number of passive accounts	High number of active PHA
Regulatory design	Why did companies not participate in trading? What is the impact of passivity on market efficiency? Which companies or sectors should be regulated under an ETS when transaction costs are taken into account? What other instruments would be efficient to regulate companies excluded from the ETS? Policy advice with regard to coverage (sector, size)	What is the trade-off between liquidity and volatility for different types of ETS participants? If and how non-regulated entities should be allowed to participate in an ETS Who are the winners of the ETS and which factors (e.g. allocation, sector, size) were important? Policy advice with regard to participation and distributional consequences of ETS design
Market monitoring		Which installations transfer beyond compliance? What determines in which country companies open their personal holding account? How can data be used to detect abuse of the system early on? Policy advice with regard to prevention of system abuse

5.1.1 Regulatory design

The observation that 98% of accounts are passive, and 56% of the total accounts are truly passive, is not surprising (Jaraitė & Kažukauskas, 2013; Zaklan, 2013), but raises several questions. First, a debated question in the literature on ETS is the role of transaction costs and other factors that discourage firms from participating in trading (Betz, Sanderson, & Ancev, 2010; Heindl, 2012; Jaraitė, Convery, & Di Maria, 2010). For a company, the smaller the amount of emissions transferred, the more relevant transaction costs become. In an ETS, transaction costs often occur in the form of upfront fixed costs, for example due to large information requirements. For policy makers, the question of transaction costs becomes relevant when determining the coverage of a scheme (e.g. in terms of the thresholds regulating which installations fall under an ETS). If the entry threshold is too high, too many firms are exempted from the scheme, and if it is too low, high transaction costs occur for smaller firms and therefore discourage them from participating in trading. Our data indicate that the capacity-based entry threshold might have been too low for many firms, as a large number of installations with very low emissions were included (e.g. due to reserve capacities) that did not therefore participate in the market. This issue has already been addressed by the European Commission, in Phase III, through the introduction of emissions-based thresholds. However, the opportunity to opt out for installations below the threshold was not well received, most probably due to the fact that companies were already regulated for eight years and the alternative was not attractive. Therefore our research findings may be more relevant for policy makers outside Europe that are in the process of deciding on thresholds. To understand the reasons for not participating in the market, better understanding those passive firms might provide further insights, leading to more in-depth policy recommendations. The finding that only a few companies actively participate also raises the question of whether an ETS is the right instrument or if other instruments (such as taxes) would be superior where active participation in a market is not a prerequisite to achieve an efficient outcome. The impact of passivity on market efficiency there- fore seems to be an issue for further research, as well as the question of what alternative instruments can be applied.

To reduce the transaction costs for trading, financial intermediaries can play a role. Our analysis reveals that actors from the financial sector (mostly banks) were indeed quite active in transacting in the ETS and appear in several clusters. Although not all cap-and-trade programmes allow non-regulated actors to take part in emissions trading, the EU ETS does. The question arises of what has been the impact of those different types of traders on the market? Two different market impacts are generally distinguished in commodity markets (Daigler & Wiley, 1999). On the one hand, traders can increase liquidity in the market, which is rather positive. On the other hand, they can induce volatility, which is rather negative. With regard to the ETS it would be interesting to assess the trade-off in volatility – liquidity for different types of ETS participants. While some banks show different transfer patterns in our analysis than others, several banks have multiple accounts that appear in different clusters, indicating that they may have played different roles. Therefore, future research on ETS transfers should also focus on the transfer/trading behaviour of non-regulated participants (particularly the financial sector) and assess the trade-off for their inclusion. This research would be particularly valuable for policy makers deciding on ETS participation, such as in China.

To what extent firms have benefited from the ETS is influenced by several factors, including the extent of over-allocation and timing of trading. To estimate the gains and losses from this database it needs to be combined with price data, then it could be used to inform policy makers on which factors have the main distributional effects.

5.1.2 Market monitoring

Looking at power generators, we find that their transfer patterns differ even when considering that they often use multiple accounts – both OHAs and PHAs. It seems that accounts belonging to large power generators in particular show transfer patterns that seem to go beyond compliance transfers. Focusing on the accounts of power generators, one could analyse how these firms have been using this market in order to better understand why such differences in transfer patterns occur and what may have been the reasons behind those transfer patterns that hint at trading beyond compliance.

