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Exploring internal trading in the EU emissions trading system: An empirical analysis

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A B S T R A C T

For more than two decades, the European Emissions Trading System (EU ETS), has regulated greenhouse gas emissions across various sectors, including energy, manufacturing, aviation, and maritime industries within the European Union (EU) and beyond. The trading of EU allowances (EUAs) allows emission targets to be met in a cost-efficient manner. This study examines internal trading, i.e., trading of allowances between companies belonging to the same National Ultimate Owner (NUO). Using data from the European Union Transaction Log, the ORBIS database, and the European Energy Exchange, we analyse company-specific internal trading patterns from 2005 to 2017. Supposing that internal trading results in lower transaction costs than external trading (e.g., through intermediaries and exchanges), our findings indicate the presence of barriers to internal trading: Only a small fraction of companies with internal trading opportunities engage in such activities, leaving most of the potential for internal trading untapped. According to the findings from panel-econometric analysis, the relation between internal trading and trading potential is not statistically significant, providing no evidence that companies prefer internal to external trading.They further suggest that internal trading is positively correlated with the number of companies belonging to the same NUO, the number of regulated installations, and with trading frequency, and negatively with allowance banking, for example. These findings remain robust across diverse alternative model specifications, sample compositions, and identification strategies, including quasi-experimental methods.

1. Introduction

Since 2005, the European Emissions Trading System (EU ETS) has regulated direct greenhouse gas (GHG) emissions from about 9000 companies operating approximately 17,500 installations across the energy, manufacturing, aviation, and maritime sectors within the European Union (EU), as well as in Iceland, Liechtenstein, and Norway. Over time, the number of EU allowances (EUAs) issued has significantly decreased, especially since 2013, in line with the EU's increasingly stringent GHG targets. Trading EUAs enables cost-efficient compliance with emission reduction targets. In the early phases of the EU ETS, most EUAs were allocated for free. However, since 2013, the majority have been auctioned, following a major reform of the system. Similarly, since the EU ETS regulates emissions at the installation level, companies operating several installations may transfer allowances between those installations (intra-company trading). [1]

Abbreviation: AOA, Aircraft Operator Account; CITL, Community Independent Transaction Log; CL, Carbon Leakage; CO_2eq, Carbon Dioxide Equivalent; CRE, Correlated Random Effects (Mundlak approach); DiD, Difference-in-Differences; EC, European Commission; EEA, European Economic Area; EEX, European Energy Exchange; EU, European Union; EU ETS, European Union Emissions Trading System; EUA, European Union Allowance; EUTL, European Union Transaction Log; GHG, Greenhouse Gas; GUO, Global Ultimate Owner; ITP, Internal Trading Potential; MNE, Multinational Enterprise; NACE, Statistical Classification of Economic Activities in Europe; NUO, National Ultimate Owner; OHA, Operator Holding Account; ORBIS, Global Company Database by Bureau van Dijk; PHA, Person Holding Account; RECLAIM, Regional Clean Air Incentives Market; RGGI, Regional Greenhouse Gas Initiative; TA, Trading Account; UNFCCC, United Nations Framework Convention on Climate Change; VIF, Variance Inflation Factor.

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[1] Under the EU ETS, an installation is defined as a stationary technical unit that performs one or more regulated activities, including related processes that may affect emissions (European Union, 2003; European Commission, 2021; European Commission, n.d.). As a result, an installation typically covers an entire production process

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Corporations with multiple companies operating installations may exploit internal trading opportunities by reallocating allowances from companies with a surplus to those with a shortage. Additionally, centralising emissions trading activities among companies under the same National Ultimate Owner (NUO) or Global Ultimate Owner (GUO) into a single or a few accounts can reduce administrative burdens and streamline trading operations. [2, 3]

From a theoretical perspective, internal trading serves as an internal market within corporate groups. Drawing on transaction cost theory (e.g. Williamson, 1985) and arguments related to information asymmetry among market participants, companies under common ownership face lower costs when reallocating allowances internally than when conducting external trades. This is mainly because internal trading is expected to involve lower search costs such as finding trading partners, bargaining costs, and costs of accessing exchanges like the European Energy Exchange (EEX). [4] Internal trading also limits exposure to external price volatility. Transaction costs can impede market efficiency and increase emission reduction costs by discouraging companies from fully participating in EUA trading. (e.g., Betz et al., 2010; Jaraitė-Kažukauskė and Kažukauskas, 2015; Naegele, 2018; Cludius and Betz, 2020; Baudry et al., 2021; Abrell et al., 2022; Hintermann and Ludwig, 2023). Similarly, only a few companies – typically 15 to 26 bidders per auction (e.g., DEHSt, 2025) - participate in EUA auctions conducted by the EEX, indicating significant transaction costs associated with external trading. Therefore, companies are expected to prioritise internal trading over external trading. Failure to do so may indicate barriers to internal trading, which could undermine the efficiency of the EU ETS.

In this study, we empirically analyse trading of EUAs between companies belonging to the same NUO. We assess the extent to which companies utilise such internal trading opportunities and examine related factors. To this end, we employ data for 2005 to 2017 from the European Union Transaction Log (EUTL), the ORBIS database, and the EEX, to construct a comprehensive dataset on transactions, account holders, free allocations, verified emissions, company characteristics, and allowance prices. In particular, combining the information provided in the EU EUTL with the ORBIS database allows us to identify trading between companies belonging to the same NUO. Our descriptive analysis indicates the extent to which companies utilise their potential for internal trading. Our multivariate panel econometric analyses explore the relationship between internal trading and factors identified in the literature as associated with companies' trading activities in the EU ETS. We thereby differentiate between two types of datasets and corresponding models: one based on all installations, and the other limited to combustion installations. The latter requires less restrictive assumptions to identify causal relationships. To this end, our identification strategy exploits institutional changes introduced from the third EU ETS trading period onward, which resulted in differential treatment of combustion installations across the energy and industry sectors.

Our descriptive results suggest that only a small fraction of companies with internal trading opportunities participate in such activities, leaving most of the potential for internal trading unexploited. Companies in the energy sector engage more strongly in internal trading than companies belonging to industry sectors. For both samples and corresponding models, our multivariate results suggest that internal trading is positively related with the number of companies belonging to the same NUO, trading frequency, and the number of installations per company, and negatively with allowance banking and with companies considered to be at risk of carbon leakage. In comparison, the relation between internal trading and trading potential is not statistically significant, providing no evidence that companies prefer internal to external trading. These results are robust across various model specifications, sample compositions, and identification strategies, including quasi-experimental methods.

To the best of our knowledge, ours is the first study to empirically analyse companies' internal trading behaviour within the EU ETS. It is closest to Nardone et al. (2025) who – focusing on companies in Italy - find that the vast majority of transactions occur between companies rather than between installations operated by the same company. Hence, their definition of 'internal trades' is very different from ours and does not consider trades between companies belonging to the same NUO. Other previous research on the EU ETS has examined transaction costs associated with trading in general (Jaraitė-Kažukauskė and Kažukauskas, 2015; Naegele, 2018; Baudry et al., 2021; Hintermann and Ludwig, 2023; Flori and Spelta, 2025), trading participation (Zaklan, 2013), various trading activities (Abrell et al., 2022), trading behaviour (Borghesi and Flori, 2018; Karpf et al., 2018; Zaklan, 2023; Lehmann and Schleich, 2025), financial performance (Liu et al., 2017; Cludius, 2018; Guo et al., 2020; Flori et al., 2024; Lehmann et al., 2024), and company value (Dewaelheyns et al., 2023), yet without distinguishing between internal and external trading. While most of these studies focus on the first (2005–2007) and second (2008–2012) trading periods, our analysis additionally encompasses five years following substantial reforms to the EU ETS in 2013.

We organise the remainder of this study as follows. In section 2, we outline the methodology, detailing the data, variables, and econometric methods employed. In section 3, we present and discuss the descriptive results and the findings from our econometric analyses. In Section 4 we summarise the key findings and conclude.

2. Empirical methods

In this section, we present the data and variables. We also describe our econometric approach.

2.1. Data

Our dataset relies on the European Union Transaction Log (EUTL) and includes information on allowance transactions, account holders, and installation data related to verified emissions and the amount of free allocation of EUAs. We gathered data on company characteristics and ownership structures, including NUOs and GUOs, from the ORBIS database provided by Bureau van Dijk, using the company registration number to match both datasets. We obtained data on daily allowance prices from the EEX. Our dataset covers the period from 2005 to April 2018. Akin to Abrell et al. (2022) and Lehmann et al. (2024), we conduct our analysis at the company level, while the volume of internally traded allowances is calculated at the level of the NUO. We define internal

[2] NUO/GUO denote the national/global ultimate owner of a company, defined as the entity that ultimately controls the company at the national/global level (Kalemli-Ozcan et al., n.d.). In our analysis, we apply a 50% ownership threshold to identify the NUO in the ORBIS database. In ORBIS, a NUO can itself be controlled by a GUO if the latter holds more than 50% of the NUO's shares. Since our analysis is conducted at the NUO level, we do not further consider the GUO ownership structure.

[3] The EU ETS includes several account types. The Operator Holding Account (OHA), is assigned to a specific installation and belongs to the company that owns that installation. Each OHA is tied to only one installation, though an installation may hold multiple OHAs. All administrative transactions with the regulatory authority must be processed through these accounts. Additionally, there are Person Holding Accounts (PHAs) and Trading Accounts (TAs), which can be voluntarily opened by regulated companies, intermediaries, or private individuals and are not linked to any specific regulated installation. PHAs and TAs are often used by companies or NUOs as central trading accounts.

[4] In theory, the sectoral composition of the NUO to which a company belongs may also affect internal trading. In particular, if the NUO is composed of vertically connected industries along the value chain, companies belonging to the same NUO are likely to trade more frequently, thereby lowering transaction costs and encouraging internal trading of EUAs. In practice, however, both final and intermediate goods are typically produced in the same installation or in different installations owned by the same company. Therefore, vertical production relationships generally do not result in inter-company trading of EUAs within the same NUO.

transactions as transactions between accounts of the same NUO. The focus on the NUO is consistent with broader findings in the literature on multinational enterprise (MNE) strategy which shows that regional and national institutional frameworks, such as local trade integration, significantly shape MNEs' internal sourcing patterns and asset allocation, even within global corporations (e.g., Huang and Li, 2021). This supports the premise that internal trading yields the greatest transaction cost savings when conducted within national structures. Similarly, spatial distances, language barriers, and differing conditions across member states may reduce or eliminate the transaction cost advantages of internal trading compared to the open market. For example, Hintermann and Ludwig (2023) and Flori and Spelta (2025) observe that companies prefer to trade within national borders, attributing this preference to information and transaction costs. We therefore focus on transactions between accounts of the same NUO rather than the GUO.

