Zurich University
of Applied Sciences

School of
Management and Law

A Comparative Analysis of the Trading Behavior of the Participants in the first three Phases of the EU Emissions Trading System

Building Competence. Crossing Borders.

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Motivation

- Which factors are the key determinants for trading allowances in the European Union Emissions Trading System?
- How did the trading behavior change over phase I, II and the first two years of phase III
- Is there a possibility calculating the opportunity costs of non-trading directly by using the transaction data of the EU ETS?

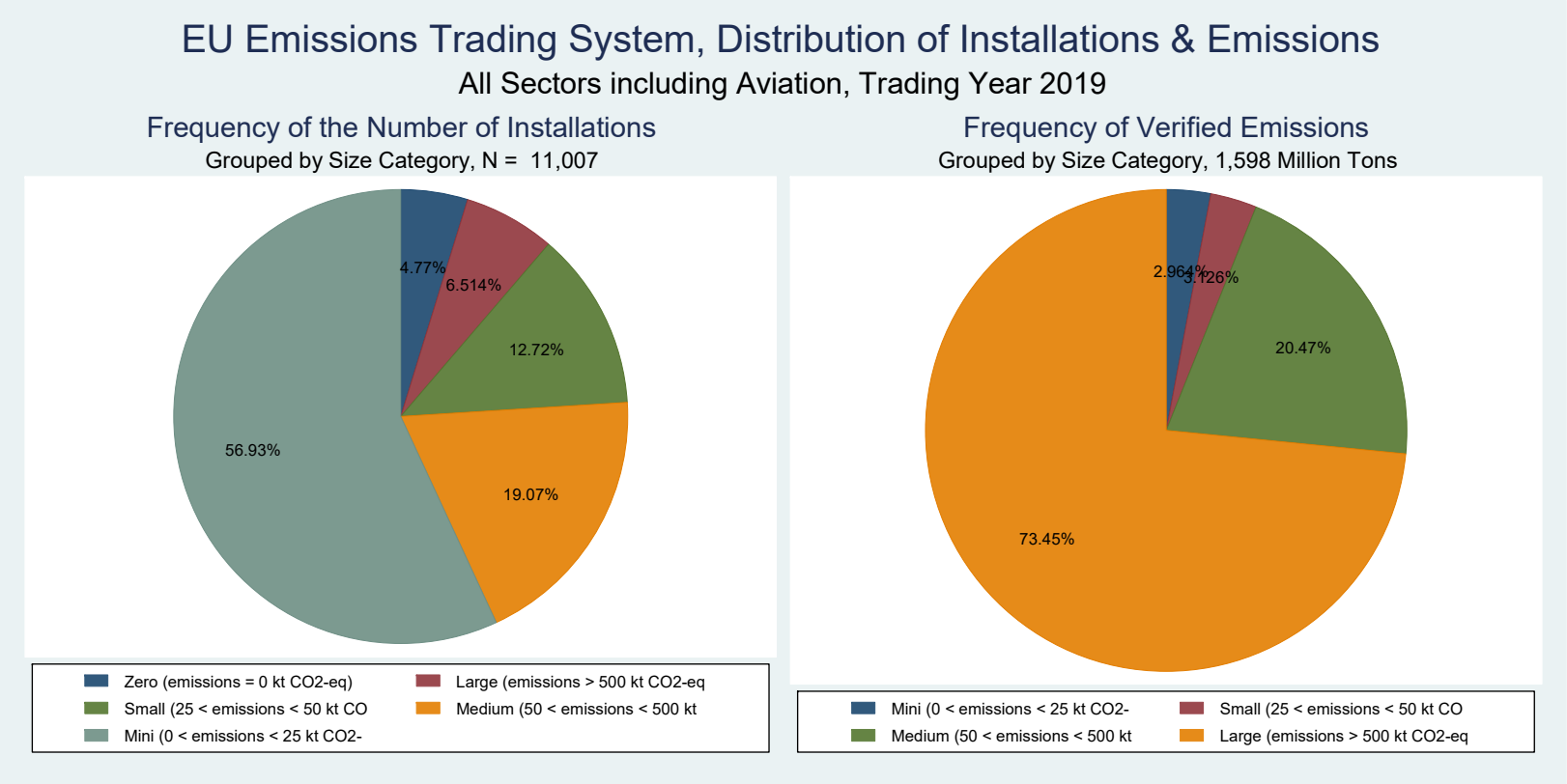
Outline of the Presentation

- Literature
- Overview of the European Union Emissions Trading System
- Research Question and Challenges
- The dataset
- Definitions used for the analysis
- Econometric strategy and determinants of the propensity to trade allowances
- Main results of the panel probit estimation from 2005 – 2014
- Impacts of transaction costs on trading behavior
