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Firm Trading Behaviour and Transaction Costs in the European Union's Emission Trading System: An Empirical Assessment[1]

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Abstract

To the best of our knowledge, this study is one of the first to empirically analyse the trading behaviour in the first phase of the European Union's Emissions Trading System. We use a unique dataset that allows investigating the importance of permit trading transaction costs, such as information costs and search costs. This paper shows that transaction costs played an important role in the initial years of the programme. These costs were significant in explaining why some ETS firms did not participate in the European emissions trading market and chose to trade allowances indirectly via third parties rather than directly. This study also supports the concerns that transaction costs might be excessive for smaller participants.

Keywords: CITL, climate policy, emissions trading, Europe, firm-level data, trading behaviour, transaction costs

[1] This working paper replaces the earlier version of this study. The main difference from the earlier study is that the current paper uses the bigger dataset and employs the different empirical strategy. The main results remain the same throughout both papers.

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1. Introduction

Emission trading gains momentum in the European Union (EU). The EU's Emission Trading System (EU ETS) has been working since 2005 and will do so at least until 2020. Recently the European Commission has announced that the EU ETS will be critical in driving a wide range of low carbon technologies into the market until 2050 (European Commission 2011).

In principle, the EU ETS, as with any other emissions-trading programme, is cost-effective (see Montgomery (1972) and Tietenberg (1990), among others). Cost-effectiveness is obtained by allowing full transferability of emissions permits. Whether or not this cost-effective outcome is achieved in practice depends on how efficiently markets operate. One source of friction in these markets is transaction costs. Some transaction costs can be administrative and some trade-related.[2] This paper focuses on the latter type of costs – trading transaction costs. Trading transaction costs are incurred during market exchanges, including price discovery costs, and costs of writing and enforcing contracts. These costs are typically borne by polluting firms covered under emissions trading.

In this paper, we investigate for the presence of trading transaction costs in the first phase (2005-2007) of the EU ETS. In particular, we seek to address the following questions in an empirical framework: What ETS firms decide to trade, and how do they differ from non-traders? Further, how do transaction costs affect trading decisions of ETS firms? Are transaction costs significant and do they decrease over time due to learning-by-doing processes? There has not been much attempt to analyse these issues in the biggest and the most complex emissions trading system from an empirical perspective.

The most important theoretical result is of Stavins (1995) who studies the potential impacts of trading transaction costs on pollution trading. Within his theoretical framework, he shows

[2] See McCann et al. (2005) for a comprehensive taxonomy of transaction costs related to environmental policies.

that, in the presence of these costs, the efficient equilibrium of the trading systems might be undermined due to a decrease in the volume of emissions traded. Montero (1998) extends Stavins's theoretical framework by incorporating uncertainty.

Although the empirical literature on transaction costs is rather rich, Krutilla and Krause (2010) in their recent survey still believe that "empirical assessments of transaction costs in the environmental literature are relatively patchy and incomplete" (p. 336). The existing empirical research has mainly focused on measuring trading transaction costs of the pioneering US permit trading programmes.[3] For example, the lead permit trading programme, aimed at reducing the amount of lead added to gasoline, experienced high trading levels. However, Kerr and Mare (1998) found that transaction costs dissipated 10-20 per cent of potential trading surpluses. A study of the RECLAIM found that without transaction costs the probability of trading would have been 32 per cent and 12 per cent higher in 1995 and 1996, respectively (Gangadharan 2000). This suggests that transaction costs are more significant in the early stages of the programme, and then decrease as the market matures, and participants learn how to trade (Cason and Gangadharan 2003). The well-known Acid Rain Program for trading SO_2 emissions can be regarded as efficient. Brokerage fees – a proxy for trading transaction costs – were estimated to be minimum (Burtraw 1996; Joskow et al. 1998).

The research on trading transaction costs in the EU ETS is rather limited. The first trading phase (2005-2007) revealed that a number of tradable permits expired worthless at the end of the first trading period (Ellerman and Trotingnon 2009; Ellerman et al. 2010). It has been discussed that it is very likely that a large part of these permits never entered the market, i.e. some ETS participants used permits only for compliance, but not for revenue purposes. To some extent this is confirmed by several country-specific case studies. Sandoff and Schaad

[3] See a recent survey by Krutilla and Krause (2010) for a detailed review of studies on transaction costs created by environmental policies.

(2009) survey Swedish ETS firms and find that ETS firms trade very infrequently, and that formulating trading strategies is not a top priority among ETS firms. This seems to be especially true for small firms. Jaraitė et al. (2010) analyse for the presence of trading transactions costs, among other types of transaction costs, in Ireland. They find that some Irish firms did not sell surplus permits in the market and conclude that this non-trading behaviour cannot be explained by trading transaction costs but rather by an inclination among smaller firms in particular to use permits for compliance only, caution at the beginning of the period and the low permit prices at the end of the trading period seem to be the primary reasons for non-participation in trading. On the other hand, Heindl (2012) surveys German ETS firms and finds that administrative costs for permit trading are not negligible and account for 19.57% of overall firm transaction costs. Also, he finds that German ETS firms face fixed costs for market participation, and that each permit available for trading adds additional transaction costs.

To the best of our knowledge, this study is one of the first to empirically analyse the trading behaviour and transaction costs in the most complex and ambitious emissions tradable programme ever developed. We use a unique dataset to investigate the trading behaviour of *all* ETS firms throughout the first phase of the EU ETS. Additionally, this dataset allows identifying several firm-level transaction costs variables and to check for their significance in firms' decisions to trade. We find that transaction costs can explain why a number of ETS firms did not participate in the European emission trading market and chose to trade allowances indirectly via third parties rather than directly. This study also supports the concerns that transaction costs might be excessive for smaller participants.

The rest of the paper is organised as follows. The next section gives a brief description of the EU ETS and the introduction to the dataset that provides the basis for this analysis. Section 3 provides an empirical framework to analyse the trading behaviour and significance of

transaction costs in the EU ETS market. The results and their implications are discussed in Section 4. Section 5 highlights the contributions of this paper and concludes.

2. Background on the EU ETS and CITL data

2.1 The brief description of the EU ETS

The EU ETS operates over pre-defined time periods, with the first period (2005-2007) being the subject of this study. The second phase coincides with the commitment period of the Kyoto Protocol (2008-2012), and this will be pursued by a third period (2013-2020).

The inclusion criteria for the first phase of the EU ETS are set in Annex I of the Emissions Trading Directive (European Parliament and Council 2003). This period covered CO_2 emissions from so called combustion installations with a rated thermal input in excess of 20 megawatts (mainly electricity and heat generators), oil refineries, the production and processing of ferrous metals, the manufacture of cement, the manufacture of lime, ceramics, glass, and pulp and paper. This coverage accounted for about a half of EU CO_2 emissions and 40 per cent of EU total greenhouse gas emissions. About 11 500 installations in all EU27 member states were covered.

Each installation should comply with the Emissions Trading Directive on annual basis. Compliance consists of surrendering tradable rights to emit, called European Union Allowances (EUAs). Each EUA allows emitting one tonne of CO_2. Each installation is required to hold a number of EUAs corresponding to its actual emissions. If it is assumed that installations surrender the allowances allocated to them first before making any exchanges in the market, the differences between each installation's actual emissions and its allocation indicate the extent of trading. Each *net long* installation (allocation is greater than actual

emissions) is a potential seller; and each *net short* installation (allocation is lower than actual emissions) is a potential buyer.

However, annual differences between allowances and actual emissions do not necessarily imply a transfer involving another installation or third party. ETS installations can bank EUAs not used in one year for use in a later year and they can borrow from the allocation for the next year to cover deficits in any given year. Banking and borrowing is allowed within but not between the trading phases.