Our dataset comprises only companies regulated under the EU ETS and includes transactions either between regulated companies or between regulated and non-regulated actors. Non-regulated actors such as banks and other market intermediaries are excluded. Furthermore, we excluded internal transactions between installations, as these are mainly organisational in nature rather than strategic. We restrict our analysis to companies with the capability to trade internally, specifically to companies belonging to a NUO with at least one other company. Additionally, our analysis excludes administrative transactions, such as the allocation of free EUAs or the surrender of allowances for compliance purposes. Following Cludius and Betz (2020), for example, a trading year ranges from May of year t to April of year t + 1, given that companies are permitted to surrender allowances for compliance for year t until 30 April of year t + 1. In Appendix A.1, we provide more detailed information on data preparation.

Our empirical analyses employ two types of datasets. The first sample comprises of all companies in the dataset described above. The second sample includes only companies operating installations classified under the EU ETS activity 'combustion'.

Table 1
Description of variables.

Variable	Description	Data source
Dependent variable		
Internal trading	Internal trading volume * EUA price.	EUTL
Covariates		
Internal trading potential	Net position NUO_J – net position (absolute value in metric tons of CO_2eq).	EUTL
Banking	Net position plus acquisitions minus transfers in a specific trading year (absolute value in metric tons of CO_2eq).	
Number of NUO companies	Number of companies owned by the NUO of a company.	ORBIS
Transaction frequency	Number trades conducted by a company in year t.	EUTL
Energy	Dummy = 1 if a company belongs to the energy sector.NACE (rev2) classification (35.00 to 35.30)	ORBIS
Number of Installations	Number of installations of a company.	EUTL
Carbon leakage	Dummy = 1 if a company primarily sells products listed on the carbon leakage list.	EU ETS regulation
Period 1	Dummy = 1 if observation pertains to first trading period (2005–2007) (base period).	EU ETS regulation
Period 2	Dummy = 1 if observation pertains to second trading period (2008–2012).	EU ETS regulation
Period 3	Dummy = 1 if observation pertains to third trading period (2013−2020).	EU ETS regulation
Region 1	Austria (AT), Germany (DE), Liechtenstein (LI) (base region).	EUTL
Region 2	Belgium (BE), France (FR), Netherlands (NL).	EUTL
Region 3	Greece (GR), Cyprus (CY), Spain (ES), Italy (IT), Malta (MT), Portugal (PT).	EUTL
Region 4	Estonia (EE), Lithuania (LT), Latvia (LV), Poland (PL).	EUTL
Region 5	Czech Republic (CZ), Hungary (HU), Slovenia (SI), Slovakia (SK).	EUTL
Region 6	Denmark (DK), Finland (FI), Iceland (IS), Norway (NO), Sweden (SE).	EUTL
Region 7	United Kingdom (UK), Ireland (IE).	EUTL
Region 8	Bulgaria (BG), Croatia (HR), Romania (RO).	EUTL

2.2. Variables

2.2.1. Dependent variable

Table 1 provides an overview of all variables. We calculate internal trading as the internal trading volume of EUAs multiplied by the average annual EUA price. Internal trading is defined as the value of EUAs exchanged between companies within the same NUO during a given year. Using a monetary measure to capture companies trading behaviour should better reflect financial incentives than using physical measures (such as trading volume in tonnes) which have typically been used in studies analysing company trading behaviour in the EU ETS (e.g., Jaraitė-Kažukauskė and Kažukauskas, 2015; Cludius, 2018). [5]

2.2.2. Covariates

Our choice of covariates is driven by our research question, data availability, and the existing literature.

2.2.2.1. Internal trading potential. We define internal trading potential (ITP) as the absolute value of the difference between a company i's net position in year t (free allocation minus verified emissions) and the aggregate net position of its NUO, i.e., the sum of the net positions of all other companies belonging to the same NUO J:

$$ITP_{it} = \left| \sum_{j \in J, j \neq i} \left(allocation_{jt} - emissions_{jt}\right) - \left(allocation_{it} - emissions_{it}\right) \right|, \text{with } i \in J \quad (1)$$

$ITP_i > 0$ indicates whether company i could transfer allowances to other companies within the same NUO to reduce their external purchase requirements, or whether companies within the same NUO could transfer allowances to company i to reduce the external purchase requirements of company i. ITP_i is large if company i's net position and the aggregate net position of its NUO have opposite signs and are both quantitatively large. [6] ITP_i is small if company i's net position and the aggregate net position of its NUO have the same sign and are of similar magnitudes. We use the value calculated for *ITP* when the net position of a company and its NUO have opposite signs. Otherwise, company i and the other companies of the same NUO (in aggregate) are either both long or both short in EUAs. In this case, there is no potential for internal trading and we set *ITP* to zero. Assuming companies prefer internal over external trading to save transaction costs, we expect a positive correlation between *ITP* and *internal trading.*

2.2.2.2. Banking. In the EU ETS, surplus allowances can be transferred into future years (banking). Only few studies on the EU ETS have

[5] We exclude the top 2% of observations, as we assume that exceptionally high internal trading volumes are motivated by restructuring processes (e.g., transferring allowances to a new trading account) rather than strategic trading behaviour.

[6] In the dataset underlying our analysis, during the first two trading periods, approximately 70% of all installations received more free allocations than needed to cover their verified emissions. For the third trading period, this share decreased to approximately 34%.

considered banking. For example, Lehmann et al. (2024) find a negative correlation between banking and profits from allowance trading. Since allowances transferred into future years cannot be traded internally, we expect a negative relation between the amounts of allowances banked and *internal trading*.

2.2.2.3. Number of NUO companies. The variable *number of NUO companies* refers to the number of companies linked to the NUO of a company that operate regulated installations under the EU ETS, thus reflecting the number of potential internal trading partners within the same NUO. We assume that the incentives to strategically utilise internal trading increase with the number of regulated companies within a NUO, as we posit that a higher number of regulated companies also raises the likelihood of having entities within the NUO with different net positions. We therefore expect a positive correlation between the *number of NUO companies* and *internal trading*.

2.2.2.4. Transaction frequency. We define *transaction frequency* as the number of trades (both internal and external) conducted by a company. According to Lehmann et al. (2024) in a related context, *transaction frequency* reflects companies' skills such as learning and experience to employ emissions trading strategically to minimise the costs of participating in the EU ETS. We therefore expect a positive correlation between *transaction frequency* and *internal trading*.

2.2.2.5. Energy. Energy companies possess structural skills related to complementary assets and capabilities that facilitate their participation in external trading of EUAs (e.g., Lehmann et al., 2024). Their experience in trading energy commodities provides them with relevant expertise for EUA trading. For example, electricity providers often engage in spot and futures markets to sell their electricity on platforms like the EEX, which also facilitates EUA trading. Relatedly, research by Jaraitė-Kažukauskė and Kažukauskas (2015) and Abrell et al. (2022) indicates that energy companies are more actively engaged in external trading of EUAs than industrial companies. Consequently, transaction costs for external trading may be lower for energy companies, implying a negative relationship between *energy* and *internal trading*. Other factors, however, suggest a positive relationship. For example, complementary assets and capabilities enabling external trading of EUAs may also enable internal trading. Furthermore, energy companies may already have established specialised trading units. These units centrally manage not only electricity trading but also the trading of EUAs, thereby enhancing internal trading by consolidating allowances into central accounts. Consequently, we have no specific expectations regarding the direction or relationship between *energy* and *internal trading*.

2.2.2.6. Number of installations. The variable *number of installations* refers to the total number of a company's installations that are regulated under the EU ETS. According to Lehmann et al. (2024), the number of installations also reflects companies' structural skills enabling external trading of EUAs. Similarly, as argued by Jaraitė-Kažukauskė and Kažukauskas (2015), for example, a higher number of installations proxies for lower transaction costs associated with external trading, such as search and information costs. Indeed, companies operating a larger number of installations typically exhibit both a higher likelihood of participation in external trading and greater trading intensity (e.g., Jaraitė-Kažukauskė and Kažukauskas, 2015; Baudry et al., 2021; Abrell et al., 2022). They also tend to trade more profitably (Lehmann et al., 2024). Because skills enabling external trading may also enable internal trading, however, the relation between *number of installations* and *internal trading* appears ambiguous.

2.2.2.7. Carbon leakage. We include a dummy variable which indicates whether a company primarily produces goods listed on the *carbon leakage* list, similar to Abrell et al. (2022), Lehmann et al. (2024), and Nardone et al. (2025).[7] These companies face greater competition from outside the EU and are unlikely to be able to fully transfer additional costs from emissions trading to their customers without losing their market position (e.g. Cludius et al., 2020). Therefore, they are expected to have stronger incentives to reduce their costs associated with emissions trading. Assuming that internal trading incurs lower transaction costs than external trading, these companies should have a greater incentive to trade internally, suggesting a positive correlation between *carbon leakage* and *internal trading*.

2.2.2.8. Periods and regions. Similarly to research in related contexts (e.g., Jaraitė-Kažukauskė and Kažukauskas, 2015), we include dummy variables to control for effects specific to different trading periods (i.e., 2005–2007, 2008–2012, and 2013–2020). For example, there may be positive learning effects related to emissions trading over time. Indeed, Abrell et al. (2022) observe companies to participate more actively and to trade more intensively in the second and third trading periods than in the first trading period. Likewise, we add dummies reflecting geographic *regions*, using the German-speaking region (*Region 1*) as the reference. The studies by Borghesi and Flori (2018) and Karpf et al. (2018) find that companies' trading behaviour in the EU ETS is related to their geographical location. According to Hintermann and Ludwig (2023) and Flori and Spelta (2025) companies tend to trade more intensively with partners from their home country, thus reflecting a 'home bias'.