- An alternative approach to measure foregone earnings of non-traders using propensity score matching techniques.
- Foregone earnings as a proxy of trading costs
- Conclusion and Outlook

Some Literature on Trading Costs and Trading Behavior

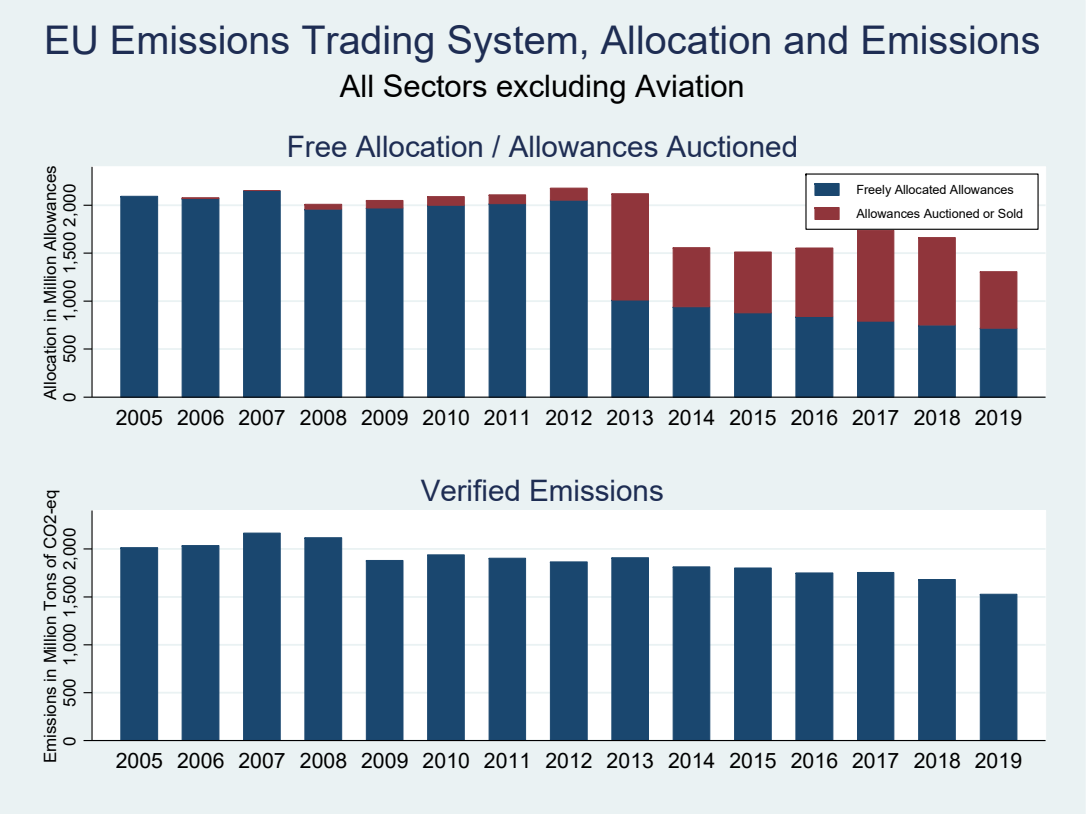
- STAVINS, R. N. 1995. Transaction costs and tradeable permits. Journal of environmental economics and management, 29, 133-148.
- HEINDL, P. 2012. Transaction costs and tradable permits: Empirical evidence from the EU emissions trading scheme. ZEW-Centre for European Economic Research Discussion Paper
- JARAITĖ, J., CONVERY, F. & DI MARIA, C. 2010. Transaction costs for firms in the EU ETS: lessons from Ireland. Climate Policy, 10, 190-215.
- JARAITĖ-KAŽUKAUSKĖ, J. & KAŽUKAUSKAS, A. 2015. Do transaction costs influence firm trading behaviour in the European emissions trading system? Environmental and Resource Economics, 62, 583-613.
- MARTIN, R., MUÛLS, M. & WAGNER, U. J. 2014. Trading behavior in the EU emissions trading scheme. Available at SSRN 2362810.