2.2 The presentation of the CITL data

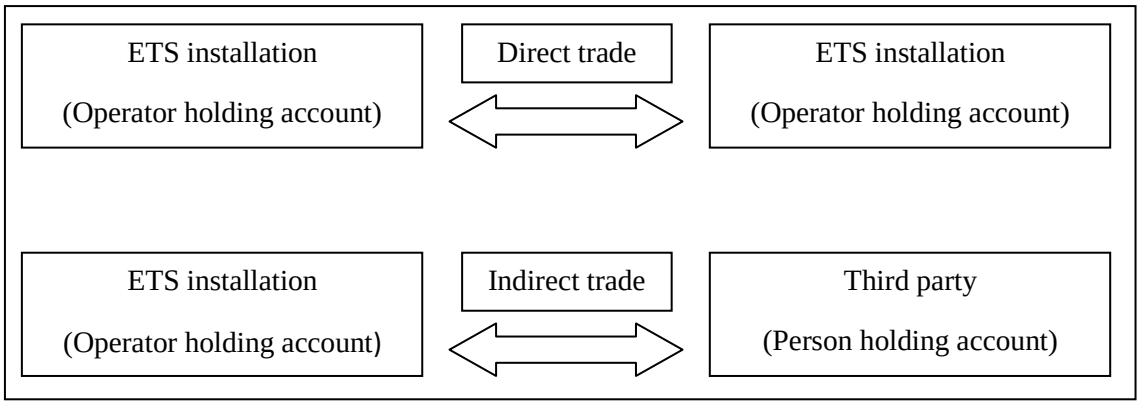
Each EU member state hosts a national registry consisting of accounts for all ETS installations. The registries keep information on the initial allocation of allowances, the annual verified actual emissions, the surrendered allowances, and all transactions in and out of the accounts. A copy of the national registry records is maintained in the Community Independent Transaction Log (CITL). The CITL is the central registry for the EU ETS. The CITL data on compliance and transactions are publicly available[4], but the data on transactions are published with a time lag of five years. This means that all transactions of EUAs that were made, for example, in 2007 became displayed from 15 January onwards of year 2012.

In this paper, the focus is only on transactions performed by ETS installations, i.e. the trading behaviour of third parties is not considered. More explicitly, we will analyse the trading behaviour of installations that *sold* some allowances to other installations or third parties, and on installations that *bought* some allowances from other installations or third parties. Technically, a transfer at no price is also possible, but prices at which allowances were transferred are not publicly available. In the CITL data, installations are named as Operator

[4]It is important to note that not all information on transactions (e.g. prices at which EUAs were traded) is made public.

holding accounts and third parties – as Person holding accounts. An exchange of allowances between two Operator holding accounts can be named as a *direct* trade, whereas a transfer between an Operator holding account and a Person holding account can be titled as an *indirect* trade (see Picture 1).[5]

Picture 1 Categorisation of trades



For the purpose of this analysis, the installation level data on compliance and transfers were aggregated to the firm level. At the time this study was performed, the transfers were available for the period 2005-2007. The last transfer was made in the end of December 2007. As the compliance period for the year 2007 finished in April 2008, it means that our dataset does not cover all transfers performed in the phase of the EU ETS. However, knowing that EUA price approached zero in the end of 2007, we expect that most transactions were performed before 2008. Also, it should be noted that the EU ETS compliance year does not correspond to a calendar year. The compliance year begins on the 1st of January and ends on the 30th of April of the next compliance year when EU ETS installations should surrender

[5] From the transaction cost perspective, indirect trading is perceived as entailing trading transaction costs. Because of this, brokerage fees are treated as a best proxy of trading transaction costs as one only engages in indirect (direct) trading if his or her transaction costs of direct trading are higher (lower) than brokerage fee.

EUAs for the previous compliance year. Therefore, the data on compliance and transfers were organised according to the EU ETS compliance year.[6]

3. The empirical strategy

The empirical strategy is built upon the main objectives of this study. We seek to answer the following questions: First, why ETS firms decide to trade allowances? Second, why ETS firms choose to exchange allowances indirectly rather than directly? Third, what factors explain the extent of trading? More specifically, our interest lies in whether transaction costs affect the trading behaviour of ETS firms.

3.1 Model choice

In our framework, ETS firms make two decisions with respect to trading in an effort to maximise their profitability: (1) whether to participate in allowance trading (a participation decision), and (2) how many allowances to trade given their participation (a quantity decision). Thus, the zero values in our data represent firms' optimal decisions rather than some sort of missing values. Because of this, corner solution models are more appropriate than selection models for our analysis.[7]

The Tobit model (Tobin 1958) might be used to deal with the above corner solution problem. However, this model can be very restrictive for both economic and statistical reasons since it assumes that the same set of variables determines both the probability of participation in trade and the level of trade, and that the factors affect both decisions in a similar way. A double-

[6] Detailed information on how the data were organised to perform this analysis can be obtained from the authors upon request.

[7] The Heckman selection approach is designed for cases when there are some sort of missing values, which might be reported as zeros in a dataset (Wooldridge 2010).

hurdle (DH) model, originally proposed by Cragg (1971), is a more flexible modelling framework in addressing corner solution problems. It assumes that firms make two decisions concerning allowance trading. Each decision might be determined by different factors and the effects of each factor can be different for each decision. The DH model fits well the research questions of this study since it allows testing whether transaction costs affect the participation and quantity decisions in different ways.

This study follows the modified Cragg's (1971) log-normal hurdle model. The first stage (Hurdle 1) of the analysis constructs a model of the probability of trading focusing on the role of transaction costs. Then we estimate a model of the probability of trading indirectly. For both cases the underlying trading decisions are modelled as:

$$Y_{it}^{*} = \boldsymbol{z_i\beta} + \boldsymbol{x_{it}\gamma} + \eta_i + \varepsilon_{it}, \tag{1}$$

where Y_{it}^{*} is a latent variable that underlines an observed indicator variable that captures whether or not a firm trades (or trades indirectly) according to the following rule:

$$Y_{it} = \begin{cases} 1 & Y_{it}^{*} > 0 \\ 0 & otherwise, \end{cases} \tag{2}$$

and

$$Pr(Y_{it} = 1 | z_i, x_{it}, \boldsymbol{\eta_i}) = \Phi(z_i\beta + x_{it}\gamma + \boldsymbol{\eta_i} + \varepsilon_{it}), \tag{3}$$

where $\boldsymbol{z_i}$ are firm-specific time invariant variables; $\boldsymbol{x_{it}}$ are firm-specific time variant variables; η_i are firm-specific time invariant unobservables such as firm culture, firm social responsibility, management background etc. The first stage uses the probit regressions to analyse factors affecting the participation in trading and indirect trading.

As said above, one of the challenges when analysing the trading behaviour is that many firms choose not to trade, so the data take on the properties of non-linear corner solution variables. The covariates of the non-linear panel model must be independent of unobserved

heterogeneity η_i. In the linear model, unobserved heterogeneity can be controlled for by including fixed firm-specific effects. In non-linear models, however, any attempt to estimate fixed unobserved heterogeneity effects will lead to the incidental parameters problem, resulting in biased and inconsistent estimates. However, using random effects requires the assumption that the random effects are not correlated with the explanatory variables in the model. This is a restrictive assumption, particularly in the context of the model we are attempting to estimate, where firm specific variables, such as choice of capital inputs and firm characteristics, are likely to be correlated with unobserved heterogeneity.