2.3. Econometric models and identification

We conducted a multivariate panel econometric analysis using annual data at the individual company level. [8] Our analysis is restricted to companies with the capability to trade internally, specifically those with at least one other company within the same NUO. For a large share of our observations, *internal trading* is zero. These zeroes indicate company-level decisions to not trade internally. In this case, employing ordinary least squares models would lead to biased parameter estimates. Instead, we estimate a "corner solution" Tobit model

$$\begin{aligned} y_{it}^{*} &= x_{it}\beta + z_i\gamma + \alpha_i + \varepsilon_{it} \\ y_{it} &= y_{it}^{*} \text{ if } y_{it}^{*} \geq 0 \\ y_{it} &= 0 \text{ if } y_{it}^{*} < 0 \end{aligned}, \quad (2)$$

where y_{it}^{*} denotes company i's latent (unobserved) level of *internal trading* at time t, y_{it} stands for company i's observed level of *internal trading* at time t, x_{it} represents time-varying covariates such as *internal trading potential*, z_i reflects time-invariant covariates such as *number of NUO companies* or *energy*, α_i captures time-invariant, company-specific unobserved factors (i.e., the panel-level random effect), and ε_{it} is the idiosyncratic error term. We cluster standard errors at the company level to account for potential heteroskedasticity and serial correlation within companies.

Tobit models are non-linear, meaning that, unlike linear models, unobserved time-constant heterogeneity (such as company culture), which may be correlated with the covariates, usually cannot be addressed by including company-specific fixed effects and using a fixed-effects estimator. Conversely, using a random effects estimator requires the unobserved heterogeneity to be uncorrelated with the covariates, a

[7] The carbon leakage list includes a wide range of products from various energy-intensive sectors, such as iron and steel, non-ferrous metals, aluminum, refineries, cement and lime, glass and ceramics, and pulp and paper (European Commission 2014/746/EU).

[8] Our panel dataset is unbalanced due to the entry and exit of companies and installations over time, as well as the entry and exit of countries. For example, non-EU countries such as Norway, Iceland, and Liechtenstein, along with new EU members Romania and Bulgaria, joined the EU ETS in 2007, while Croatia entered in 2013.

condition that is likely too restrictive in our context. Therefore, following studies such as Jaraitė-Kažukauskė and Kažukauskas (2015) and Abrell et al. (2022), we use the correlated random effects (CRE) estimator developed by Mundlak (1978). The CRE accounts for time-invariant unobserved heterogeneity by including company-specific means of the time-varying variables in the regression equation. Hence,

$$\alpha_{1,i} = \overline{x}_i\varphi + \mu_i, \tag{3}$$

where $\overline{x}_i$ is the mean of the x_{it} over time for company i, and $\mu_i \sim N\left(0, \sigma_\mu^2\right)$.[9]

In our empirical specification, to mitigate the impact of outliers on the results, we use the log-transformed values of all variables except for *number of NUO companies, number of installations* and for all the dummy variables. The coefficients associated with the log-transformed covariates correspond to elasticities. The Tobit models were estimated using the xttobit procedure in Stata 17. Our empirical analysis comprises of two types of samples and models, relying on different identification strategies to establish causality for our key covariate *ITP* which is a continuous variable.

First, we estimate eqs. (2) and (3) for the sample including all installations. Our treatment variable is continuous and there is no clear "before" and "after" period. Hence, standard difference-in-difference (DiD) approaches are not applicable. Instead, our identification strategy assumes that *ITP* is exogenous conditional on observed covariates. That is, we assume that there are no omitted variables that are correlated with both *ITP* and *internal trading*. Assuming the treatment to be exogenous appears plausible given that *ITP* is primarily determined by allocation rules specified in the EU Emissions Trading Directive (European Parliament and Council, 2023), which are externally imposed on companies.

Second, we consider a subset of companies for which the change in allocation rules in the third trading period provides a quasi-experimental setting that facilitates causal inference. For the subsample that only uses combustion installations, causal identification exploits the allocation reform introduced in 2013. Thereby, we distinguish between companies operating combustion installations in the energy sector and companies operating combustion installations in the industry sectors. Prior to the reform, the same allocation rules applied to combustion installations in all sectors. Since 2013, combustion installations in the energy sector ('treatment group') have effectively received no free allowances, as they were deemed less exposed to international competition and capable of passing on most, if not all, of the opportunity costs associated with using EUAs (e.g. Sijm et al., 2006; Dagoumas and Polemis, 2020). In contrast, combustion installations in the industry sectors ('control group') continued to receive allowances for free. Before 2013, both groups were subject to identical allocation rules. Since our primary interest lies in the relationship between *ITP* and *internal trading*, and in how this relationship may have changed as a result of the reform, we include all interaction terms combining the reform indicator (*Period 3*), the treatment indicator (*energy*), and *ITP*. Hence, eq. (2) becomes

$$\begin{aligned} y_{it}^* = {} & \delta_1 \textit{Period}\ 3_t + \delta_2(\textit{Period}\ 3_t \times \textit{ITP}_{it}) + \delta_3(\textit{Period}\ 3_t \times \textit{energy}) \\ & + \delta_4(\textit{energy} \times \textit{ITP}_{it}) + \delta_5(\textit{Period}\ 3_t \times \textit{energy} \times \textit{ITP}_{it}) + \widetilde{x}_{it}\widetilde{\beta} + z_i\gamma \\ & + \alpha_i + \varepsilon_{it}. \end{aligned} \tag{2'}$$

This setup mimics a DiD framework with a continuous treatment effect. Reflecting our expectation that a larger *ITP* increases *internal trading*, the removal of free allocation of EUAs for the treatment group is expected to lower the effect of *ITP* on *internal trading* from 2013 onward compared to the control group. In a linear model, we would therefore expect a negative sign for δ_5. Because the Tobit model is non-linear, δ_5 does not capture this triple-interaction effect (e.g., Greene, 2010). Instead, we focus on the marginal effects of the interaction between *Period 3* (compared to the pre-treatment *Period 2*), *Energy* (compared to combustion installations in the non-energy sector) and *ITP*. Since in non-linear models, these marginal effects depend on the level of *ITP*, among others, it is not possible to perform a test on the general statistical significance of the triple-interaction terms. As suggested by Greene (2010), we instead employ a graphical analysis. For identification, we examine whether the parallel-trends assumption holds.

3. Results and discussion

In this section, we present and discuss the findings of our descriptive analysis, followed by the results of our multivariate analysis, distinguishing between the models estimated for the sample including all installations, and for the sample including combustion installations only. We also present the findings from a series of robustness checks.

3.1. Results from the descriptive analysis

The analysis is based on a final sample of 2507 companies, comprising a total of 15,947 observations. Among the companies with the opportunity for internal trading (defined as companies belonging to a NUO with at least two companies), only 260 (approximately 10.4 %) trade internally.[10]

Regarding internal trading potential, 3408 observations exhibit a positive *ITP*, corresponding to about 21,4 % of all observations. About 17 % of companies with $ITP > 0$ in a given year, engage in internal trading (Table 2).

Table 2
Share of companies trading internally by sector (2005–2017).

Sector	Companies trading internally in at least one year as a share of		Companies trading internally every year as a share of	
	$ITP > 0$	all	$ITP > 0$	all
Energy*	21.2 %	12.6 %	8.6 %	7.3 %
Refining	21.7 %	13.5 %	8.7 %	5.4 %
Iron and Steel	7.9 %	5.6 %	3.2 %	2.2 %
Nonferrous metals	0.0 %	0.0 %	0.0 %	0.0 %
Lime/Cement	16.4 %	11.8 %	1.5 %	2.2 %
Glass	22.2 %	15.2 %	8.9 %	7.6 %
Ceramics	10.3 %	6.0 %	3.7 %	2.0 %
Mineral Wool	0.0 %	0.0 %	0.0 %	0.0 %
Gypsum/Plasterboard	0.0 %	0.0 %	0.0 %	0.0 %
Pulp/Paper	8.5 %	5.2 %	4.9 %	3.0 %
Chemicals	12.2 %	8.5 %	7.3 %	8.5 %
Total	17.0 %	10.4 %	6.7 %	5.5 %

* The energy sector is defined based on the NACE (rev2) classification (35.00 to 35.30) rather than on the ETS activity 'combustion of fuels.' The latter category would include those industrial sectors that are not attributable to any other ETS activity. See also Section 2.2.2. Aggregation of ETS activity at industry sector level is based on Gores et al. (2021).

[9] The x_i are known as Mundlak terms. They capture the "between variation" and can be interpreted as representing the long-run effects. In contrast, the time-varying variables capture the "within variation" and can be interpreted as reflecting the short-run effects. Because we are concerned, that the effects of unobserved heterogeneity may be correlated with the covariates, our analysis and interpretation of the results focusses on the time-varying effects.

[10] To assess the sensitivity of these findings to different levels of aggregation, we also examined internal trading at the GUO level. Applying the same logic as before, we observe only 1 company more that trades internally than for our analysis based on the NUO level. This finding corroborates our decision to focus on the NUO level to analyse companies' internal trading behaviour.

The share of energy companies trading internally tends to be higher than that of industry companies. We also observe that some companies trade internally even when $ITP = 0$, possibly because they pool EUAs in a central trading account – independent of whether they are short or long. Their share represents approximately 8.6 % of companies with $ITP = 0$ in a given year. For each sector, it is lower than the share of companies with $ITP > 0$ that engage in internal trading. In sum, only 1.3 % of companies with $ITP > 0$ fully exploiting their internal trading opportunities in a given year, meaning their trading volume matches or exceeds their internal trading potential. Overall, between 2005 and 2017, only about 1.6 % of the internal trading potential was exploited.

We present an overview of the descriptive statistics for the dependent variables and the covariates in Table A2.1 in Appendix A2.

3.2. Results from the multivariate analysis for the sample including all installations

In this section we present and discuss the results of our preferred model specification. We focus on the estimated average marginal effects (and average discrete effects for dummy variables), as they offer an intuitive interpretation of the relationship between the dependent variable and the covariates. [11] In addition to the expected marginal effects on average *internal trading*, Table 3 presents the extensive margin, i.e., the change in the proportion of companies engaging in internal trading, and the intensive margin, i.e., the change in the mean of internal trading among companies that already trade internally. Distinguishing between the extensive and intensive margin allows us to disentangle two mechanisms: the extent to which a covariate relates to barriers to participation in internal trading (extensive margin) and the extent to which it relates to the intensity of internal trading for companies that already trade internally (intensive margin).