EU Emissions Trading System: Number of Installations versus Verified Emissions in 2019 (Data source: EEA)



- 60% of the participants are mini installations: Emissions < 25,000 CO_2eq / year.
- 75% of the emissions are emitted by large installations: Emissions > 500,000 CO_2eq / year.

EU Emissions Trading System: Allocation and Emissions 2005 - 2019 (Data source: EEA)



- Phase I (2005-2007): Cap on allowances according to national allocation plans, free allocation is the default, allowances could not be banked to phase II.
- Phase II (2008-2012): Cap on allowances 6.5% lower compared to 2005, free allocation around 90%, allowances could be banked to phase to phase III.
- Phase III (2013-2020): Union-wide cap for stationary installations decreases by 1.74% every year, 57% of the allowances were auctioned.

Research Question and Challenges

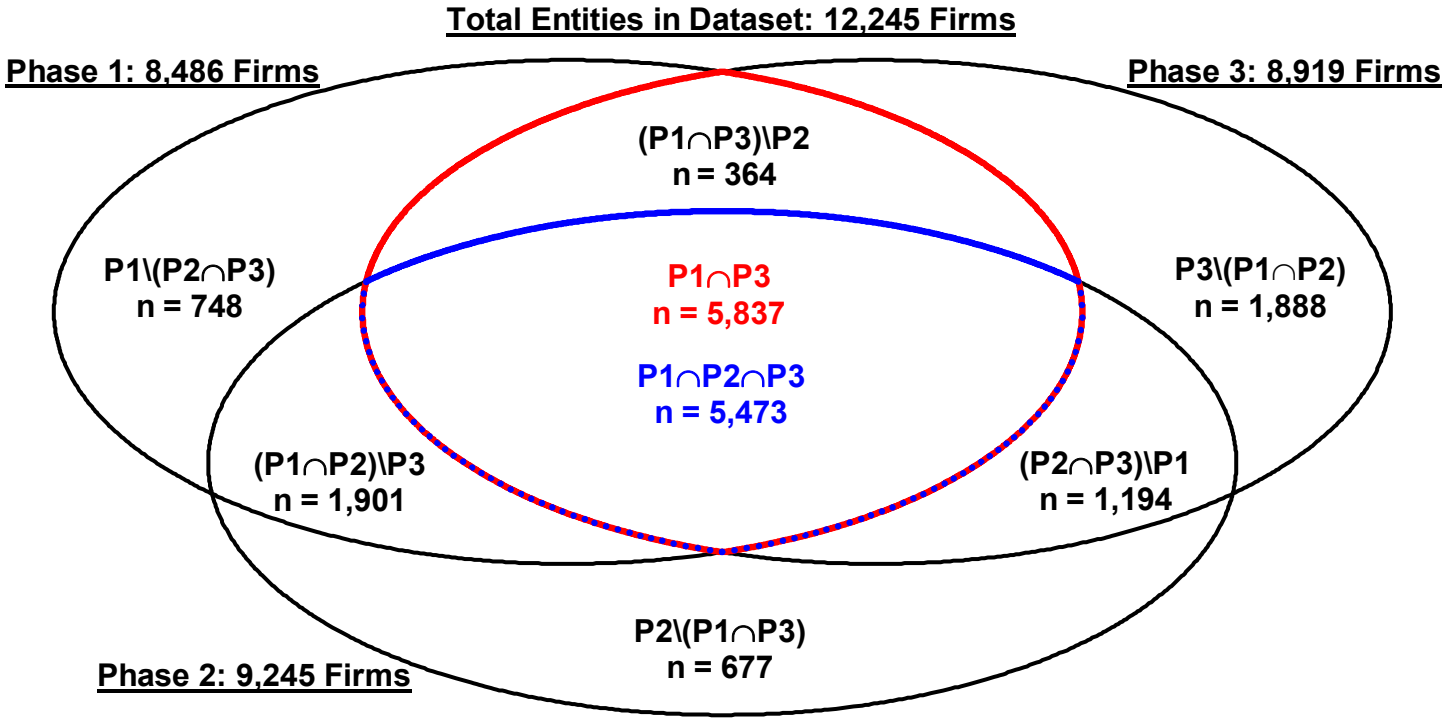
Challenges

- Revealing trading decisions and their evolution over the last three EU ETS phases by linking compliance and transactions data from the European Union Transaction Log (EUTL).

Research questions

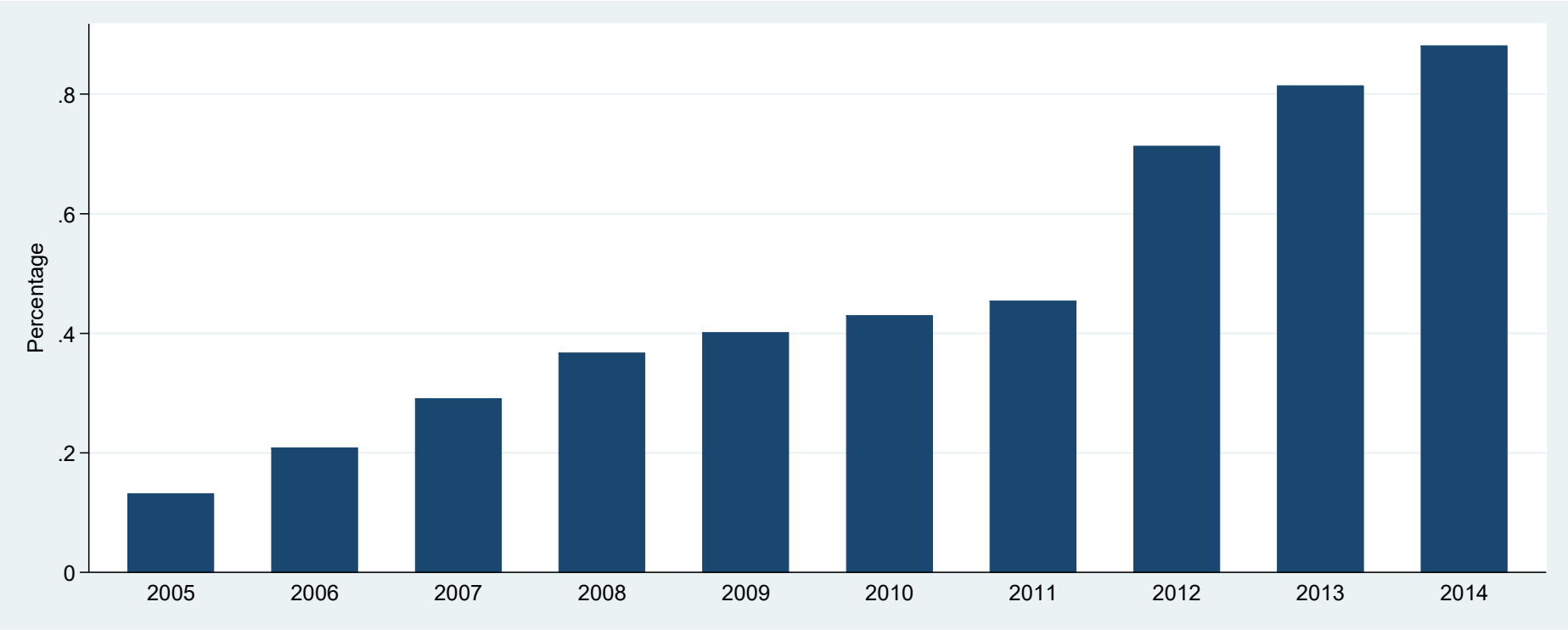
- What are the determinants of the propensity to trade allowances and how did this propensity response to institutional changes from phase to phase and over time?
- How can the opportunity costs of those firms that do not sell their allocation surplus be revealed by using directly the European Union Transaction Log linked with annual average transaction price data.