The assumption of independence between covariates and unobserved heterogeneity can be relaxed using a corrected random effects (CRE) framework which follows Mundlak (1978) and Chamberlain (1984). To control for potential correlations between the random effects and the other exogenous variables, the CRE option is to model the unobserved heterogeneity (η_i) as a function of the means of the time varying explanatory variables:

$$\eta_i = \bar{\boldsymbol{x}}_{\boldsymbol{i}}\boldsymbol{\psi} + a_i, \qquad (4)$$

where $\bar{\boldsymbol{x}}_{\boldsymbol{i}}$ is an average of $\boldsymbol{x}_{\boldsymbol{it}}$ over time for each firm. We assume that time invariant a_i is distributed as $N(0, \sigma_a^2)$ and is uncorrelated with $\boldsymbol{x}_{\boldsymbol{it}}$ and other time invariant exogenous variables.

The model can now be written as:

$$Pr(Y_{it} = 1|\boldsymbol{z}_{\boldsymbol{i}}, \boldsymbol{x}_{\boldsymbol{it}}, \bar{\boldsymbol{x}}_{\boldsymbol{i}}, a_i) = \Phi(\boldsymbol{z}_{\boldsymbol{i}}\boldsymbol{\beta} + \boldsymbol{x}_{\boldsymbol{it}}\boldsymbol{\gamma} + \bar{\boldsymbol{x}}_{\boldsymbol{i}}\boldsymbol{\psi} + a_i + \varepsilon_{it}). \qquad (5)$$

In the second stage (Hurdle 2), we investigate to what extent the transaction costs variables affect the extent of trading. For this purpose, we use a model that accounts for time invariant unobserved heterogeneity:

$$log\ (Trade_{it}) = \boldsymbol{z}_{\boldsymbol{i}}\boldsymbol{\beta} + \boldsymbol{x}_{\boldsymbol{it}}\boldsymbol{\gamma} + \eta_i + \nu_{it}, \qquad (6)$$

where a $log\,(Trade_{it})$ variable is the amount of traded allowances (in logs) by individual firms; v_{it} is an error term. The remaining terms are defined above. As in the case of panel probit models, unobserved heterogeneity is controlled by including the Mundlak terms to maintain the time-invariant variables in our model specifications.

This paper maintains Cragg's (1971) original assumptions that conditional on the explanatory variables, the errors between Hurdle 1 and Hurdle 2 are independent and normally distributed and that the covariance between the two errors equals zero.

Before exploiting the panel nature of the dataset, we also estimate the cross-sectional hurdle models for each available year to explore the learning-by-doing effects of allowance trading.

3.2 The choice of factors affecting trade

The above models include a number of variables as the determinants of the trading decisions. These variables are: firm output, firm capital, firm net allocation position, firm size in terms of allocation, the sectoral and regional dummies, and some transaction costs variables.

Firm output is an indicator of firm size in terms of its main activity. We use firm-level revenue to proxy firm output.[8] Additionally, this variable might indicate whether a firm is a part of growing or declining industry. Notice, that revenue takes into account only income received from the main activity, i.e. income associated with trading allowances is not reflected in this variable and therefore this does not cause an endogeneity problem.

[8] Firm-level revenue as well as fixed capital are obtained from the Amadeus (Bureau van Dijk). This database includes firm-level accounting and other data in standardised financial format. The general source for the Amadeus is national official public bodies in European countries. The Amadeus database is a very useful information source for cross-country comparisons as it provides harmonised accounts for large fraction of European firms. A lot of effort has been used to identify ETS firms in this dataset. Detailed information of how this identification was performed can be received from the authors upon request.

The technology of a firm is an important factor influencing the level of pollution. Also, technology depicts pollution abatement potential and hence a possibility to free up allowances. Fixed capital is used in this paper to proxy technology. Fixed capital, conditional on firm size (capital intensity), might indicate technological differences across firms. Additionally, we use the sectoral dummies, which will give an idea of products being manufactured by each ETS firm. However, these dummies are very aggregate and probably will not give much firm specific information.

Firm annual net allocation positions are used to capture the potential extent of trading. As said above, we expect that firms with the positive net allocation positions are the potential sellers of allowances, whereas firms with the negative net allocation position are the potential buyers of allowances.

Following Jaraitė et al. (2010), we group ETS firms according to the level of firms' allocated permits into three categories: large (with an allocation share larger than 2% of the particular country's total allocation, medium (0.1% - 2%) and small (up to 0.1%). We expect small ETS firms to be less experienced in trading when compared to large ETS firms who trade on daily basis in different markets (e.g. electricity generators).

We also include few regional dummies to understand whether there is any geographical variation in the decision to trade allowances. We were unable to use country-level dummies due to the issue of multicollinearity.

As discussed above, a number of firms did not sell their surplus allowances during the first phase of the EU ETS. One of the reasons for this could be high transaction costs that might prevent firms entering the market. When transaction costs are non-zero, some firms might opt out of the market meaning that we should take into account transaction costs variables when modelling the trading decisions. Based on the available data, we construct two variables – search costs and information costs – that identify transaction costs in the EU ETS market.

According to Gangadharan (2000), search costs can potentially be rather high for heterogeneous firms as they do not often interact in the same input or output markets. Also, some ETS firms consist of more than one ETS installation meaning that these firms have a possibility to trade/transfer allowances within a firm. This reduces their search costs. Also, we might expect these firms to trade directly without the help of a broker. Using information from the CITL and national allocation plans we are able to count the number of ETS installations within each ETS firm.

The number of transactions that is performed by a firm can capture information costs to some degree. This gives the number of times a firm enters the market. Every time a firm trades directly or indirectly it gains more experience in the market, obtains more information. We expect that as the number of transaction increases, information costs go down. We construct a dummy variable, which is equal to one if a firm traded twice or more in the years 2005 and 2006.

4. The results

4.1 The descriptive statistics

Table I summarises the dataset according to the year, the type of trade, and the allocation position. The dataset consists of 17 495 observations for the period 2005-2007 and covers ETS firms that operate in twenty-two EU countries.[9] About a quarter of ETS firms sold some allowances, and about one sixth of ETS firms bought some allowances. The year 2006 was more active than the year 2005 in terms of both selling and buying activities. This might be

[9] Some adjustments were made to the CITL data. As a result of that, several unrepresentative observations dropped out. The details can be obtained from the authors upon request. Bulgaria, Cyprus, Malta, Luxembourg and Romania were excluded from the analysis due to lack of data.

explained by the fact that many member states were late to set up their national registries.[10] As expected, most firms who sold some allowances had the positive net allocation positions. About a half of firms who bought some allowances were "long" too. We might expect that these firms primarily bought allowances not for compliance, but for financial speculation purposes. The data reveals that more than thousand ETS firms were active on both sides of the market within the same year.

[Insert Table I about here]

As explained in Section 2, ETS installations could either trade EUAs directly with other ETS installations or indirectly via third parties (person holding accounts). Table II and Table III reveal more than half of trading firms performed transfers via person holding accounts. However, we might suspect that some of person holding accounts might be affiliated with operator holding accounts. In other words, some ETS installations may establish separate person holding accounts to carry all EUA-related transactions. In this case, transactions between affiliated accounts should be treated as direct transfers rather than the indirect ones. Table II and Table III reveal that about 13 per cent of selling firms and about 9 per cent of buying firms carried EUA transactions with affiliated person holding accounts.[11] Also, it is evident that real third parties (e.g. banks, clearers, traders) were rather active in the first trading phase – about 27 per cent and 17 per cent of sellers and buyers, respectively, used their services.

[Insert Table II and Table III about here]

From Table IV it is evident that Germany, France, Poland, Spain and the United Kingdom were the top sellers. In Estonia, Finland and the Netherlands about half ETS firms sold their

[10] EEA (2006, 29 p.) notes that "by April 2005, only few registries were connected to the CITL and only limited transactions were undertaken."