We note that one of the three Mundlak terms in Table A3.1 is statistically significant, indicating that a random-effects estimator would yield biased and inconsistent parameter estimates. The estimated intraclass correlation coefficient (rho) equates to 0.73, suggesting that most of the variance of *internal trading* is explained by differences between companies rather than within companies, thereby confirming the relevance of the panel structure. Moreover, variance inflation factors (mean VIF = 2.1, all individual VIFs below 5) indicate that multicollinearity is not a concern in our specification.

3.2.1. Internal trading potential

Table 3 does not provide convincing evidence of a statistical correlation between *ITP* and *internal trading* ($p = 0.30$). Also, the effect size on average *internal trading*, and the extensive and intensive margins are small. Therefore, our findings provide no support that companies with a higher *ITP* engage more in *internal trading*. This means that we do not find evidence that companies of the same NUO offset net positions internally to minimise external trading. Instead, these findings are consistent with the notion that there are barriers to internal trading. One possible explanation is that internal transactions may involve significant transaction costs - particularly if internal trading strategies are not centrally coordinated at the NUO level. For example, internal trading may involve negotiations between companies (e.g. over the price and traded volumes of EUAs) which may be more complex than trading at market prices on external platforms. Other barriers to internal trading may be due to differences in corporate taxes across locations. In this case, NUOs may shift EUAs (and hence accounting profits) to companies located in locations with the most favourable tax legislation. Indeed, Schultz (2024) finds that towards the end of a calendar year, allowances are transferred from subsidiaries in strict accounting jurisdictions to those in more lenient ones, suggesting arbitrage. Likewise, unless the NUO requires companies to trade internally, they may be reluctant to do so because internal trading affects companies' performance measures. For example, companies may prefer to purchase EUAs on the external market rather than increase the cash flow of an affiliated company within the same NUO through internal trading, as this could compromise their relative position within the same corporate group or holding.

Table 3
Estimated average marginal effects on internal trading (sample including all installations). †

	Extensive margin [change in Prob (internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	−0.000	−0.010	−0.003
	(0.000)	(0.009)	(0.002)
Banking	−0.001***	−0.053***	−0.014**
	(0.000)	(0.020)	(0.005)
Number of NUO companies	0.001***	0.047***	0.012***
	(0.000)	(0.007)	(0.002)
Transaction frequency	0.006***	0.299***	0.077***
	(0.001)	(0.042)	(0.012)
Energy	0.002	0.080	0.021
	(0.005)	(0.230)	(0.059)
Number of installations	0.001*	0.025*	0.007*
	(0.000)	(0.014)	(0.004)
Carbon leakage	−0.016***	−0.776***	−0.200***
	(0.005)	(0.269)	(0.072)
Period 2	0.005*	0.262*	0.067*
	(0.003)	(0.136)	(0.035)
Period 3	0.008***	0.379***	0.098***
	(0.002)	(0.117)	(0.031)
Region 2 (BE, FR, NL)	−0.021	−1.032	−0.265
	(0.013)	(0.654)	(0.170)
Region 3 (GR, IT, PT, ES, CY, MT)	−0.034***	−1.656***	−0.426***
	(0.008)	(0.388)	(0.108)
Region 4 (EE, LT, LV, PL)	−0.015*	−0.716*	−0.184*
	(0.008)	(0.373)	(0.098)
Region 5 (CZ, HU, SI, SK)	−0.009	−0.435	−0.112
	(0.010)	(0.506)	(0.131)
Region 6 (DK, FI, IS, NO, SE)	−0.025***	−1.235***	−0.317***
	(0.006)	(0.297)	(0.082)
Region 7 (UK, IE)	−0.035***	−1.726***	−0.444***
	(0.011)	(0.545)	(0.147)
Region 8 (BG, HR, RO)	−0.039***	−1.920***	−0.494***
	(0.009)	(0.450)	(0.126)
Observations	15,947		
Companies	2507		

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

† Robust standard errors appear in parentheses.

3.2.2. Banking

Our results suggest a negative correlation between *banking* and *internal trading*. A 1 % increase in *banking* corresponds to a decrease in average *internal trading* of about 0.01 %. The extensive margin implies that a 1 % increase in *banking* corresponds to a decrease in the probability of a company trading internally by about 0.1 percentage points. As suggested by the intensive margin, companies already trading internally decrease *internal trading* by 0.05 % in response to a 1 % increase in *banking*. These findings support our expectation that internal trading decreases as companies choose to bank more allowances.

[11] In Table A2.2, we present the estimates of the coefficients for the latent level of internal trading, as described in Equation (2).

3.2.3. Number of NUO companies

Our results indicate a statistically significant positive correlation between the number of NUO-affiliated companies and *internal trading*. An additional company within the same NUO corresponds to an increase in the probability that a company trades internally by approximately 0.1 percentage points and raises *internal trading* by 4.7 % among companies already trading internally. The corresponding change in the average internal trading value amounts to 1.2 %. As expected, a company's internal trading value increases with the number of companies belonging to the same NUO. The extensive margin, however, is small, suggesting that the *number of NUO companies* may play a minor role in a company's decision to engage in internal trading.

3.2.4. Transaction frequency

The coefficient associated with *transaction frequency* is positive and statistically significant. A 1 % increase in *transaction frequency* is associated with a 0.6 percentage point higher likelihood that a company will trade internally, an increase in *internal trading* by 0.3 % for companies that trade internally, and an increase in the average internal trading value by 0.08 %. Thus, similar to Abrell et al. (2022) and Lehmann et al. (2024) in a related context, this finding supports the view that higher strategic skills (here: through learning and experience) are conducive to internal trading.

3.2.5. Energy

The coefficient associated with *energy* is not statistically significant, possibly due to opposing mechanisms. While energy companies tend to be more experienced in related trading activities than industry companies, suggesting a positive relation between *energy* and *internal trading*, they also often have centralised trading units managing EUAs, indicating a negative relationship. Our null result for *energy* is consistent with the findings of Nardone et al. (2025), who find no evidence that trading between installations operated by the same company is more prevalent among energy companies than industrial companies.

3.2.6. Number of installations

We find a statistically significant positive correlation between the *number of installations* and *internal trading*. An additional installation regulated under the EU ETS corresponds to an increase in the probability that a company trades internally by about 0.1 percentage points and increases the internal trading value by 2.5 % among companies already trading internally. This amounts to a change in the average *internal trading* of 0.7 %. This finding supports the view that a larger number of installations reflect higher structural skills enabling internal trading of EUAs. It is consistent with previous studies focusing on external trading (e.g. Jaraitė-Kažukauskė and Kažukauskas, 2015; Baudry et al., 2021; Abrell et al., 2022; Lehmann et al., 2024) and on intra-company trading (Nardone et al., 2025).

3.2.7. Carbon leakage

We find a statistically significant negative correlation between *carbon leakage* status and *internal trading*. Companies at risk of carbon leakage are 1.6 percentage points less likely to engage in internal trading than others. Among those that do, their internal trading volume is 78 % lower and their average trading value is about 20 % lower. These results contradict our initial expectation. When interpreting our no result for *ITP*, we speculate that companies may be reluctant to trade internally because internal trading affects their cash flows and hence their relative position within a NUO. This barrier to internal trading may be particularly pronounced for companies at risk of carbon leakage. We further note that our findings for carbon leakage are consistent with the existing literature. In particular, Nardone et al. (2025) find a significant negative relation between companies considered at risk of carbon leakage and their participation in trading between installations of the same company

3.2.8. Periods and regions

We find that the average internal trading value was higher in period 2 and period 3 than in period 1, ceteris paribus. This finding appears to be mostly driven by companies who already traded internally rather than by more companies starting to trade internally over time. In general, these findings suggest that companies may have learned to better utilise their internal trading options over time, similar to the findings by Nardone et al. (2025) and Abrell et al. (2022) in related contexts.

Finally, our results for the regional dummies indicate that, in *regions 3, 5, 6,* and *8*, the share of companies trading internally, the share of internal trading of companies already trading internally, and the average internal trading value was lower than in the German-speaking region. These findings align with Abrell et al. (2022) regarding various companies' emissions trading activities.

3.3. Results from the multivariate analysis for the sample including combustion installations only

First, we note that limiting the sample to operators of combustion installations reduces the sample size from 15,947 to 9294 observations. We then assess the validity of the parallel-trends assumption, which is crucial for identifying the causal effect of *ITP* on *internal trading*. First, a visual comparison of the means of *internal trading* for treatment and control groups across period 1 and period 2 suggests that the parallel trends assumption holds (Fig. A2.1 in Appendix 2). Second, we conduct a placebo test which treats period 2 instead of period 3 as the treatment period using period 1 as the base period. Neither *Period 2* nor any of the associated interaction terms turns out to be statistically significant (see Table A2.3). Third, we perform a placebo test that considers period 2 as the post-treatment period while excluding *Period 3*. Again, this specification yields no statistically significant pseudo-effects for *Period 2* or any of the associated interaction terms (see Table A2.4). Taken together, these diagnostic tests support the validity of our identification strategy.

Turning to the results, we find that one of the Mundlak terms is statistically significant (see in Table A2.5) implying that a random-effects estimator would be biased and inconsistent, similar to our findings for the sample including all installations. The estimated intra-class correlation coefficient (rho = 0.73) confirms the relevance of the panel structure, as most of the variance in the dependent variable is explained between rather than within companies. Finally, variance inflation factors (mean VIF = 2.3, all individual VIFs below 5) suggest that multicollinearity is not a concern.

Subsequently, we analyse the marginal effects of the triple interaction term (*energy*×*Period3* × *ITP*) for the extensive and intensive margin. This allows us to assess how the relationship between *ITP* and *internal trading* changes due to the treatment in period 3, for *energy* companies and the control group. In particular, we are interested in whether the difference between the marginal effects for the treatment and control group changes as *ITP* increases. We estimate and display the marginal effects at integer values of *ITP* ranging from 1 to 17, corresponding to the range of *ITP* (see Table A2.7).