The EU ETS market did become a victim of several illegal attacks in its second phase, which we do not see in our data given that it only contains the first phase. VAT fraud and phishing did occur, as well as other forms of abuse such as money laundering that may not yet have been detected. This database, which needs to be updated with data from the second phase, may be analysed in different ways to help to detect those misuses early on and to give advice to policy makers on how an effective market oversight mechanism could be designed (Prada, 2010).

In addition, an analysis relating transfer patterns to their country of origin would be helpful in order to identify peculiarities across countries. During data processing, it became obvious that PHAs with an over-proportionally large total transfer volume were opened in Denmark (e.g. the accounts of Garth Edwards trading for Shell or Jeroen Brandehof trading for GDF Suez, although neither company is of Danish origin). Was this due to the fact that the Danish registry was the first to be operational or the easiest in which to open an account, or are there other reasons (e.g. each country has different national VAT levels)? This shows that firms could have strategically picked the country in which to open a PHA. Policy makers who have designed this market need to be aware of those issues and ensure that requirements for opening accounts are harmonized.

5.2 Interesting research questions for the private sector

As well as research that is interesting for policy makers, there are topics that seem to be most interesting for the private sector. For example, how companies respond to the new instrument of emissions trading and what management practices are implemented may be an area of interest, especially for management scholars. The sub-cluster analysis revealed that a substantial number of accounts are managed centrally. This is relevant, for example, when one firm owns several installations (which would each get its own OHA) but manages the accounts of the installations centrally. If the firm owns installations in several countries, this bundling could happen on a national level, but also on an international level. Alternatively, a firm can decide to let each installation manage its EUAs individually, or to bundle several installations (e.g. different blocks of one power plant), which then act independently. To better understand whether and at what level firms typically make use of the managing accounts at a higher hierarchy level, one would need to aggregate accounts to different levels, e.g. national and international levels. Our analysis only used the highest aggregation level, the parent company, and future research may provide more insights and go beyond existing studies that usually rely on surveys of a small sample of companies or case studies (Heindl & Lutz, 2012).

The aggregated data may also be used to assess the strategic approach companies have chosen towards this new instrument. In theory, regulated firms use the market for compliance trades. However, firms are also profit maximizers and may use the market to make money as in any other financial market, and thus trade allowances beyond compliance reasons. In this regard our analysis shows that some large oil and power producers show very similar transfer patterns to large banks (e.g. the *Partnering* cluster). These firms, however, were involved in the design of the EU ETS (e.g. regarding the allocation rules) from a very early date and may have market insights that banks may not have. Determining the winners and losers of this market by matching their transfer patterns with prices could be of interest. Going one step further and combining the winners and losers with management strategies may allow firms to identify dominant management strategies.

To conclude, this article analyses the newly released CITL data on the EU ETS and is the first to include PHAs in the analysis. The inclusion of PHAs in future analyses is highly recommended, as our results show that it is PHAs, in particular, that are highly active.