[11] More details on how this identification was performed can be obtained from the authors upon request.

allowances in the market. In terms of buying activity, the most active were Germany, Italy, the United Kingdom, France and Spain. To some extent the geographical distribution of trading activities reflect the net allocation positions for each country (see Table IV). For example, Germany, France and Poland had the largest positive net allocation positions and were among the top sellers of allowances; while Italy, the UK and Spain had the largest negative net allocation positions and were among the top buyers of allowances.

[Insert Table IV about here]

The average size of firm-level selling/buying transactions and its geographical distribution is presented in Table IV. It is important to remind that these transfers might also include transfers at no price. On average, an ETS firm sold 213.8 thousand EUAs and bought 227.0 thousand EUAs. ETS firms in the UK, the Netherlands and Estonia sold on average the largest amount of permits, whereas ETS firms in the UK, the Netherlands and Spain bought on average the largest amount of permits.

Table V presents the descriptive statistics of all variables used in this study. Separately, the summary statistics are reported for firms that sold and bought some allowances. It is evident that firms that traded some allowances were bigger in terms of capital and revenues than an average ETS firm. Firms that bought some allowances had larger capital and revenue compared to firms that sold some EUAs. The average net allocation position, i.e. the difference between the allocated allowances and verified emissions, was positive for sellers and negative for buyers. Also, firms who traded some EUAs consisted of more installations than the average firm. It is also evident that buyers had, on average, more installations than sellers. The summary statistics for sectoral dummies reveal that firms in the glass, ceramics and plastic sector and firms in the power generating sector were the most active in allowance trading.

[Insert Table V about here]

4.2 The discussion of the main estimation results[12]

Decision to trade

The results of the cross-sectional and panel first stage hurdle models are presented in Table VI. Columns 1-4 summarise the determinants of the decision to sell allowances; Columns 5-8 summarise the determinants of the choice to buy allowances. It is evident that the transaction costs variables – search costs and information costs – were significant in explaining the trading decisions in the first phase of the EU ETS. ETS firms with larger number of ETS installations were more likely to participate in trading. This might indicate that for an ETS firm with multiple installations it was easier to find a trading partner, i.e. it could sell/buy its allowances within a firm meaning that its search costs were lower than for an ETS firm with a single installation. Also, ETS firms with multiple installations might have a separate unit to deal with EU ETS issues and a coordinated compliance strategy. Another important result related to transaction costs is that information costs were significant in the years 2006 and 2007. If the number of trades recorded in 2005 and 2006 was equal or greater than two, then the probability that an average ETS firm trades in 2006 and 2007 is higher. This suggests that firms that entered the market several times have more information on the procedures to be followed and hence incur lower information costs. In the panel probit models (see columns 4 and 8), this result is captured by the coefficients for the Mundlak terms of the information costs variables.[13]

[12] Due to a large number of missing observations for firm revenue and fixed capital, these variables were excluded from the models reported in this paper. The results of the models that include these variables are discussed later on.

[13] The Mundlak terms can be thought of as representing the permanent (long-run) changes in the relevant variables, i.e. the level effects while the time-varying variables capture the transient changes or shock effects (short-run).

Also, the marginal analysis on the probit models reveals that the importance of transactions costs was declining over time. [14] For example, the marginal effects indicate that holding all variables at their respective means (and the dummy variables at their sample proportions), if the number of installations within an average ETS firm increases by one, a probability of selling allowances increases by 2.6% in 2005, by 3.6% in 2006, and only by less than 1% in 2007. Also, ETS firms that sold allowances two times or more in 2005 had a 31.6% higher probability of selling allowances in 2006 than ETS firms that sold allowances once. This probability decreases to 13.1% in the year 2007. The same patterns are observed for buyers.

[Insert Table VI about here]

As expected, ETS firms with larger net allocation positions were more likely to sell allowances and less likely to buy them. We also find that firm size matters in making trading decisions: medium and large ETS firms in terms of allocation were more likely to trade allowances. In other words, small ETS firms were less prone to participate in allowance trading. This result supports the concerns raised by the European Commission (e.g. see CEC (2008)) that trading transaction costs might be excessive for smaller participants. The coefficients of the sectoral dummy variables indicate that ETS firms in the power generating sector were more likely to participate in allowance trading than other ETS firms. This might be explained by the size of energy generating firms as well as their trading experience in other input and output markets. The coefficients for the regional dummies reveal that most countries were less likely to buy allowances and more prone to sell them when compared to Germany. These results to some extent reflect the country-level net allocation positions.

Decision to trade indirectly

[14] The marginal effects for all non-linear models were estimated too. They are in line with the estimates of the baseline specifications and, hence, are not reported here, but available from the authors upon request.

The second aim of this study is to understand why ETS firms choose to trade allowances indirectly rather than directly.[15] As discussed above, firms with high transaction costs are more likely to trade allowances indirectly via third parties. The results of the cross-sectional and panel first stage hurdle models for the indirect trading choice are presented in Table VII. Columns 1-4 summarise the determinants of the decision to sell allowances indirectly; Columns 5-8 summarise the determinants of the choice to buy allowances indirectly.

[Insert Table VII about here]

Transactions costs appear to be significant in explaining the choice to trade allowances indirectly. As expected, ETS firms with multiple installations were less likely to trade indirectly. This confirms our arguments presented above that search costs for ETS firms with multiple installations are lower. These firms have a possibility to trade within firm boundaries; also, they are bigger and have a sufficient in-house capacity to trade directly with other ETS firms. Another finding is that firms who traded their allowances in the previous periods are less likely to trade EUAs indirectly. This result is relevant for both sellers and buyers. However, it is not significant for the year 2007. This finding is along our expectations that firms experienced in trading would be less prone to trade indirectly.

The remaining estimates show that the net allocation position had no or very negligible effect on the decision to trade allowances indirectly. Medium and large ETS firms in terms of allocation were less prone to trade indirectly. The coefficients of the sectoral dummy variables indicate that ETS firms in the power generating sector were more likely to trade indirectly than firms in the other sectors. We suggest that this result does not signify that power generator had higher transaction costs, but available in-house capacity to trade indirectly. The coefficients for the regional dummies are significant only for some regions.

[15] See Subsection 2.2 for the definitions of direct and indirect trading.

The noticeable result is that ETS firms operating in the member states that accessed the EU in 2004 were more likely to sell their allowances indirectly. To some extent this might signify that these firms did not have a sufficient capacity and experience to trade directly with other ETS firms.

Extent of trading

The last aim of this study is to investigate whether trading transaction costs are important in explaining the extent of trading. According to Stavins (1995), fixed trading transaction costs can affect whether or not a particular transaction takes place but not its magnitude. Variable trading transaction costs or so-called positive marginal transaction costs reduce the amount exchanged in each trade and may diminish the number of trades. In return, this may affect the overall cost-effectiveness of the permit trading programme. To understand whether transaction costs affect the extent of trading the second stage hurdle models are estimated.

Table VIII presents the results of the cross-sectional and panel (random effects) second stage hurdle models. Columns 1-4 summarise the results for sellers and Columns 5-8 – for buyers. The results indicate that both transaction costs variables have a significant effect on the amount of permits traded. This might indicate that transaction costs in the EU ETS are not only fixed in nature, but also are affected by the amount of allowances traded. The number of installations within a firm had a positive effect on the amount of allowances sold, but not bought. As discussed above, this might signify that firms with multiple installations are more active in selling allowances due to larger in-house trading capacity. This is also confirmed by the coefficients for size dummies. Medium and large ETS firms traded more permits than small ETS firms. Another important result related to transaction costs is that past trading experience had a significant effect in explaining the extent of trading. The remaining estimates are similar to the ones of the first stage hurdle models and, hence, are not discussed here.