Fig. 1 illustrates the results for the extensive margin (left panel) and intensive margin (right panel) showing the effect of the policy reform on *internal trading* by level of *ITP* for combustion installations in the energy sector (treatment group) and the industry sectors (control group). For both the control and treatment groups, the marginal effects appear to become more negative for higher values of *ITP*, suggesting that companies with higher *ITP* generally reacted more strongly to the reform in period 3. In particular though, Fig. 1 provides no indication that the difference between the marginal effects for the treatment and control group changes as *ITP* increases, neither for the extensive margin, nor for the intensive margin. This finding supports the null result regarding the effects of *ITP* on *internal trading*, as observed in the sample relying on data for all installations and using an alternative methodology in Section 3.2.

Finally, we note that the results for the remaining covariates are

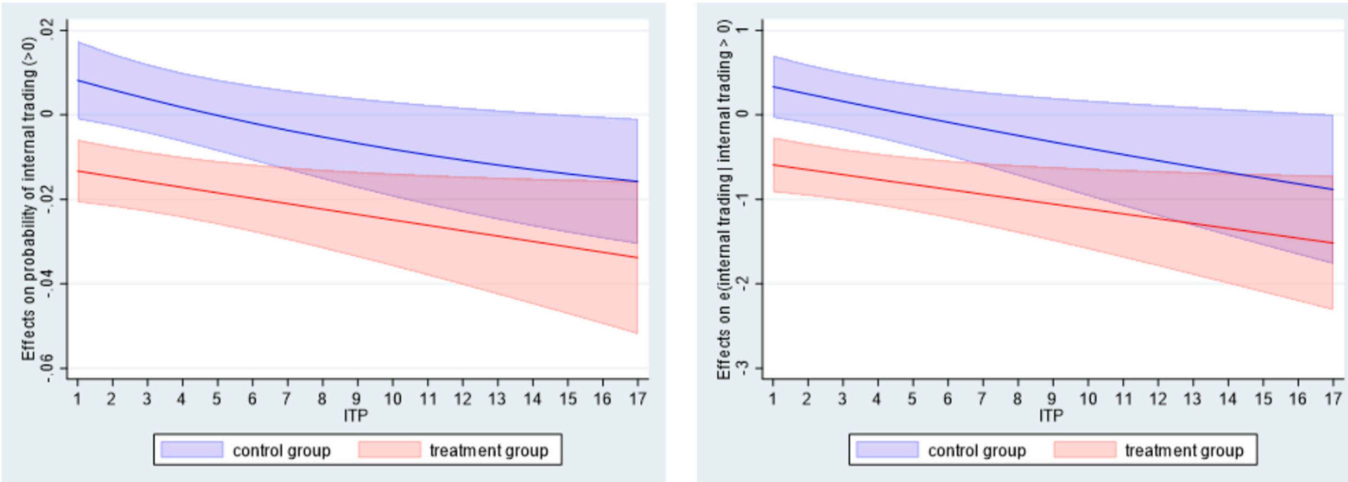

Fig. 1. Marginal effects of the policy reform on *internal trading* by sector and *ITP* (analysis including combustion installations only).
Note: Estimations based on the dataset described in Section 2.1 and Appendix 1. Left panel shows extensive margin, right panel shows intensive margin. Shaded areas correspond to 90 % CI.

broadly consistent with those reported in Section 3.2 (see Table A2.6). Coefficients which are statistically significant exhibit the same signs as in the analysis for the sample including all installations. In the sample including combustion installations only, coefficients that are no longer statistically significant, i.e. *banking*, the *number of installations*, and *Region 4*, retain the same sign as reported in Section 3.2. The differences in statistical significance are likely due to the lower statistical power in the sample including combustion installations only.

3.4. Robustness checks

To assess the robustness of the findings presented in Table 3, we conducted a series of supplementary analyses allowing for alternative model specifications.

First, to mitigate potential omitted variable bias, we included two variables from the ORBIS database which previous studies find to be related with emissions trading activities. We include the number of *employees* to capture the size of a company. Previous studies (e.g., Jaraitė-Kažukauskė and Kažukauskas, 2015; Baudry et al., 2021; Abrell et al., 2022) find larger companies to be more actively involved in emissions trading. We further include *revenue per worker*, defined as revenue per employee. Abrell et al. (2022) find companies with higher revenue per worker to be more actively engaged in various emissions trading activities. Assuming that larger companies and companies with higher revenue per worker are better at exploiting internal trading opportunities, we expect a positive correlation between both variables and *internal trading*. Including *employees* and *revenue per worker*, however, leads to a substantial reduction in sample size due to missing values. The number of observations decreases from 15,947 to 9444 and the number of companies from 2507 to 2037. Results of estimating this model appear in Table A3.1. Accordingly, the marginal effects associated with *employees* and *revenue per worker* are small, and not statistically significant at conventional levels. The findings for most other variables are similar to those reported in Table 3. However, the coefficients for *banking* and *number of installations* are no longer statistically significant at conventional levels, most likely due to the lower statistical power.

Second, we estimated a model that includes only companies with *ITP* > 0 in the respective year, rather than all companies. This restriction reduces the number of observations to 3408 and the number of companies to 1364 companies. The results presented in Table A3.2 are qualitatively very similar to those shown in Table 3, yet *number of installations* is no longer statistically significant, most likely due to the lower statistical power.

Third, to examine whether our findings are sensitive to the definition of outliers, we re-estimated our model after removing the top 5 % of observations with the highest levels of internal trading, instead of removing the top 2 %. The results which are presented in Table A3.3 are generally quite similar to those shown in Table 3.

Fourth, we examine whether results differ between net buyers and net sellers, which are defined as companies whose net position (free allocation minus verified emissions) is negative (net buyers) or positive (net sellers). For example, net buyers may opt for internal transactions if they anticipate securing lower prices from companies within the same NUO, compared to those offered by brokers or exchanges. Similarly, net sellers may favour external transactions if they anticipate obtaining higher prices on the market than through internal trades. To assess whether these disparities affect the relationship between internal trading and the covariates, we estimate the models separately for net buyers and net sellers using both the sample including all installations and the quasi-experimental sample including combustion installations only. We document the findings for the sample including all installations in Tables A3.4 for net buyers and in Table A3.5 for net sellers. Fig. A3.1 displays the key finding for the sample using combustion installations only for net sellers. Due to the generous allocation of allowances during the first two trading periods for industry sectors in particular (e.g. Ellerman and Buchner, 2008), there are too few net buyers among operators of combustion installations in these sectors in the pre-treatment period to reliably estimate the model for the quasi-experimental setting.[12]

In general, the outcomes of the split-sample estimations are consistent with those reported in Sections 3.2 and 3.3 for the full samples. Some minor differences are observed in the results for net buyers (in the sample using all installations), where statistical significance tends to be lower than in the full sample, likely due to reduced statistical power stemming from the smaller number of observations. Consistent with our findings in Section 3.3., our results for net sellers for the quasi-experimental set up show no indication that the difference between the marginal effects for the treatment and control groups changes as *ITP* increases, either for the extensive or for the intensive margin.

Finally, we attempted to estimate double hurdle models because they imply less restrictive assumptions than Tobit models. For example, in double hurdle models, the signs of the intensive and extensive margins

[12] We observe only 112 industry companies that were net buyers with a positive *ITP* before 2013, of which only six engaged in internal trading.

of a particular covariate may differ. Unfortunately, none of the double hurdle models that we estimated converged for our data.

4. Conclusions

This study is the first to analyse internal trading of EU allowances, which is expected to incur lower transaction costs than external trading. It covers the first three trading periods and is based on a comprehensive dataset that integrates information from the EUTL and the ORBIS database which provides company characteristics and allows identifying transactions within the same NUO as internal trading.

The findings from our descriptive analysis suggest that most companies, including those with large potentials for internal trading, do not trade internally. Thus, substantial opportunities for internal trading remain untapped, possibly resulting in inefficient levels of transactions and abatement costs within the EU ETS.

The findings from our multivariate analyses imply a null result for the relation between companies' internal trading and their potentials for internal trading. Possible explanations include barriers to internal trading such as transaction costs that exceed those of external trading, strategic priorities such as transferring allowances to companies located in regions with the most favourable tax conditions, and competition between companies within a NUO. The latter may also explain why we find a negative correlation between internal trading and companies at risk of carbon leakage. Put differently, the null result on internal trading potential undermines the premise that external trading is more costly to companies than internal trading.

Next, our finding that EUA banking is negatively related to internal trading supports the view that banking allowances reduces the amount available for internally balancing net positions. We further find that the number of companies within a given NUO are positively associated with internal trading volumes, reflecting that companies in larger NUOs have greater opportunities for internal trading. The small extensive margin, however, suggests that this plays a minor role in a company's decision to engage in internal trading only. We further find that companies that trade more frequently also engage in more internal trading, possibly due to learning effects that enable them to utilise all available options to minimise costs within the EU ETS. In addition, a higher number of installations correlates with increased internal trading, possibly because companies operating more installations possess better structural skills for trading EUAs. Furthermore, we find that internal trading volumes are higher in periods 2 and 3 than in period 1, likely reflecting that companies have become more adept at utilising their internal trading options over time. Finally, companies in German-speaking countries generally show higher internal trading volumes than those in non-German-speaking countries.

These findings generally align with the existing literature on related topics. They are also robust across diverse alternative model specifications, sample compositions, and identification strategies, including a quasi-experimental approach. Nevertheless, some caveats remain. For example, due to data limitations, our analysis did not account for factors which may affect companies' internal trading decisions, such as performance targets for companies within an NUO, and variations in corporate taxes across company locations. Further, in our study, internal trading may be measured with error. For instance, companies may trade through a trading company set up by their NUO. Yet, unless this trading company legally belongs to their NUO, those trades would not be considered internal trades. Additionally, certain trading behaviours – such as pooling the entire stock of EUAs within a single trading account - could hide the extent to which companies exploit their internal trading potential, particularly if such pooling is applied regardless of whether such a potential exists or not. Our analysis draws on secondary data to examine internal trading. Hence, the scope of analysis is shaped by the availability of data. To deepen the understanding of the factors enabling and impeding internal and external trading within the EU ETS, future research may collect primary data through company surveys and detailed case study interviews. Furthermore, future research could employ gravity analysis to jointly examine internal and external trading, thus building on Hintermann and Ludwig (2023) and Flori and Spelta (2025) in related contexts. Future studies could also examine internal trading in other greenhouse gas emissions trading systems, including the national systems in China, Korea, and the UK, and the regional systems in the US such as California's Cap-and-Trade Program and the Regional Greenhouse Gas Initiative (RGGI). Similar studies may be applied to trading schemes targeting other pollutants, including SO_x and NO_x under RECLAIM in the US.