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Notes

1. To make the warming potential of GHGs comparable, global warming potentials are used to translate any GHG (e.g. N_2O) into tCO_2e (IPCC, 2007).
2. In 2007 the EU ETS was extended to 27 Member States when Romania and Bulgaria joined the EU, then again in 2013 when Croatia joined the EU (European Commission, 2013).
3. See http://ec.europa.eu/clima/policies/ets/index_en.htm
4. For a detailed description of the EU ETS, see e.g. Betz (2015).
5. See http://ec.europa.eu/environment/ets/ (retrieved 14 May 2012).
6. The terminology becomes complex and needs further explanation, as the CITL does compromise transactions with international specifications (Kyoto Protocol) as well as EU specifications (Commission of the European Communities, 2004). For example, issuance takes place when Assigned Amount Units from Party Holding Accounts (Kyoto requirement) are converted into EUAs. Allocation takes place when those EUAs are transferred into an OHA account (EU requirement). Surrendering takes place when EUAs are handed back into the Party Holding Account (EU requirement). Retirement takes place when the EUA identifier is deleted and units are transferred into the Party Retirement Account of the period (international requirement). Cancellation and replacement is the way that 'banking' is executed meaning EUAs are cancelled in one period and added to the number of EUAs in the next period.
7. CITL types 01-51, 04-03, 10-01, 10-02, 10-53, and 10-55, respectively.
8. Specifically, we used the 'Account Identifier' fields for transfers and the 'Identifier in Reg' field for OHAs and PHAs.
9. Where available. PHAs, for example, do not have an emissions profile.
10. 133 from Denmark, 46 from Belgium, 36 from Austria, 14 from Greece, 7 from Finland, 4 each from Hungary and Germany, and 1 from France.
11. Our data set shows a discrepancy of 172 million EUAs between sales and purchases. This difference is due to the exclusion of 305 accounts.
12. The approach of using account-level data instead of aggregated data at the firm level has been chosen as it has several advantages. First, no important information is lost, such as differing trading patterns of the same firm using various accounts. Second, the data are not biased. An aggregation will always be biased as a decision needs to be made if the aggregation is based on a subsidiary level of a company in a country, or at the parent company level. The decision will need information regarding at which level the company is managing carbon. This may vary from company to company, so no aggregation level will fit all companies. If the subsidiary level within a country is chosen, assigning PHAs to the country they are situated in can be misleading as many PHAs are opened in countries where exchanges are located (France for Bluenext and the UK for the European Climate Exchange (ECX)). Third, the analysis becomes even more complicated if the ownership changes over the period.
13. In total, five accounts had negative balances of around 3.6 million allowances.
14. Based on the CITL transfer data, we selected additional variables describing the transfer activity of an account, e.g. the volume of EUAs submitted. However, the additional value in the cluster analysis proved to be low. This was also supported by a correlation analysis, which revealed that these other variables correlate strongly with the selected six variables, therefore adding only minimal information while at the same time adding (unnecessary) complexity to the analysis.
15. As cluster analysis is based on between-object differences, this does not distort the cluster analysis.
16. Accounts that have been chosen to manage the EUAs of a company comprising several installations (e.g. several power plants owned by a parent company) will reflect this in the number of accounts from which EUAs are received. Usually, the total amount of allocated EUAs is transferred once at the beginning of the compliance year and out of the account before the surrendering date.

References

Anderson, B., Leib, J., Martin, R., McGuigan, M., de Muuls, P. L., & Wagner, U. J. (2011). *Climate change policy and business in Europe: Evidence from interviewing managers* (Occasional Paper 27). London: Centre for Economic Performance. Retrieved from http://cep.lse.ac.uk/pubs/download/occasional/op027.pdf

Betz, R. (2015). Emissions trading in practice: Lessons learnt from the EU Emissions Trading Scheme. In S. Managi (Ed.), *The Routledge handbook of environmental economics in Asia* (pp. 182–206). London: Routledge.

Betz, R., Eichhammer, W., & Schleich, J. (2004). Designing national allocation plans for EU emissions trading – A first analysis of the outcome. *Energy and Environment*, *15*, 375–425. doi:10.1260/095830504149465

Betz, R., Rogge, K., & Schleich, J. (2006). EU emissions trading: An early analysis of national allocation plans for 2008–2012. *Climate Policy*, *6*, 361–394. doi:10.1080/14693062.2006.9685608

Betz, R., Sanderson, T., & Ancev, T. (2010). In or out: Efficient inclusion of installations in an emissions trading scheme? *Journal of Regulatory Economics*, *37*(2), 162–179. doi:10.1007/s11149-009-9109-0

Commission of the European Communities. (2004). *Commission Regulation (EC) No 2216/2004 of 21 December 2004 for a standardised and secured system of registries pursuant to Directive 2003/87/EC of the European Parliament and of the Council and Decision No 280/2004/EC of the European Parliament and of the Council*. OJ L386/35, 29 December 2004, pp. 1–75.

Coase, R. H. (1960). The problem of social cost. *The Journal of Law and Economics*, *3*, 1–44.

Crocker, T. D. (1966). The structuring of atmospheric pollution control systems. In H. Wolozin (Ed.), *The Economics of Air Pollution* (pp. 61–86). New York, NY: Norton.

Daigler, R. T., & Wiley, M. K. (1999). The impact of trader type on the futures volatility–volume relation. *The Journal of Finance*, *54*, 2297–2316. doi:10.1111/0022-1082.00189

Dales, J. H. (1968). *Pollution, property & prices*. Toronto: University of Toronto Press.

EEA. (2008). *Application of the emissions trading directive by EU member states* (Report No. 2/2006). Copenhagen: Author.