[Insert Table VIII about here]

Inclusion of revenue and fixed assets

As a final step of this study, we run the above models with two additional economic variables – revenue from the main activity and fixed capital – to control for firm size and technology. Revenue might be also an indicator of whether a firm is a part of an expanding or declining industry. The inclusion of revenue and fixed assets did not affect the main findings on transaction costs discussed above. The results indicate that firms with higher revenue are more likely to trade allowances and less likely to trade indirectly. Revenue has no affect on the amount of permits traded. ETS firms with higher fixed assets are more likely to trade indirectly. This result might be linked to the finding discussed above that firms operating in the power generating sector (power generators have significantly higher fixed assets) are more likely to trade indirectly via third parties due to available in-house capacity.

5. The conclusions

Several authors (Coase 1960; Tietenberg 2006) have commented on the importance of a comprehensive approach to assessing transaction costs. The assessment of trading transaction costs is especially important in the early stages of any pollution trading programme. To the best of our knowledge, our study is the first to empirically analyse permit trading transaction costs for *all* firms covered under the first phase the EU's Emissions Trading System.

This study exploits the unique dataset that allows investigating the trading behaviour of ETS firms as well as significance of trading transaction costs, such as information costs and search costs. In particular, we aimed to address the following questions in an empirical framework: What firms decide to trade, and how do they differ from non-traders? Further, how do transaction costs affect decisions of ETS firms? Are transaction costs significant and do they

decrease over time due to learning-by-doing processes? Our analysis shows that transaction costs played an important role in the initial years of the EU ETS. These costs were significant in explaining why some ETS firms did not participate in the European emissions trading market and chose to trade allowances indirectly via third parties. Also, it is evident that the importance of transaction costs was declining over time. This study also supports the concerns raised by the European Commission (e.g. see CEC, 2008) that transaction costs might be excessive for smaller participants.

The further research on the trading behaviour in the EU ETS might focus on EUA price and market power effects as well as on the trading behaviour of third parties and their interactions with ETS installations.

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Table I The presentation of the dataset

Year	Total no. of firms	No. of sellers	No. of "long" sellers	No. of buyers	No. of "long" buyers
2005	5 871	1 481	1 318	735	381
2006	5 889	1 950	1 719	1 283	592
2007	5 735	862	775	706	311
Total	17 495	4 293	3 812	2 724	1 284

Sources: CITL and authors' calculations.

Table II Classification of selling transactions performed by ETS firms

Year	No. of sellers	No. of direct sellers	No. of indirect sellers	No. of bank-related indirect sellers	No. of ETS-related indirect sellers	No. of "the rest" indirect sellers
2005	1 481	487	1 209	400	174	783
2006	1 950	598	1 600	532	223	994
2007	862	262	689	206	140	384
Total	4 293	1 347	3 498	1 138	537	2 161

Sources: CITL and authors' calculations.

Table III Classification of buying transactions performed by ETS firms

Year	No. of buyers	No. of direct buyers	No. of indirect buyers	No. of bank-indirect buyers	No. of ETS-related indirect buyers	No. of "the rest" indirect buyers
2005	735	457	374	67	94	256
2006	1 283	592	820	235	104	517
2007	706	266	477	161	43	288
Total	2 724	1 315	1 671	463	241	1 061

Sources: CITL and authors' calculations.

Table IV The geographical distribution of trading activity

Country	Total no. of firms	3-year net allocation position, million EUAs	No. of firms who sold some EUAs	Mean of no. EUAs sold, thousands	No. of firms who bought some EUAs	Mean of no. EUAs bought, thousands
Austria	336	0.22	29	56.2	22	28.2
Belgium	581	15.26	145	278.5	71	276.8
Czech Republic	748	37.23	269	183.9	81	116.9
Denmark	676	1.78	225	150.4	150	171.8
Estonia	82	16.36	41	450.0	14	330.0
Finland	417	14.03	194	122.4	147	56.1
France	1 666	71.26	609	138.0	239	85.0
Germany	2 928	62.85	661	199.4	560	148.4
Greece	276	0.94	10	275.7	9	114.2
Hungary	432	12.37	119	104.6	52	83.0
Ireland	208	-5.47	27	20.4	40	52.6
Italy	1 596	-42.06	184	390.0	310	276.8
Latvia	158	3.30	54	69.5	21	52.7
Lithuania	192	15.22	69	232.4	16	182.1
Netherlands	377	22.42	177	473.6	69	540.2
Poland	1 625	90.34	326	224.5	110	61.6
Portugal	565	10.01	118	128.7	57	115.2
Slovakia	383	16.12	135	119.5	49	78.4
Slovenia	268	-0.48	10	25.4	28	23.0
Spain	2 064	-52.10	321	157.0	222	344.1
Sweden	740	9.02	272	59.3	185	55.5
United Kingdom	1 177	-106.21	298	577.7	272	763.2
Total	17 495	13.14	4 293	213.8	2 724	227.0

Sources: CITL and authors' calculations.

Table V The descriptive statistics

		All firms		Firms that sold EUAs		Firms that bought EUAs	
Variable	Measurement units	Obs.	Mean	Obs.	Mean	Obs.	Mean
Firms that sold some allowances	A dummy variable	17495	0.245	4293	1.000	2724	0.492
Firms that bought some allowances	A dummy variable	17495	0.156	4293	0.312	2724	1.000
No. of permits sold	Thousands EUAs	17495	52.5	4293.0	213.8	2724.0	226.4
No. of permits bought	Thousands EUAs	17495	35.4	4293.0	121.5	2724.0	227.0
If sold only indirectly	A dummy variable	17495	0.146	4293	0.596	2724	0.155
If bought only indirectly	A dummy variable	17495	0.072	4293	0.086	2724	0.460
Difference btw. allocation and emissions	Thousands EUAs	17495	11.0	4293.0	44.2	2724.0	-44.0
Number of installation within a firm	No. of installations	17495	1.736	4293	2.697	2724	3.188
If sold more than twice in 2005-2006	A dummy variable	11456	0.077	2800	0.146	1982	0.224
If bought more than twice in 2005-2006	A dummy variable	11456	0.170	2800	0.361	1982	0.263
Small firms in terms of allocation	A dummy variable	17495	0.766	4293	0.566	2724	0.616
Medium firms in terms of allocation	A dummy variable	17495	0.200	4293	0.354	2724	0.298
Largest firms in terms of allocation	A dummy variable	17495	0.035	4293	0.081	2724	0.086
France and Belgium	A dummy variable	17495	0.128	4293	0.176	2724	0.114
Germany	A dummy variable	17495	0.167	4293	0.154	2724	0.206
Hungary and Austria	A dummy variable	17495	0.044	4293	0.034	2724	0.027
Italy Greece Portugal and Spain	A dummy variable	17495	0.257	4293	0.147	2724	0.220
Estonia Latvia Lithuania	A dummy variable	17495	0.025	4293	0.038	2724	0.019
Netherlands	A dummy variable	17495	0.022	4293	0.041	2724	0.025
CZ Poland Slovakia Slovenia	A dummy variable	17495	0.173	4293	0.172	2724	0.098
Denmark Finland and Sweden	A dummy variable	17495	0.105	4293	0.161	2724	0.177
UK and Ireland	A dummy variable	17495	0.079	4293	0.076	2724	0.115
Power generation	A dummy variable	17495	0.187	4293	0.281	2724	0.230
Food beverages and tobacco	A dummy variable	17495	0.068	4293	0.057	2724	0.065
Textiles and leather	A dummy variable	17495	0.017	4293	0.010	2724	0.004
Wood and paper	A dummy variable	17495	0.145	4293	0.141	2724	0.134
Coke cement and refined products	A dummy variable	17495	0.063	4293	0.082	2724	0.081
Chemicals and pharmaceutical products	A dummy variable	17495	0.049	4293	0.056	2724	0.048
Glass ceramics and plastic	A dummy variable	17495	0.195	4293	0.126	2724	0.137
Metals	A dummy variable	17495	0.016	4293	0.014	2724	0.012
Computers and machinery	A dummy variable	17495	0.031	4293	0.019	2724	0.023
Other sectors	A dummy variable	17495	0.229	4293	0.214	2724	0.265
Revenue	Millions euro	11758	654.0	3037.0	1092.3	1874.0	1366.7
Fixed assets	Millions euro	12018	440.6	3107.0	772.5	1895.0	1093.3