Our analysis provides relevant insights for policymakers seeking to better understand trading behaviour and enhance the efficiency of emissions trading systems. A central design element in this context is the point of regulation. In the EU ETS, regulation at the installation level offers key advantages, such as legal certainty and precise monitoring and verification of emissions. However, this decentralised structure may impede intra- and inter-company trading, as it requires each installation to manage allowances independently, thereby increasing transaction costs and administrative complexity. Regulating emissions at the level of the NUO for example, could alleviate these inefficiencies by allowing companies to centralise allowance management and streamline compliance across multiple sites. This may also facilitate more strategic trading decisions and greater responsiveness to market signals. However, these benefits must be carefully weighed against potential costs, such as reduced transparency, weaker oversight, and legal ambiguities regarding compliance responsibility. Finally, our results suggest that internal trading faces barriers, implying that for many companies, external trading may be less costly than internal trading. Identifying and understanding these barriers is essential for designing policies that improve the economic efficiency of the EU ETS.

CRediT authorship contribution statement

Sascha Lehmann: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Joachim Schleich:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the language quality. After using this tool, the authors reviewed and edited the content as needed.

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Appendix A1 Compilation of the data [13]

Data sources and preparation

The European Commission (EC) manages the Union Registry, a centralised electronic database that documents all transactions carried out within the EU ETS. This includes allocations granted free of charge, the surrendering of allowances, and transactions conducted between various market participants. These activities are monitored and authorised through the European Union Transaction Log (EUTL) [14], which is responsible for recording and verifying every transaction. With a delay of three years, this data is publicly available via the EUTL interface where it can be downloaded for free.

Only entities with registered accounts are permitted to engage in trading emissions allowances. Each stationary installation under the EU ETS is required to maintain at least one Operator Holding Account (OHA), while airlines must open at least one Aircraft Operator Account (AOA). These accounts are used for receiving free allocations and fulfilling surrender obligations. Beyond these, companies and even private individuals may open Person Holding Accounts (PHA) or Trading Accounts (TA) to facilitate participation in allowance trading. Additionally, administrative accounts are maintained by EU institutions and individual Member States for regulatory purposes such as the primary allocation and the cancellation of EUAs.

The EUTL provides various account-level details, including account names, Member State of registration, company registration identifiers, designated account holders, and associated installations. For installations, data is available on activity type, physical address, verified emissions, and the amount of allocated and surrendered EUAs. Transaction-level records capture information on both accounts involved in a transaction, transaction type, date, and volume of allowances transferred, but not on the transaction price. To incorporate market price information, we used the unweighted annual average of spot prices from the EEX and linked these values to the corresponding years in the EUTL dataset.

Prior to a major structural reform in 2012, transaction monitoring was carried out via the decentralised Community Independent Transaction Log (CITL). As part of the reform, the CITL was integrated into the centralised EUTL managed by the EC, with new OHAs being assigned to all installations during the transition (see A.1.2).

To aggregate account-level data to the level of a company, NUO, and GUO we link EUTL data with company-level information from the ORBIS database via corporate registration numbers. ORBIS data further includes the number of employees, total revenues, industry classifications according to NACE codes, and the country of the headquarter. We provide further details regarding the matching methodology between these data sources in A.1.3.

Following the data matching, we constructed a panel dataset at the transaction level, which we then aggregated to reflect annual transactions per company. Entities that did not report either verified emissions or receive free allocations were excluded from the analysis, as they are not relevant to our research question.

The resulting dataset comprises 42,007 accounts, of which 8142 could not be matched to any identifiable company. The remaining accounts correspond to 12,319 companies. However, the subset of companies included in our analyses is significantly smaller, as we exclude aircraft operators and companies lacking both allocations and verified emissions, resulting in a sample of approximately 9000 companies. Moreover, we restrict the sample to companies that are able to trade internally - that is, companies with at least one other company belonging to the same NUO. The final analytical sample consists of 2507 companies.

Matching of historical and current Operator Holding Accounts (OHAs)

As part of the 2012 restructuring of the EUTL, the system was expanded to include new account categories, such as Aircraft Operator Accounts. This reform also involved new OHAs assigned to all installations participating in the EU ETS. However, the current EUTL dataset contains only the updated OHAs, with no direct reference to their predecessors. Consequently, we had to reconstruct the linkages between former OHAs and the corresponding installations.

To achieve this, we applied the following matching procedure:

(1) Name-based Matching: The account and installation names were compared, and matches were accepted only in cases where the correspondence was unambiguous.
(2) Address-based Matching: Where name comparisons proved inconclusive, we relied on matching account and installation addresses, again requiring unique associations.
(3) Transaction-based Matching: If 1 and 2 did not work, we used installation-level information on allocated and surrendered EUAs as criteria and searched for the transaction and corresponding account and the administrative account of the respective registration. Again, we only accepted unique matches. As criteria, we first used transfers on allocated and then on surrendered EUAs.

By applying this methodology, we were able to successfully match approximately 99 % of old OHAs with their new OHAs.

Linking EUTL data to companies in the ORBIS database

Following the 2012 restructuring of account systems within the EU ETS, all account holders were mandated to provide VAT identification numbers, which could be either national or EU VAT numbers. Since the ORBIS database also includes VAT information, it is, in principle, possible to link EUTL accounts to companies listed in ORBIS. However, in practice, this process is hindered by data entry errors, inconsistent formatting, and occasional omissions. To overcome these issues, we implemented a fuzzy matching approach using a combination of variables: the VAT registration number, the account name associated with the number, and the contact address linked to the account. These variables served as the basis for an automated batch search within ORBIS. This procedure returned multiple potential matches along with a matching score for each option. Final matches were selected manually, assessing the consistency and plausibility of the values across the individual data fields.

[13] A.1 partially relies on Lehman et al. (2024), with some sections quoted verbatim.
[14] https://union-registry-data.ec.europa.eu/report/welcome.

Appendix A2 Additional results

Table A2.1
Descriptive statistics of the dependent variable and all covariates (sample including all installations).

Variable	Obs.	Mean	Std. dev.	Min	Max
Dependent variable					
Internal trading	15,947	100,571	3,214,939	0	291,000,000
Covariates					
Internal trading potential	15,947	187,905	1,723,947	0	50,900,000
Banking	15,947	10,183	3,570,672	−414,000,000	213,000,000
Number of NUO companies	15,947	7.4	13.1	2	72
Transaction frequency	15,947	29	267	0	9957
Energy	5342			1	1
Number of Installations	14,057	3.9	6.4	1	80
Carbon leakage	5260			1	1
Period 1	6230			1	1
Period 2	3612			1	1
Period 3	6105			1	1
Region 1 (AT, DE, LI)	1018			1	1
Region 2 (BE, FR, NL)	561			1	1
Region 3 (GR, CY, ES, IT, MT, PT)	2825			1	1
Region 4 (EE, LT, LV, PL)	1760			1	1
Region 5 (CZ, HU, SI, SK)	531			1	1
Region 6 (DK, FI, IS, NO, SE)	5949			1	1
Region 7 (UK, IE)	584			1	1
Region 8 (BG, HR, RO)	2141			1	1

Table A2.2
Estimated coefficients of the latent level of internal trading (sample including all installations).

	Coefficient (Standard errors in parentheses)
Internal trading potential	−0.092
	(0.087)
Banking	−0.493***
	(0.190)
Number of NUO companies	0.437***
	(0.066)
Transaction frequency	2.779***
	(0.390)
Energy	0.743
	(2.142)
Number of Installations	0.236*
	(0.128)
Carbon leakage	−7.216***
	(2.507)
Period 2	2.436*
	(1.265)
Period 3	3.527***
	(1.086)
Region 2	−9.591
	(6.085)
Region 3	−15.39***
	(3.617)
Region 4	−6.658*
	(3.470)
Region 5	−4.041
	(4.703)
Region 6	−11.470***
	(2.766)
Region 7	−16.040***
	(5.074)
Region 8	−17.850***
	(4.201)
Mean internal trading potential	0.423
	(0.287)
Mean banking	1.416
	(1.090)
Mean transaction frequency	0.793**
	(0.402)
Constant	−58.830***
	(5.365)
Observations	15,947
Companies	2507

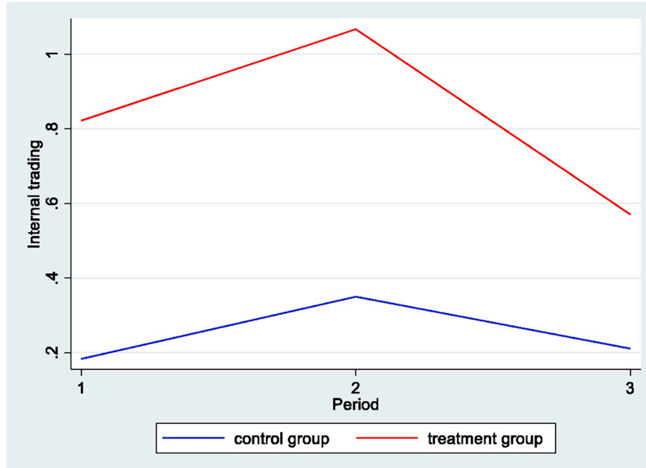

Fig. A2.1. Means of internal trading for operators of combustion installations in energy and industry sectors across trading periods.

Table A2.3
Estimated coefficients of the latent level of internal trading; placebo test which treats period 2 instead of period 3 as the treatment period (analysis including combustion installations only).