Constructing the Data Set (Source: European Union Transaction Log)



- Operator holding accounts: includes all compliance data such as allocated allowances, verified emissions, surrendered allowances.
- Transactions: keeps record of all physical allowance transactions, such as acquiring and transferring data between operator holding accounts and other account types.
- The final dataset: includes all compliance and transaction data on firm level 1 (aggregated by account holder name). It consists of 122,450 individual observations from 2005 - 2014. There are various overlappings useful for panel data analysis.

Cumulated Trading Participation Rates in the EU ETS Dataset between 2005-2014



- Between the first compliance year 2005 and 2014 the cumulated trading participation rate rose from around 15% to around 90%.
- In 2014, only 10% of the firms have no trading experience in 2014.
- Reasons for the increase of trading:
  - Auctioning instead of free allocation is going to be the default method in phase IV (2021-2030)
  - The cap is reduced every year which leads to less installations with allocation surplus.

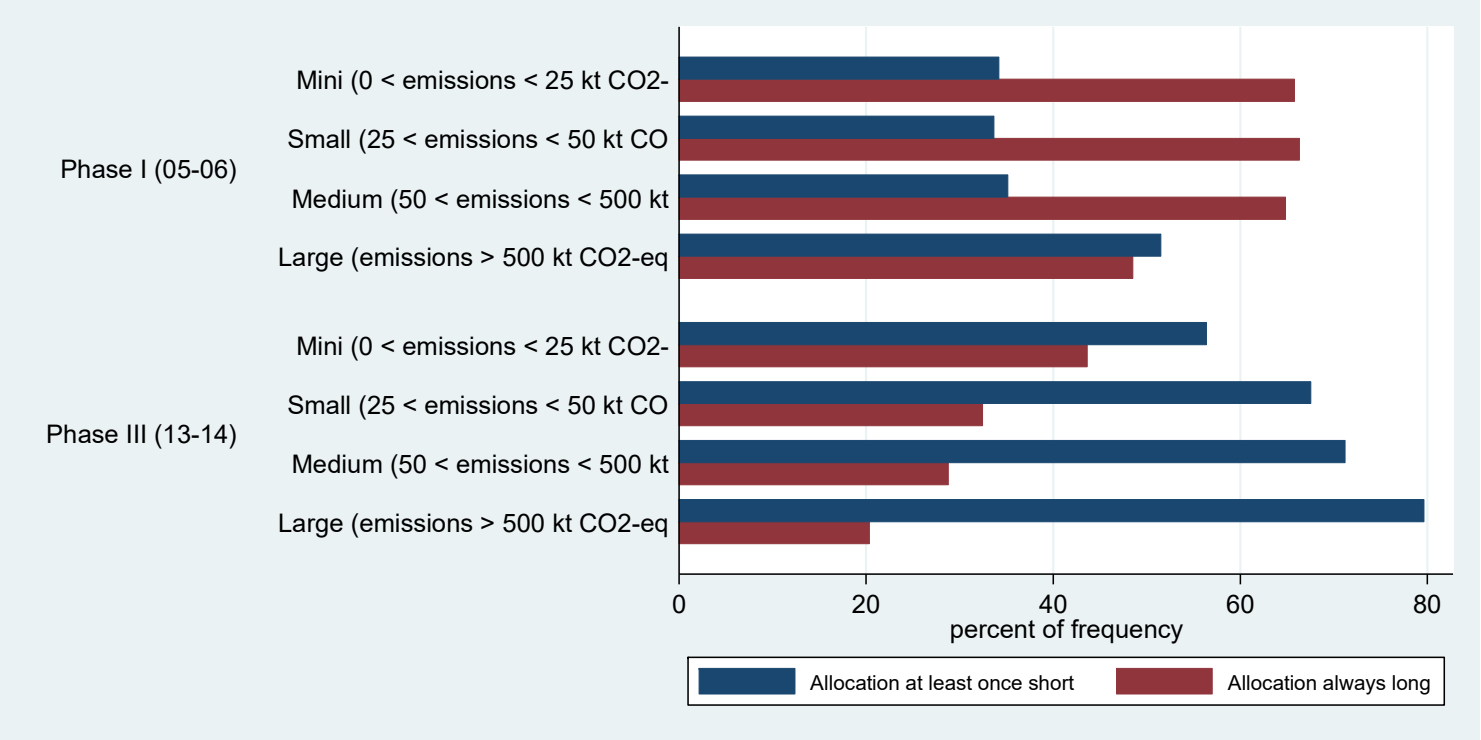
Definitions used for the Econometric Analysis: Data needed from EUTL: Compliance and Transactions