Table VI The determinants of the participation in the EU ETS market (Hurdle 1)

	If firms sold some EUAs				If firms bought some EUAs			
Variables	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Net allocation	0.0001**	0.0002***	0.0003***	0.0000	-0.0003***	-0.0003***	0.0000	-0.0002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)	(0.0001)
No. of installation within a firm	0.0853***	0.0983***	0.0410***	0.0279***	0.1327***	0.0850***	0.0248***	0.0101
	(0.0097)	(0.0116)	(0.0088)	(0.0080)	(0.0101)	(0.0112)	(0.0078)	(0.0067)
If sold twice and more (lag)		0.8236***	0.5445***	-0.9695***				
		(0.0543)	(0.0535)	(0.0648)				
If bought twice and more (lag)						1.1290***	0.6927***	-1.0898***
						(0.0840)	(0.0685)	(0.0938)
Medium firms	0.5487***	0.4397***	0.5941***	0.3715***	0.4368***	0.2652***	0.2489***	0.2025***
	(0.0512)	(0.0503)	(0.0563)	(0.0467)	(0.0605)	(0.0536)	(0.0604)	(0.0457)
Largest firms	0.6736***	0.5103***	0.9255***	0.5593***	0.7892***	0.3602***	0.4791***	0.1984**
	(0.1097)	(0.1120)	(0.1087)	(0.0959)	(0.1218)	(0.1183)	(0.1147)	(0.0931)
France and Belgium	0.3746***	0.2174***	0.3962***	0.2935***	-0.0658	-0.4262***	-0.1906**	-0.2856***
	(0.0675)	(0.0682)	(0.0804)	(0.0635)	(0.0829)	(0.0741)	(0.0820)	(0.0621)
Hungary and Austria	-0.8743***	0.0865	-0.2456*	0.0939	-0.8259***	-0.4764***	-0.4254***	-0.3671***
	(0.1260)	(0.0958)	(0.1253)	(0.0918)	(0.1613)	(0.1099)	(0.1281)	(0.0934)
Italy, Greece, Portugal and Spain	-0.3907***	-0.2149***	-0.0284	-0.0489	-0.2612***	-0.1559**	-0.1516**	-0.1367***
	(0.0643)	(0.0608)	(0.0753)	(0.0572)	(0.0782)	(0.0607)	(0.0671)	(0.0511)
Estonia, Latvia, Lithuania	0.4770***	-0.4034***	-0.0866	-0.2185*	-0.2570*	-0.7160***	-0.5586***	-0.6087***
	(0.1226)	(0.1273)	(0.1462)	(0.1163)	(0.1516)	(0.1505)	(0.1788)	(0.1310)
Netherlands	0.8150***	0.5328***	0.0780	0.2222*	0.2519*	-0.3614**	-1.0064***	-0.7384***
	(0.1283)	(0.1335)	(0.1506)	(0.1188)	(0.1434)	(0.1435)	(0.2277)	(0.1352)
CZ, Poland, Slovakia, Slovenia	-0.3590***	0.1869***	0.0732	0.1754***	-0.7884***	-0.4654***	-0.3182***	-0.3615***
	(0.0679)	(0.0622)	(0.0778)	(0.0591)	(0.0979)	(0.0690)	(0.0789)	(0.0591)
Denmark, Finland and Sweden	0.5294***	0.1572**	-0.0056	0.0521	0.3472***	-0.0152	-0.2454***	-0.1225*
	(0.0712)	(0.0732)	(0.0890)	(0.0680)	(0.0797)	(0.0739)	(0.0877)	(0.0636)
UK and Ireland	0.1947**	-0.0103	-0.1189	-0.0901	0.2799***	-0.0303	-0.1876*	-0.1142
	(0.0816)	(0.0834)	(0.1063)	(0.0793)	(0.0904)	(0.0829)	(0.0989)	(0.0715)
Food, beverages and tobacco	-0.3683***	-0.2835***	-0.4982***	-0.3081***	-0.1816*	0.1496*	0.0889	0.1470*
	(0.0873)	(0.0829)	(0.1102)	(0.0792)	(0.1060)	(0.0869)	(0.1047)	(0.0755)

(cont' Table 5)	If firms sold some EUAs				If firms bought some EUAs			
Variables	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Textiles and leather	-0.2480	-0.3280**	-1.1980***	-0.4368***	-0.7513**	-0.4043**	-0.8512**	-0.4836***
	(0.1559)	(0.1476)	(0.3753)	(0.1524)	(0.3059)	(0.1898)	(0.3819)	(0.1799)
Wood and paper	-0.1713***	-0.3169***	-0.2241***	-0.2761***	-0.2392***	-0.0643	0.2290***	0.0957
	(0.0664)	(0.0652)	(0.0770)	(0.0607)	(0.0834)	(0.0702)	(0.0804)	(0.0600)
Coke, cement and refined products	-0.6153***	-0.2468***	0.0523	0.0199	-0.3616***	-0.0941	0.4079***	0.2391***
	(0.0915)	(0.0847)	(0.0899)	(0.0757)	(0.1073)	(0.0905)	(0.0953)	(0.0743)
Chemicals and pharmaceutics	-0.2265**	-0.1905**	-0.1868*	-0.1438*	-0.0962	-0.1201	0.2442**	0.0718
	(0.0956)	(0.0935)	(0.1078)	(0.0858)	(0.1142)	(0.1045)	(0.1115)	(0.0863)
Glass, ceramics and plastic	-0.4669***	-0.3009***	-0.2180***	-0.1796***	-0.6506***	-0.1345**	0.2948***	0.1230**
	(0.0661)	(0.0612)	(0.0750)	(0.0575)	(0.0934)	(0.0675)	(0.0766)	(0.0570)
Metals	-0.6659***	-0.3919***	-0.1429	-0.1691	-0.0403	0.0583	-0.1485	-0.0032
	(0.1818)	(0.1482)	(0.1782)	(0.1375)	(0.1984)	(0.1607)	(0.2158)	(0.1430)
Computers and machinery	-0.4605***	-0.5795***	-0.2005	-0.3345***	-0.1737	-0.0025	-0.1623	-0.0552
	(0.1218)	(0.1204)	(0.1401)	(0.1106)	(0.1505)	(0.1248)	(0.1622)	(0.1098)
Other sectors	-0.4605***	-0.4116***	-0.1832***	-0.2200***	-0.0513	0.0173	0.0353	0.0543
	(0.0612)	(0.0598)	(0.0696)	(0.0551)	(0.0706)	(0.0640)	(0.0762)	(0.0550)
Year 2006 dummy				0.8473***				0.4361***
				(0.0367)				(0.0331)
Net allocation (Mundlak term)				0.0002				0.0002*
				(0.0001)				(0.0001)
Sold twice and more (lag, Mundlak term)				2.9699***				
				(0.1017)				
Bought twice and more (lag, Mundlak term)								3.1612***
								(0.1300)
Constant	-0.6623***	-0.6068***	-1.3547***	-1.7328***	-1.2689***	-0.8257***	-1.3204***	-1.4298***
	(0.0615)	(0.0619)	(0.0732)	(0.0699)	(0.0734)	(0.0645)	(0.0736)	(0.0633)
Log likelihood	-2798.9	-3133.7	-2025.9	-4581.5	-1759.6	-2671.7	-1965.5	-4339.1
Wald test (Chi2)	1034.2	1093.1	771.1	1365.0	909.3	750.8	331.6	1021.0
Wald test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations (total)	5 871	5 754	5 702	11 456	5 871	5 754	5 702	11 456