	Coefficient (Standard errors in parentheses)
Period 2	1.772
	(2.047)
EnergyxPeriod 2	−1.643
	(2.622)
Period 2xITP	0.467
	(0.388)
EnergyxPeriod 2xITP	−0.319
	(0.501)
Energy	2.817
	(3.388)
EnergyxITP	0.646
	(0.43)
Internal trading potential	−0.380
	(0.334)
Banking	−0.086
	(0.288)
Number of NUO companies	0.510***
	(0.090)
Transaction frequency	2.638***
	(0.489)
Number of Installations	0.058
	(0.155)
Carbon leakage	−7.302**
	(3.403)
Region 2 (BE, FR, NL)	−6.377
	(7.453)
Region 3 (GR, IT, PT, ES, CY, MT)	−11.830***
	(4.327)
Region 4 (EE, LT, LV, PL)	−7.652*
	(4.540)
Region 5 (CZ, HU, SI, SK)	0.232
	(6.325)
Region 6 (DK, FI, IS, NO, SE)	−11.800***
	(3.467)
Region 7 (UK, IE)	−21.730***
	(8.427)
Region 8 (BG, HR, RO)	−22.630***
	(5.977)
Mean ITP	0.410
	(0.405)
Mean Banking	−1.571**
	(0.655)
Mean Transaction frequency	0.861
	(1.366)
Constant	−56.010***
	(7.126)
Observations	9294
Companies	1553

Table A2.4
Estimated coefficients of the latent level of internal trading; placebo test that considers period 2 as the post-treatment period while excluding Period 3 (analysis including combustion installations only).

	Coefficient (Standard errors in parentheses)
Period 2	1.833
	(2.267)
Period 3	5.409**
	(2.598)
EnergyxPeriod 2	−1.917
	(2.907)
EnergyxPeriod 3	−9.822***
	(3.444)
Period 2xITP	0.418
	(0.427)
Period 3xITP	−0.424
	(0.492)
Period 2xEnergyxITP	−0.325
	(0.550)
Period 3xEnergyxITP	−0.054
	(0.631)
Energy	3.082
	(3.385)
EnergyxITP	0.560
	(0.472)
Internal trading potential	−0.389
	(0.370)
Banking	−0.314
	(0.247)
Number of NUO companies	0.500***
	(0.078)
Transaction frequency	2.929***
	(0.472)
Number of Installations	0.177
	(0.145)
Carbon leakage	−9.172***
	(3.110)
Region 2 (BE, FR, NL)	−2.651
	(6.356)
Region 3 (GR, IT, PT, ES, CY, MT)	−13.730***
	(4.046)
Region 4 (EE, LT, LV, PL)	−5.872
	(3.968)
Region 5 (CZ, HU, SI, SK)	1.474
	(5.714)
Region 6 (DK, FI, IS, NO, SE)	−11.870***
	(3.193)
Region 7 (UK, IE)	−19.030***
	(6.961)
Region 8 (BG, HR, RO)	−24.420***
	(5.648)
Mean ITP	0.446
	(0.350)
Mean Banking	−1.295**
	(0.516)
Mean Transaction frequency	1.015
	(1.261)
Constant	−59.140***
	(6.244)
Observations	9294
Companies	1553

Table A2.5
Estimated coefficients of the latent level of internal trading (analysis including combustion installations only).

	Coefficient (Standard errors in parentheses)
Period 3 x Energy	−8.548***
	(2.823)
Period 3 x ITP	−0.746**
	(0.377)
Energy x ITP	0.298
	(0.239)

(*continued on next page*)

Table A2.5 (*continued*)

	Coefficient (Standard errors in parentheses)
Period 3 x Energy x ITP	0.207
	(0.487)
ITP	−0.067
	(0.180)
Energy	1.813
	(2.784)
Period 3	3.661*
	(2.083)
Banking	−0.309
	(0.247)
Number of NUO companies	0.503***
	(0.078)
Transaction frequency	2.938***
	(0.474)
Number of installations	0.180
	(0.146)
Carbon leakage	−9.200***
	(3.128)
Period 1	−1.390
	(1.263)
Region 2 (BE, FR, NL)	−2.681
	(6.427)
Region 3 (GR, IT, PT, ES, CY, MT)	−13.80***
	(4.074)
Region 4 (EE, LT, LV, PL)	−5.973
	(4.007)
Region 5 (CZ, HU, SI, SK)	1.564
	(5.756)
Region 6 (DK, FI, IS, NO, SE)	−11.94***
	(3.221)
Region 7 (UK, IE)	−19.15***
	(7.006)
Region 8 (BG, HR, RO)	−24.750***
	(5.690)
Mean ITP	0.447
	(0.353)
Mean banking	−1.299**
	(0.518)
Mean transaction frequency	1.026
	(1.271)
Constant	−57.62***
	(6.138)
Observations	9294
Companies	1553

Table A2.6
Estimated average marginal effects on internal trading (analysis including combustion installations only).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]
Internal trading potential	0.000	−0.018
	(0.000)	(0.013)
Banking	−0.001	−0.034
	(0.001)	(0.027)
Number of NUO companies	0.001***	0.056***
	(0.000)	(0.009)
Transaction frequency	0.008***	0.326***
	(0.001)	(0.053)
Energy	0.001	0.019
	(0.007)	(0.286)
Number of installations	0.000	0.020
	(0.000)	(0.016)
Carbon leakage	−0.024***	−1.022***
	(0.008)	(0.346)
Period 1	−0.004	−0.154
	(0.003)	(0.140)
Period 3	−0.006*	−0.161
	(0.003)	(0.148)
Region 2 (BE, FR, NL)	−0.007	−0.298
	(0.017)	(0.714)
Region 3 (GR, IT, PT, ES, CY, MT)	−0.015	−0.663
	(0.010)	(0.445)

(*continued on next page*)

Table A2.6 (*continued*)

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]
Region 4 (EE, LT, LV, PL)	−0.036***	−1.533***
	(0.010)	(0.451)
Region 5 (CZ, HU, SI, SK)	0.004	0.174
	(0.015)	(0.639)
Region 6 (DK, FI, IS, NO, SE)	−0.031***	−1.327***
	(0.008)	(0.357)
Region 7 (UK, IE)	−0.049***	−2.127***
	(0.018)	(0.777)
Region 8 (BG, HR, RO)	−0.064***	−2.748***
	(0.015)	(0.627)
Region 8 (BG, HR, RO)	0.004	0.184
	(0.005)	(0.208)
Observations	9294	
Companies	1553	

Marginal effects for interaction terms are shown in Table A2.7

Table A2.7
Estimated average marginal effects of the reform on the relationship between ITP and internal trading (analysis including combustion installations only).

	Extensive margin [change in Prob(internal trading > 0)]		Intensive margin [change in E(internal trading | internal trading > 0)]	
	Energy = 0	Energy = 1	Energy = 0	Energy = 1
ITP = 1	0.008	−0.013***	0.333	−0.592***
	(0.006)	(0.005)	(0.224)	(0.197)
ITP = 2	0.006	−0.015***	0.245	−0.650***
	(0.005)	(0.004)	(0.212)	(0.187)
ITP = 3	0.004	−0.016***	0.159	−0.708***
	(0.005)	(0.004)	(0.208)	(0.183)
ITP = 4	0.002	−0.017***	0.075	−0.766***
	(0.005)	(0.005)	(0.214)	(0.193)
ITP = 5	0.000	−0.018***	−0.007	−0.824***
	(0.005)	(0.005)	(0.226)	(0.193)
ITP = 6	−0.002	−0.020***	−0.088	−0.882***
	(0.005)	(0.005)	(0.244)	(0.206)
ITP = 7	−0.004	−0.021***	−0.168	−0.940***
	(0.006)	(0.005)	(0.266)	(0.223)
ITP = 8	−0.005	−0.022***	−0.245	−0.998***
	(0.006)	(0.006)	(0.290)	(0.243)
ITP = 9	−0.007	−0.024***	−0.322	−1.056***
	(0.006)	(0.006)	(0.317)	(0.266)
ITP = 10	−0.008	−0.025***	−0.397	−1.114***
	(0.007)	(0.007)	(0.344)	(0.290)
ITP = 11	−0.009	−0.026***	−0.470	−1.171***
	(0.007)	(0.007)	(0.372)	(0.315)
ITP = 12	−0.011	−0.027***	−0.542	−1.229***
	(0.008)	(0.008)	(0.400)	(0.342)
ITP = 13	−0.012	−0.029***	−0.613	−1.287***
	(0.008)	(0.008)	(0.428)	(0.369)
ITP = 14	−0.013	−0.030***	−0.682	−1.344***
	(0.008)	(0.009)	(0.456)	(0.397)
ITP = 15	−0.014*	−0.031***	−0.750	−1.402***
	(0.008)	(0.010)	(0.483)	(0.426)
ITP = 16	−0.015*	−0.033***	−0.817	−1.459***
	(0.009)	(0.010)	(0.511)	(0.454)
ITP = 17	−0.016*	−0.034***	−0.883	−1.517***
	(0.009)	(0.011)	(0.538)	(0.483)
Observations	9294			
Companies	1553			

Appendix A3 Robustness checks

Table A3.1
Estimated marginal effects including number of employees and productivity (analysis including all installations).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	−0.000	−0.019	−0.005
	(0.00)	(0.012)	(0.003)
Banking	−0.001	−0.035	−0.009
	(0.001)	(0.027)	(0.007)
Number of NUO companies	0.001***	0.045***	0.012***
	(0.000)	(0.009)	(0.003)
Transaction frequency	0.007***	0.328***	0.086***
	(0.001)	(0.054)	(0.016)
Energy	0.007	0.340	0.089
	(0.006)	(0.294)	(0.078)
Number of Installations	0.000	0.018	0.005
	(0.000)	(0.015)	(0.004)
Carbon leakage	−0.011*	−0.547*	−0.143*
	(0.006)	(0.303)	(0.081)
Employees	0.001	0.053	0.014
	(0.003)	(0.139)	(0.037)
Productivity	0.001	0.024	0.006
	(0.002)	(0.107)	(0.028)
Period 2	0.008**	0.400**	0.105**
	(0.004)	(0.176)	(0.047)
Period 3	0.010***	0.480***	0.126***
	(0.003)	(0.147)	(0.040)
Region 2	−0.010	−0.483	−0.127
	(0.014)	(0.657)	(0.173)
Region 3	−0.029***	−1.400***	−0.367***
	(0.010)	(0.464)	(0.128)
Region 4	−0.011	−0.538	−0.141
	(0.009)	(0.431)	(0.114)
Region 5	−0.006	−0.302	−0.079
	(0.011)	(0.533)	(0.140)
Region 6	−0.026***	−1.228***	−0.322***
	(0.007)	(0.330)	(0.093)
Region 7	−0.039***	−1.870***	−0.491***
	(0.013)	(0.624)	(0.171)
Region 8	−0.048***	−2.331***	−0.611***
	(0.012)	(0.557)	(0.161)
Observations	9444		
Companies	2037		