- $a_{it} - e_{it}$: Allocation Position = Allocated Allowances – Verified Emissions
  - $a_{it} - e_{it} > 0$: Allocation surplus: The net position of firm i in year t is “long“.
  - $a_{it} - e_{it} < 0$: Allocation deficit: The net position of firm i in year t is “short“.
  - $a_{it} - e_{it} = 0$: Allocation balanced: Firm i in year t is compliant.

- $ab_{it} = a_{it} - s_{it} + purch_{it} - sales_{it}$:
  - Annual Balance =
    Allocated Allowances – Surrendered Allowances – Sales + Purchases
  - In case of no trade, the allocation position is equal to the annual balance.

- Banking $firm_i = \sum_{t=1}^{n} ab_{it}$
  - Banked allowances at the end of phase I expired.
  - Banked allowances at the end of phase II could be carried over to phase III.

Comparison of the Distribution of the Allocation Position of the Firms in Phase I and Phase III



- In phase I, the majority of the firms' allocation position, unless large emitters, was always long.
- In phase III (years 2013 - 2014) the majority of the firms' allocation position was at least once short.
- Larger emitters tend to have shorter positions in general.

Propensity to Trade: Econometric Strategy

Binary choice model using panel data:
y_{it} = 1 if firm i conducts at least one trade in period t

- $\text{Prob}(y_{it} = 1 \mid \mathbf{x_{it}}, \mathbf{z_i}, \eta_i) = \Phi(\mathbf{x'_{it}\beta} + \mathbf{z'_i\gamma} + \eta_i + \varepsilon_{it})$
  - $\mathbf{x_{it}}$ are the entity-specific time-varying variables such as the logarithm of the yearly allocation position.
  - η_i are entity-specific unobserved time-constant effects such as firm culture, management behavior or firm-specific technology.
  - $\mathbf{z_i}$ are entity specific time-invariant observed characteristics, such as sector affiliation, country and size.
  - Following Mundlak (1978) $\eta_i = \bar{\mathbf{x}}'_i\boldsymbol{\delta} + \alpha_i$ including for every time-varying regressor x_{it} an $\bar{x}_i$ as the average of the x_{it} over t.

The binary response probability model can then be written as

- $P(\text{yes}_t = 1 \mid \mathbf{x_{it}}, \bar{\mathbf{x}}_i, \mathbf{z_i}, \alpha_i) = \Phi(\mathbf{x'_{it}\beta} + \bar{\mathbf{x}}'_i\boldsymbol{\delta} + \mathbf{z'_i\gamma} + \alpha_i + \varepsilon_{it})$

Propensity to Trade: Results and Discussion I: Panel Probit Estimation Results for pI, pII & pIII & for all ps'