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table VII The determinants of the choice to trade allowances indirectly

	If firms sold some EUAs only indirectly				If firms bought some EUAs only indirectly			
Variables	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Net allocation	-0.0000	0.0001*	0.0000	-0.0001	0.0002**	0.0000	0.0001	-0.0003
	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0003)
No. of installation within a firm	-0.0865***	-0.1136***	-0.0285***	-0.0990***	-0.0714***	-0.0831***	-0.0423***	-0.1148***
	(0.0128)	(0.0128)	(0.0102)	(0.0147)	(0.0159)	(0.0137)	(0.0132)	(0.0236)
If sold twice and more (lag)		-0.1546**	0.1104	0.1178				
		(0.0726)	(0.0995)	(0.1183)				
If bought twice and more (lag)				0.1570		-0.3130***	0.1570	0.4131**
				(0.1294)		(0.1083)	(0.1294)	(0.2106)
Medium firms	-0.2948***	-0.0633	-0.0991	-0.1101	0.0517	-0.1320	-0.4938***	-0.3742**
	(0.0842)	(0.0749)	(0.1114)	(0.1050)	(0.1240)	(0.0966)	(0.1322)	(0.1622)
Largest firms	-0.7196***	-0.4136***	-0.4380***	-0.6962***	-0.2055	-0.1508	-0.4229*	-0.4090
	(0.1567)	(0.1399)	(0.1688)	(0.1890)	(0.2065)	(0.1780)	(0.2202)	(0.2893)
France and Belgium	-0.0249	0.1484	-0.1869	0.1255	0.2543	0.0503	-0.3287*	-0.3401
	(0.1175)	(0.1080)	(0.1550)	(0.1508)	(0.1807)	(0.1434)	(0.1813)	(0.2319)
Hungary and Austria	0.4103	0.4828***	0.0829	0.6646***	-0.9468*	0.0742	-0.3533	-0.2158
	(0.3068)	(0.1684)	(0.2591)	(0.2375)	(0.5601)	(0.2255)	(0.2936)	(0.3634)
Italy, Greece, Portugal and Spain	0.0211	0.2162*	0.2731	0.3487**	0.3647**	0.2339**	0.2400*	0.4835**
	(0.1376)	(0.1122)	(0.1676)	(0.1564)	(0.1816)	(0.1141)	(0.1453)	(0.1921)
Estonia, Latvia, Lithuania	0.7065***	0.5837***	0.6065**	0.9833***	0.1752	0.1452	-0.3010	-0.0920
	(0.1932)	(0.2156)	(0.2850)	(0.2978)	(0.3173)	(0.3043)	(0.4311)	(0.5127)
Netherlands	0.3431*	0.2834	0.1700	0.5015**	-0.1164	-0.2723	-0.8252	-0.7076
	(0.1844)	(0.1754)	(0.2704)	(0.2535)	(0.2827)	(0.2638)	(0.6606)	(0.4848)
CZ, Poland, Slovakia, Slovenia	0.5601***	0.5018***	0.5786***	0.9242***	-0.0225	0.2259	0.1422	0.2184
	(0.1429)	(0.1069)	(0.1598)	(0.1611)	(0.2497)	(0.1398)	(0.1798)	(0.2250)
Denmark, Finland and Sweden	-0.0784	-0.1649	0.4327**	-0.0195	-0.5185***	-0.2743**	0.1339	-0.4370**
	(0.1188)	(0.1122)	(0.1795)	(0.1588)	(0.1658)	(0.1254)	(0.1859)	(0.2169)
UK and Ireland	-0.0268	0.1098	-0.1373	0.1424	0.3710**	0.3083**	0.1515	0.4173*
	(0.1472)	(0.1390)	(0.2307)	(0.1984)	(0.1788)	(0.1430)	(0.2239)	(0.2477)
Food, beverages and tobacco	0.0708	-0.2224	-0.2591	-0.3437*	-0.5270**	-0.1620	0.1108	-0.1388
	(0.1566)	(0.1380)	(0.2410)	(0.1970)	(0.2445)	(0.1613)	(0.2461)	(0.2743)

(cont' Table 7)	If firms sold some EUAs only indirectly				If firms bought some EUAs only indirectly			
Variables	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Textiles and leather	0.7618*	0.1332		0.3318		-0.0637		0.0656
	(0.3914)	(0.3209)		(0.4974)		(0.4651)		(0.8722)
Wood and paper	0.0592	-0.3619***	-0.3016**	-0.4644***	-0.3082*	-0.1568	-0.4730**	-0.6266***
	(0.1117)	(0.1028)	(0.1521)	(0.1453)	(0.1867)	(0.1338)	(0.1837)	(0.2304)
Coke, cement and refined products	-0.1337	-0.3435***	-0.2728*	-0.4237**	-0.5327**	-0.2284	-0.2322	-0.5951**
	(0.1614)	(0.1260)	(0.1538)	(0.1659)	(0.2305)	(0.1628)	(0.1945)	(0.2636)
Chemicals and pharmaceutics	0.2090	-0.1676	0.0110	-0.1796	-0.3615	-0.3499*	-0.5528**	-0.8390**
	(0.1621)	(0.1441)	(0.2086)	(0.2022)	(0.2454)	(0.1992)	(0.2459)	(0.3305)
Glass, ceramics and plastic	0.3919***	-0.0964	-0.2153	-0.1355	-0.7862***	0.1589	-0.0215	0.0789
	(0.1406)	(0.1073)	(0.1640)	(0.1490)	(0.2620)	(0.1328)	(0.1797)	(0.2164)
Metals	-0.2087	0.2772	0.1736	0.2431	-0.8196*	0.6021*	-0.3797	0.7047
	(0.3701)	(0.2920)	(0.3616)	(0.3735)	(0.4842)	(0.3415)	(0.5409)	(0.5581)
Computers and machinery	-0.1379	-0.2778	0.2120	-0.1747	-0.0906	0.3312	0.0610	0.4349
	(0.2541)	(0.2339)	(0.3394)	(0.3153)	(0.3208)	(0.2515)	(0.4326)	(0.4347)
Other sectors	-0.0990	-0.3145***	-0.1268	-0.3765***	-0.1705	-0.1797	-0.0683	-0.3020
	(0.1014)	(0.0937)	(0.1393)	(0.1309)	(0.1397)	(0.1135)	(0.1701)	(0.1919)
Year 2006 dummy				0.1643**				-0.3360***
				(0.0785)				(0.1172)
Net allocation (Mundlak term)				0.0002				0.0004
				(0.0003)				(0.0004)
Sold twice and more (lag, Mundlak term)				-0.4585***				
				(0.1687)				
Bought twice and more (lag, Mundlak term)								-1.0001***
								(0.2843)
Constant	0.4835***	0.6661***	0.1993	0.6932***	-0.0634	0.2925**	0.5360***	1.0648***
	(0.1081)	(0.0978)	(0.1468)	(0.1563)	(0.1564)	(0.1164)	(0.1661)	(0.2376)
Log likelihood	-884.31201	-1143.1277	-551.44189	-1686.449	-406.32593	-794.13796	-440.81644	-1215.4689
Wald test (Chi2)	230.07	303.58	72.26	127.4	88.07	182.5	78.37	62.36
Wald test (p-value)	0	0	0	0	0	0	0	0
Observations (total)	1,481	1,944	855	2,800	733	1,278	703	1,982