Ellerman, A. D., & Buchner, B. K. (2007). The European Union Emissions Trading Scheme: Origins, allocation, and early results. *Review of Environmental Economics and Policy*, *1*(1), 66–87. doi:10.1093/reep/rem003

Engels, A., Knoll, L., & Huth, M. (2008). Preparing for the 'real' market: National patterns of institutional learning and company behaviour in the European Emissions Trading Scheme (EU ETS). *European Environment*, *18*, 276– 297. doi:10.1002/eet.485

European Comission. (2013). *Factsheet – The EU emissions trading system (EU ETS)*. Retrieved from http://ec.europa.eu/clima/publications/docs/factsheet_ets_en.pdf

Field, A. (2009). *Discovering statistics using SPSS (and sex and drugs and rock 'n' roll)* (3rd ed.). London: Sage. Gangadharan, L. (2000). Transactions costs in pollution markets: An empirical study. *Land Economics*, *76*, 601–614. Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (2006). *Multivariate data analysis* (5th ed.). Upper Saddle River, NJ: Prentice-Hall International.

Heindl, P. (2012). *Transaction costs and tradable permits: Empirical evidence from the EU Emissions Trading Scheme* ZEW (Discussion Paper No. 12 – 021). Mannheim: Centre for European Economic Research (ZEW). Retrieved from http://ftp.zew.de/pub/zew-docs/dp/dp12021.pdf

Heindl, P., & Lutz, B. J. (2012). *Carbon management – evidence from case studies of German firms under the EU ETS* (ZEW Discussion Paper No. 12 – 079). Mannheim: Centre for European Economic Research (ZEW). Retrieved from http://ftp.zew.de/pub/zew-docs/dp/dp12079.pdf

Hoffmann, V. H. (2007). EU ETS and investment decisions: The case of the German electricity industry. *European Management Journal*, *25*, 464–474. doi:10.1016/j.emj.2007.07.008

IPCC. (2007). *Climate change 2007: The physical science basis*. Geneva: Intergovernmental Panel on Climate Change. Jaraite, J., Jong, T., Kažukauskas, A., Zaklan, A., & Zeitlberger, A. (2013). *Ownership links and enhanced EUTL dataset*.

Florence: European University Institute. Retrieved from http://fsr.eui.eu/CPRU/EUTLTransactionData.aspx Jaraitė, J., & Kažukauskas, A. (2013). *Firm trading behaviour and transaction costs in the European Union's Emission Trading System: An empirical assessment* (Working Paper presented at the EAERE conference in Toulouse). Retrieved from http://www.webmeets.com/EAERE/2013/prog/viewperson.asp?i=31168

Joskow, P. L., Schmalensee, R., & Bailey, E. M. (1998). The political economy of market-based environmental policy: The U.S. Acid Rain program. *The American Economic Review*, *88*, 669–685.

Laurikka, H., & Koljonen, T. (2006). Emissions trading and investment decisions in the power sector – a case study in Finland. *Energy Policy*, *34*, 1063–1074. doi:10.1016/j.enpol.2004.09.004

Löschel, A., Brockmann, K. L., Heindl, P., Lutz, B. J., & Schumacher, J. (2011). *KfW/ZEW CO_2 barometer 2011, Hoher Anpassungsbedarf im EU-Emissionshandel ab 2013 - deutliche Defizite bei der Vorbereitung in den Unternehmen.* Frankfurt am Main: KfW Bankengruppe. Retrieved from ftp://ftp.zew.de/pub/zew-docs/co2panel/CO2Barometer2011.pdf

Löschel, A. K., Kiehl, P., Heindl, V., Lo, H., Koschel, S., & Koesler (2010). *KfW/ZEW CO_2 barometer 2010: Effizienzpo- tenziale des Emissionshandels noch nicht ausgeschöpft - Strategien und Management deutscher Unternehmen*. Frankfurt am Main: KfW Bankengruppe. Retrieved from ftp://ftp.zew.de/pub/zew-docs/co2panel/CO2Barometer2010.pdf Martinez, K. K., & Neuhoff, K. (2005). Allocation of carbon emission certificates in the power sector: How generators profit from grandfathered rights. *Climate Policy*, *5*, 61–78. doi:10.1080/14693062.2005.9685541

Neuhoff, K., Martinez, K. K., & Sato, M. (2006). Allocation, incentives and distortions: The impact of EU ETS emissions allowance allocations to the electricity sector. *Climate Policy*, *6*, 73–91. doi:10.1080/14693062.2006. 9685589

Pang-Ning, T., Steinbach, M., & Kumar, V. (2006). *Introduction to data mining.* Library of Congress. Boston: Pearson Addison Wesley.