Dependent Variable: Trade (0 = No, 1 = Yes) VARIABLES	(1) Probit 2005-2007	(2) Probit 2008-2012	(3) Probit 2013-2014	(4) Probit 2005-2014	(5) Probit Buyer 2005-2014	(6) Probit Seller 2005-2014
Log(1 + Allocation Position)	-0.0204**	0.00850**	-0.00848**	-0.00458**	-0.0206**	0.0255**
	(0.00237)	(0.00165)	(0.00182)	(0.000887)	(0.000897)	(0.00101)
Log(1 + Lag Banking)	-0.00578**	0.00802**	-0.0176**	0.00307**	-0.00991**	0.0248**
	(0.00210)	(0.00149)	(0.00223)	(0.000867)	(0.000898)	(0.000970)
No. of Installations	0.0245**	0.140**	0.121+	0.0246**	0.0358**	0.0244**
	(0.00930)	(0.0339)	(0.0629)	(0.00922)	(0.0121)	(0.00897)
Is Subsidiary Company = 1, Is Subsidiary	0.0339	0.0405	0.0439	0.0533*	0.0130	0.0846**
	(0.0662)	(0.0381)	(0.0381)	(0.0233)	(0.0228)	(0.0239)
Size Category = 2, Small (25 < emissions < 50 kt CO2-eq)	0.305**	0.354**	0.258**	0.269**	0.255**	0.216**
	(0.0483)	(0.0308)	(0.0332)	(0.0192)	(0.0183)	(0.0203)
Size Category = 3, Medium (50 < emissions < 500 kt CO2-eq)	0.414**	0.561**	0.557**	0.439**	0.455**	0.396**
	(0.0445)	(0.0294)	(0.0329)	(0.0183)	(0.0175)	(0.0194)
Size Category = 4, Large (emissions > 500 kt CO2-eq)	0.638**	0.773**	1.128**	0.598**	0.606**	0.619**
	(0.0709)	(0.0463)	(0.0621)	(0.0303)	(0.0279)	(0.0304)
Sector = 2, Mineral Oil Refineries	0.749**	0.364**	0.0662	0.302**	0.163*	0.206**
	(0.163)	(0.118)	(0.121)	(0.0786)	(0.0709)	(0.0695)
Sector = 3, Coke Ovens	0.0351	0.235	0.151	0.101	-0.0451	0.0725
	(0.221)	(0.176)	(0.284)	(0.105)	(0.107)	(0.119)
Sector = 4, Metal Ore Roasting or Sintering	-0.448	-0.264	-0.325	-0.261+	-0.161	-0.190
	(0.434)	(0.230)	(0.365)	(0.142)	(0.133)	(0.188)
Sector = 5, Pig Iron or Steel	-0.283**	-0.237**	-0.0764	-0.0136	0.0608+	-0.183**
	(0.109)	(0.0650)	(0.0524)	(0.0371)	(0.0339)	(0.0401)
Sector = 6, Cement and Lime	-0.353**	0.194**	-0.172**	0.0301	0.0454	0.00636
	(0.0863)	(0.0533)	(0.0633)	(0.0318)	(0.0303)	(0.0330)
Sector = 7, Glass and Glass Fibre	0.0378	0.00351	-0.405**	-0.0870**	-0.154**	0.0551
	(0.0859)	(0.0520)	(0.0572)	(0.0332)	(0.0308)	(0.0344)
Sector = 8, Ceramics, Bricks, Stoneware and Porcelain	0.0855	0.365**	-0.0161	0.200**	0.185**	0.195**
	(0.0521)	(0.0345)	(0.0387)	(0.0210)	(0.0208)	(0.0222)
Sector = 9, Pulp and Paper	0.120+	0.0290	0.0653	0.0569*	-0.0156	0.101**
	(0.0625)	(0.0442)	(0.0515)	(0.0286)	(0.0272)	(0.0279)
Sector = 10, Chemicals	-0.263	0.133	0.419**	0.352**	0.192**	0.343**
	(0.185)	(0.108)	(0.0709)	(0.0521)	(0.0458)	(0.0505)
Sector = 99, Other activity opted-in under Art. 24	-0.408**	-0.258**	-0.537**	-0.321**	-0.248**	-0.248**
	(0.117)	(0.0896)	(0.106)	(0.0588)	(0.0562)	(0.0613)
Year = 2006 (BL 2005)	0.274**					
	(0.0282)					
Year = 2007 (BL 2005)	0.701**					
	(0.0303)					
Year = 2009 (BL 2008)		-0.0234				
		(0.0192)				
Year = 2010 (BL 2008)		0.0569**				
		(0.0207)				
Year = 2011 (BL 2008)		0.101**				
		(0.0223)				
Year = 2012 (BL 2008)		1.548**				
		(0.0311)				
Year = 2014 (BL 2013)			0.337**			
			(0.0209)			
Period = 2, P08-12 (BL P05-07)				0.579**	0.747**	0.573**
				(0.0130)	(0.0150)	(0.0151)
Period = 3, P13-14 (BL P05-07)				1.134**	1.287**	0.758**
				(0.0193)	(0.0187)	(0.0209)
Mundlak Term Allocation Position	0.0422**	0.0460**	-0.00850**	0.0231**	-0.00962**	0.0599**
	(0.00466)	(0.00343)	(0.00330)	(0.00196)	(0.00190)	(0.00210)
Mundlak Term Banking	-0.0765**	-0.0992**	-0.00724+	-0.0599**	-0.0127**	-0.0924**
	(0.00467)	(0.00364)	(0.00410)	(0.00218)	(0.00213)	(0.00216)
Constant	-3.006**	-1.856**	-0.0809	-1.563**	-1.789**	-2.159**
	(0.171)	(0.0762)	(0.106)	(0.0427)	(0.0437)	(0.0497)
Observations	25,458	46,225	17,838	89,521	89,521	89,511
Number of firms in sample	8,486	9,245	8,919	12,245	12,245	12,240
Country Controls	YES	YES	YES	YES	YES	YES
Rho	0.429	0.337	0.205	0.191	0.156	0.181