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table VIII The determinants of the extent of trading (Hurdle 2)

Variables	If firms sold some EUAs				If firms bought some EUAs			
	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Net allocation	0.0001	0.0001*	0.0003***	-0.0002	-0.0005***	-0.0004***	-0.0003***	-0.0004**
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
No. of installation within a firm	0.0264***	0.0321***	0.0273***	0.0196***	0.0186	0.0160	-0.0006	-0.0019
	(0.0100)	(0.0087)	(0.0089)	(0.0073)	(0.0148)	(0.0106)	(0.0122)	(0.0086)
If sold twice and more (lag)		0.2886***	0.2985***	-0.6481***				
		(0.0843)	(0.1052)	(0.0814)				
If bought twice and more (lag)						0.7254***	0.2659	-0.7313***
						(0.1382)	(0.1638)	(0.1514)
Medium firms	1.8249***	1.8148***	1.4594***	1.5845***	1.8652***	1.9455***	1.8075***	1.7352***
	(0.1063)	(0.0853)	(0.1178)	(0.0732)	(0.2052)	(0.1263)	(0.1676)	(0.1019)
Largest firms	4.2319***	3.9071***	2.8494***	3.3865***	4.0464***	3.8316***	2.6325***	3.1664***
	(0.1891)	(0.1557)	(0.1779)	(0.1279)	(0.3259)	(0.2238)	(0.2763)	(0.1787)
France and Belgium	0.2097	-0.0080	-0.1644	0.0373	0.0144	-0.0338	-0.7069***	-0.1587
	(0.1515)	(0.1263)	(0.1676)	(0.1069)	(0.3108)	(0.1886)	(0.2293)	(0.1465)
Hungary and Austria	-1.5924***	-0.5198***	-0.9542***	-0.5388***	-1.8620***	-0.9311***	-0.7475*	-0.6741***
	(0.3716)	(0.1880)	(0.2797)	(0.1619)	(0.7085)	(0.3015)	(0.3811)	(0.2364)
Italy, Greece, Portugal and Spain	-0.6482***	-0.1280	-0.0847	0.0195	-0.5045	-0.1067	-0.4196**	-0.1697
	(0.1738)	(0.1299)	(0.1809)	(0.1096)	(0.3121)	(0.1516)	(0.1842)	(0.1181)
Estonia, Latvia, Lithuania	-0.8901***	-1.1972***	-0.2912	-0.7260***	-0.5918	-1.4527***	-0.6311	-0.9976***
	(0.2308)	(0.2384)	(0.2972)	(0.1968)	(0.5595)	(0.4151)	(0.5659)	(0.3373)
Netherlands	-0.3830	-0.2030	-0.4657	-0.1724	-0.0832	0.0123	0.1039	0.0537
	(0.2346)	(0.2050)	(0.2941)	(0.1777)	(0.4698)	(0.3361)	(0.7703)	(0.2994)
CZ, Poland, Slovakia, Slovenia	-0.0655	0.2970**	0.0659	0.2639***	-0.6773	-0.6479***	-0.6914***	-0.4796***
	(0.1739)	(0.1198)	(0.1683)	(0.1023)	(0.4306)	(0.1852)	(0.2302)	(0.1448)
Denmark, Finland and Sweden	-1.0890***	-1.4715***	-0.9155***	-1.3049***	-1.1259***	-1.5843***	-1.0860***	-1.4153***
	(0.1530)	(0.1312)	(0.1919)	(0.1137)	(0.2675)	(0.1629)	(0.2377)	(0.1354)
UK and Ireland	0.2454	0.1972	-0.0364	0.1472	-0.0982	-0.1425	-0.2657	-0.1674
	(0.1879)	(0.1620)	(0.2470)	(0.1404)	(0.3090)	(0.1895)	(0.2832)	(0.1567)
Food, beverages and tobacco	-0.6362***	0.0198	-0.1966	-0.0030	-0.4060	-0.1294	-0.4731	-0.2243
	(0.2002)	(0.1588)	(0.2627)	(0.1386)	(0.4060)	(0.2143)	(0.3112)	(0.1764)

(cont' Table 8)	If firms sold some EUAs				If firms bought some EUAs			
Variables	2005	2006	2007	2005-2007	2005	2006	2007	2005-2007
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Textiles and leather	-0.9133**	-0.3799	-0.1200	-0.3808	0.3086	-0.3882	-1.3091	-0.4202
	(0.3811)	(0.3377)	(1.3832)	(0.3173)	(1.6442)	(0.6247)	(1.6743)	(0.5642)
Wood and paper	0.1015	-0.0107	-0.1071	-0.0477	0.2030	-0.2474	-0.4823**	-0.2901**
	(0.1439)	(0.1192)	(0.1633)	(0.1012)	(0.3188)	(0.1777)	(0.2358)	(0.1417)
Coke, cement and refined products	0.0617	-0.0021	0.0030	0.0781	0.2657	-0.2726	0.0977	0.0119
	(0.2088)	(0.1453)	(0.1645)	(0.1172)	(0.3851)	(0.2138)	(0.2516)	(0.1636)
Chemicals and pharmaceutics	0.3338	0.1304	-0.1927	0.1008	0.5317	-0.2575	-0.4185	-0.2632
	(0.2074)	(0.1658)	(0.2235)	(0.1413)	(0.4281)	(0.2633)	(0.3159)	(0.2038)
Glass, ceramics and plastic	-0.5058***	-0.3504***	-0.6971***	-0.3529***	-0.2486	-0.6303***	-0.8168***	-0.6022***
	(0.1693)	(0.1194)	(0.1749)	(0.1024)	(0.4149)	(0.1754)	(0.2277)	(0.1384)
Metals	0.8179*	-0.0173	0.3492	0.2271	-0.6205	-0.3096	0.3707	-0.1348
	(0.4620)	(0.2937)	(0.3693)	(0.2426)	(0.7597)	(0.4227)	(0.7006)	(0.3547)
Computers and machinery	-0.5556*	-0.1512	-0.5176	-0.1971	-0.4727	-0.4972	0.0390	-0.2470
	(0.3189)	(0.2736)	(0.3474)	(0.2191)	(0.5749)	(0.3222)	(0.5325)	(0.2729)
Other sectors	-0.2053	-0.3200***	-0.1606	-0.2009**	-0.1411	-0.5690***	-0.3608*	-0.4533***
	(0.1300)	(0.1066)	(0.1471)	(0.0905)	(0.2332)	(0.1481)	(0.2183)	(0.1229)
Year 2006 dummy				-0.0868				-0.3220***
				(0.0542)				(0.0789)
Net allocation (Mundlak term)				0.0003*				0.0000
				(0.0002)				(0.0002)
Sold twice and more (lag, Mundlak term)				1.5713***				
				(0.1162)				
Bought twice and more (lag, Mundlak term)								2.0029***
								(0.1846)
Constant	2.4416***	2.3725***	2.6580***	2.1502***	1.4275***	1.9078***	2.4219***	2.0022***
	(0.1355)	(0.1097)	(0.1579)	(0.1051)	(0.2615)	(0.1503)	(0.2126)	(0.1347)
F-test (Wald test (Chi2) for panel models)	1481.0	68.2	29.5	2079.2	18.2	47.5	17.1	1438.3
F-test (p-value) (Wald test (p-value) for panel models)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	1,481	1,944	856	2,800	735	1,278	704	1,982
R-squared (within for panel models)	0.422	0.438	0.438	0.071	0.349	0.455	0.356	0.003