Table A3.2
Estimated marginal effects including only observations with internal trading potential (analysis including all installations).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	−0.000	−0.012	−0.004
	(0.000)	(0.010)	(0.003)
Banking	−0.001**	−0.047**	−0.014**
	(0.001)	(0.022)	(0.007)
Number of NUO companies	0.001***	0.045***	0.013***
	(0.000)	(0.007)	(0.002)
Transaction frequency	0.008***	0.330***	0.099***
	(0.001)	(0.045)	(0.015)
Energy	0.001	0.056	0.017
	(0.006)	(0.246)	(0.074)
Number of Installations	0.000	0.020	0.006
	(0.000)	(0.015)	(0.005)
Carbon leakage	−0.019***	−0.797***	−0.240***
	(0.007)	(0.288)	(0.090)
Period 2	0.010***	0.409***	0.123***
	(0.004)	(0.151)	(0.046)
Period 3	0.012***	0.510***	0.153***
	(0.003)	(0.131)	(0.041)
Region 2	−0.027	−1.138	−0.342
	(0.018)	(0.746)	(0.227)
Region 3	−0.040***	−1.690***	−0.508***
	(0.010)	(0.405)	(0.131)
Region 4	−0.015	−0.650	−0.196

(*continued on next page*)

Table A3.2 (*continued*)

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
	(0.009)	(0.397)	(0.121)
Region 5	−0.005	−0.214	−0.064
	(0.013)	(0.546)	(0.165)
Region 6	−0.031***	−1.300***	−0.391***
	(0.007)	(0.312)	(0.101)
Region 7	−0.041***	−1.714***	−0.516***
	(0.013)	(0.566)	(0.177)
Region 8	−0.045***	−1.887***	−0.568***
	(0.011)	(0.476)	(0.153)
Observations	3408		
Companies	1364		

Table A3.3
Estimated marginal effects from Tobit model excluding 5 % (instead of 2 %) outliers in internal trading (analysis including all installations).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	0.000	−0.008	−0.002
	(0.000)	(0.010)	(0.002)
Banking	0.001**	0.052**	0.012**
	(0.000)	(0.022)	(0.005)
Number of NUO companies	0.001***	0.044***	0.010***
	(0.000)	(0.007)	(0.002)
Transaction frequency	0.001**	0.036**	0.008**
	(0.000)	(0.017)	(0.004)
Energy	−0.015***	−0.781***	−0.175***
	(0.005)	(0.276)	(0.064)
Number of Installations	0.007***	0.394***	0.088***
	(0.001)	(0.058)	(0.014)
Carbon leakage	0.007**	0.372**	0.083**
	(0.003)	(0.148)	(0.034)
Period 2	0.010***	0.521***	0.117***
	(0.002)	(0.130)	(0.031)
Period 3	−0.018	−0.953	−0.213
	(0.012)	(0.640)	(0.145)
Region 2	−0.029***	−1.551***	−0.348***
	(0.007)	(0.391)	(0.095)
Region 3	−0.014**	−0.749**	−0.168*
	(0.007)	(0.377)	(0.086)
Region 4	−0.009	−0.487	−0.109
	(0.009)	(0.511)	(0.115)
Region 5	−0.023***	−1.236***	−0.277***
	(0.005)	(0.298)	(0.072)
Region 6	−0.027***	−1.457***	−0.327***
	(0.010)	(0.535)	(0.124)
Region 7	−0.036***	−1.953***	−0.438***
	(0.009)	(0.472)	(0.115)
Region 8	0.000	−0.008	−0.002
	(0.000)	(0.010)	(0.002)
Observations	15,340		
Companies	2505		

Table A3.4
Estimated marginal effects net sellers (analysis including all installations).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	0.000	−0.015	−0.003
	(0.000)	(0.013)	(0.003)
Banking	−0.001***	−0.078***	−0.018***
	(0.001)	(0.028)	(0.006)
Number of NUO companies	0.001***	0.039***	0.009***
	(0.000)	(0.007)	(0.002)
Transaction frequency	0.005***	0.261***	0.059***
	(0.001)	(0.049)	(0.012)
Energy	0.002	0.133	0.030
	(0.004)	(0.242)	(0.055)
Number of Installations	0.000*	0.025*	0.006*

(*continued on next page*)

Table A3.4 (*continued*)

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
	(0.000)	(0.015)	(0.003)
Carbon leakage	−0.014***	−0.758***	−0.171**
	(0.005)	(0.286)	(0.067)
Period 2	0.010***	0.541***	0.122***
	(0.004)	(0.202)	(0.047)
Period 3	0.012***	0.634***	0.143***
	(0.004)	(0.190)	(0.045)
Region 2	−0.015	−0.809	−0.182
	(0.012)	(0.646)	(0.147)
Region 3	−0.025***	−1.346***	−0.303***
	(0.007)	(0.394)	(0.094)
Region 4	−0.007	−0.406	−0.091
	(0.007)	(0.380)	(0.086)
Region 5	−0.003	−0.162	−0.036
	(0.009)	(0.513)	(0.116)
Region 6	−0.022***	−1.173***	−0.264***
	(0.006)	(0.307)	(0.075)
Region 7	−0.029***	−1.588***	−0.358***
	(0.011)	(0.574)	(0.135)
Region 8	−0.035***	−1.916***	−0.432***
	(0.009)	(0.496)	(0.121)
Observations	12,776		
Companies	300		

Table A3.5
Estimated marginal effects net buyers (analysis including all installations).

	Extensive margin [change in Prob(internal trading > 0)]	Intensive margin [change in E(internal trading | internal trading > 0)]	Change in average internal trading
Internal trading potential	0.000	−0.013	−0.005
	(0.001)	(0.020)	(0.007)
Banking	0.000	0.007	0.003
	(0.001)	(0.033)	(0.012)
Number of NUO companies	0.002***	0.062***	0.023***
	(0.000)	(0.011)	(0.005)
Transaction frequency	0.008***	0.250***	0.093***
	(0.003)	(0.080)	(0.031)
Energy	0.010	0.319	0.119
	(0.011)	(0.369)	(0.139)
Number of Installations	0.000	0.011	0.004
	(0.001)	(0.019)	(0.007)
Carbon leakage	−0.012	−0.381	−0.142
	(0.012)	(0.403)	(0.151)
Period 2	0.018*	0.570*	0.213*
	(0.010)	(0.326)	(0.123)
Period 3	0.023***	0.733***	0.274***
	(0.008)	(0.259)	(0.100)
Region 2	−0.031	−1.005	−0.375
	(0.040)	(1.282)	(0.481)
Region 3	−0.057***	−1.851***	−0.691***
	(0.019)	(0.623)	(0.248)
Region 4	−0.037**	−1.196**	−0.447*
	(0.018)	(0.596)	(0.229)
Region 5	−0.059*	−1.906*	−0.712*
	(0.032)	(1.057)	(0.403)
Region 6	−0.037***	−1.182***	−0.442**
	(0.013)	(0.446)	(0.175)
Region 7	−0.074***	−2.382***	−0.890**
	(0.027)	(0.898)	(0.351)
Region 8	−0.056***	−1.791***	−0.669***
	(0.019)	(0.645)	(0.253)
Observations	3171		
Companies	146		

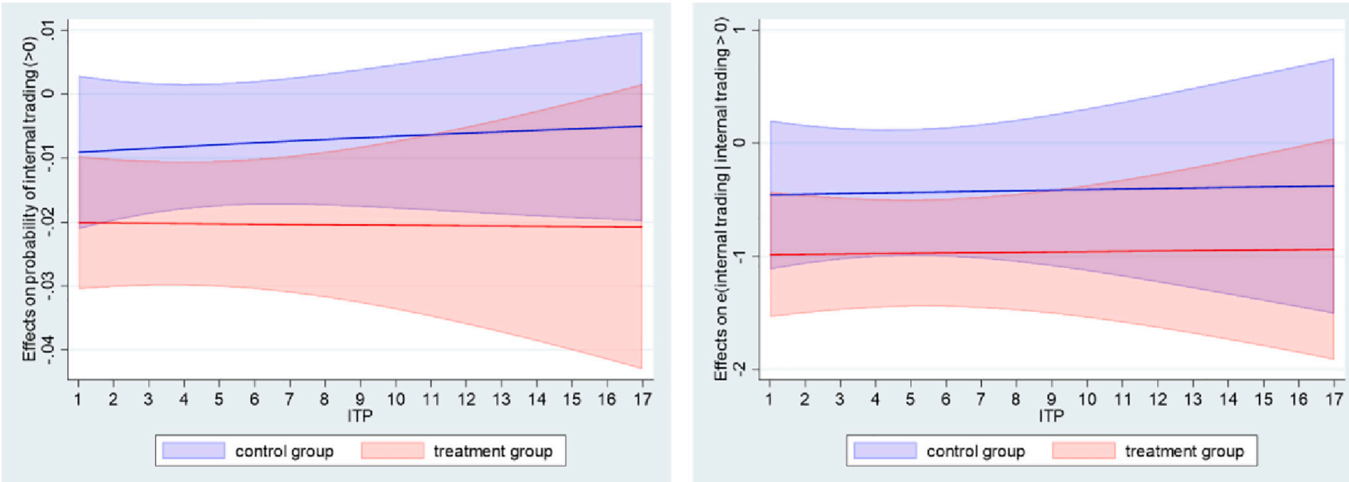

Fig. A3.1. Marginal effects of the reform on the relationship between ITP and internal trading net sellers only (analysis including combustion installations only). Note: Estimations based on the dataset described in Section 2.1 and Appendix 1. Left panel shows extensive margin, right panel shows intensive margin. Shaded areas correspond to 90 % CI.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2025.109035.

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