Pinske, J., & Kolk, A. (2007). Multinational corporations and emissions trading: Strategic responses to new institutional constraints. *European Management Journal*, *25*, 441–452. doi:10.1016/j.emj.2007.07.003

Prada, M. (2010). *The regulation of CO_2 markets, Report*. Retrieved from http://www.ladocumentationfrancaise.fr/ var/storage/rapports-publics/104000201/0000.pdf

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*, 513–523. doi:10.1016/j. ecolecon.2010.09.032

Schleich, J., & Betz, R. (2004). EU emissions trading and transaction costs for small and medium sized companies. *Intereconomics*, *39*(3), 121–123.

Schmidt, T. S., Schneider, M., & Hoffmann, V. H. (2012). Decarbonising the power sector via technological change -Differing contributions from heterogeneous firms. *Energy Policy*, *43*, 466–479. doi:10.1016/j.enpol.2012.01.041

Schmidt, T. S., Schneider, M., Rogge, K. S., Schuetz, M. J. A., & Hoffmann, V. H. (2012). The effects of climate policy on the rate and direction of innovation: A survey of the EU ETS and the electricity sector. *Environmental Innovation and Societal Transitions*, *2*, 23–48. doi:10.1016/j.eist.2011.12.002

Tibshirani, R., Walther, G., & Hastie, T. (2001). Estimating the number of clusters in a data set via the gap statistic. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, *63*, 411–423.

Trotignon, R., & Delbosc, A. (2008). *Allowance trading patterns during the EU ETS trial period: What does the CITL reveal?* (Climate Report No. 13). CDC Climat. Retrieved from http://www.cdcclimat.com/Climate-Report-no13- Allowance.html

Zaklan, A. (2013). *Why do emitters trade carbon permits? Firm-level evidence from the European Emission Trading Scheme* (Working Paper presented at the EAERE conference in Toulouse). Retrieved from http://www.webmeets.com/ EAERE/2013/prog/viewperson.asp?i=31492

Zhang, Y.-J., & Wei, Y.-M. (2010). An overview of current research on EU ETS: Evidence from its operating mechanism and economic effect. *Applied Energy*, *87*, 1804–1814. doi:10.1016/j.apenergy.2009.12.019

Appendix

Table A1 Descriptive statistics of the attribute variables

	Mean	Std. Dev.	Minimum	Maximum	*N*
Account type	0.10	–	0	1	7355
Sector affiliation (NACE)	1.50	0.75	0	3	7355
Size (verified emissions) (kt)	237	1089	0	30,126	6628
Allocation position (1000 EUAs)					
2005	55.2	501.2	-6217	13,422	6628
2006	-42.2	527.1	-16,296	10,501	6628
2007	-2.3	313.5	-7606	4991	6628

N represents the number of accounts covered.

Table A2 Main clusters' descriptive statistics of share intra-firm transfers

	Passive	Medium Active	Acquiring	Partnering	Highly Active	Continuous	Future Clearing
Mean share of intra-firm transfers	39%	30%	52%	23%	16%	67%	0
St. Dev. share of intra-firm transfers	46%	30%	42%	23%	22%	22%	–
No. of accounts	7212	78	41	11	7	5	1
Percent of total accounts	98.06%	1.06%	0.56%	0.15%	0.10%	0.07%	0.01%

Table A3 Cluster centres of z-score normalized variables

Trading pattern	Passive	Medium Active	Acquiring	Partnering	Trans-ferring	Continuous	Future Clearing
Transaction volume (1000 EUAs)	-0.09	2.46	3.13	6.52	17.04	13.67	38.89
Net acquisition (1000 EUAS)	-0.06	0.36	7.51	0.99	0.31	19.14	-0.02
Transactions relative to allocation	-0.08	2.51	2.16	6.75	17.59	14.12	40.09
No. of accounts acquired from	-0.09	4.58	1.39	16.60	6.72	4.91	3.08
No. of accounts transferred to	-0.09	4.47	1.24	15.35	9.35	6.85	5.02
Dispersion of transfers	0.03	-1.63	-1.02	-2.15	-1.62	-2.10	-1.02
No. of accounts	7,212	78	41	11	7	5	1
Percent of total accounts	98.06%	1.06%	0.56%	0.15%	0.10%	0.07%	0.01%