Note: Asterisks and plus indicate the significance level at 1% (**), 5% (*) and 10% (+). The standard errors in parentheses are robust corrected for serial correlation across clusters. Rho is the correlation between the α_i and the idiosyncratic error term ε_{it}. The table shows the coefficients of Phase I, II, III the 2 periods panel probit estimations (Rows 1 -3) separately and the estimations for all phases (Rows 4 -6). Dependent variable: Columns 1 to 4: Trade (0 = No, 1 = Yes), Column 5: Purchase (0 = No, 1 = Yes). Column: Sale (0 = No, 1 = Yes). The binary predictor subsidiary means that the installation is part of a firm with two or more installations. The Mundlak term is the coefficient of the average logarithm of the banking with lag 1. Baseline size category 1 is "Mini (0 < emissions < 25 kt CO2-eq)". Baseline sector 1 is "Combustion > 20 MW". The year and period dummies are the coefficients against the baseline (BL) year/period. Data Source: European Union Transaction Log.

Propensity to Trade: Results and Discussion II: Summery of the most important Regression Results

Allocation Position

- Larger allocation positions, reduce the propensity to engage in trading ☺.
- Larger allocation positions reduce the propensity to buy allowances and increase the propensity to sell allowances ☺.

Banking

- Larger banking positions, reduce the propensity to engage in trading ☺.
- Larger banking allocation positions reduce the propensity to buy allowances and increase the propensity to sell allowances ☺.

Subsidiary firms

- Firms belonging to a parent company tend to engage more in trading than standalone firms ☺.

Propensity to Trade: Results and Discussion III: Summery of the most important Regression Results

Size: measured as average annual emissions of a firm

- Compared to the baseline size category (Mini: 0 < emissions < 25 kt CO2-eq) the propensity to engage in trading increases with the size of the emitter ☺.

Sectors

- Analyzing the differences between sectors opens the door for new research. The sector affiliation changed between phase I and phases II and III. The sectors had to be translated into a unique category system leading to a loss of some information. Additional firms-specific data should be linked to analyze sectors 😐.

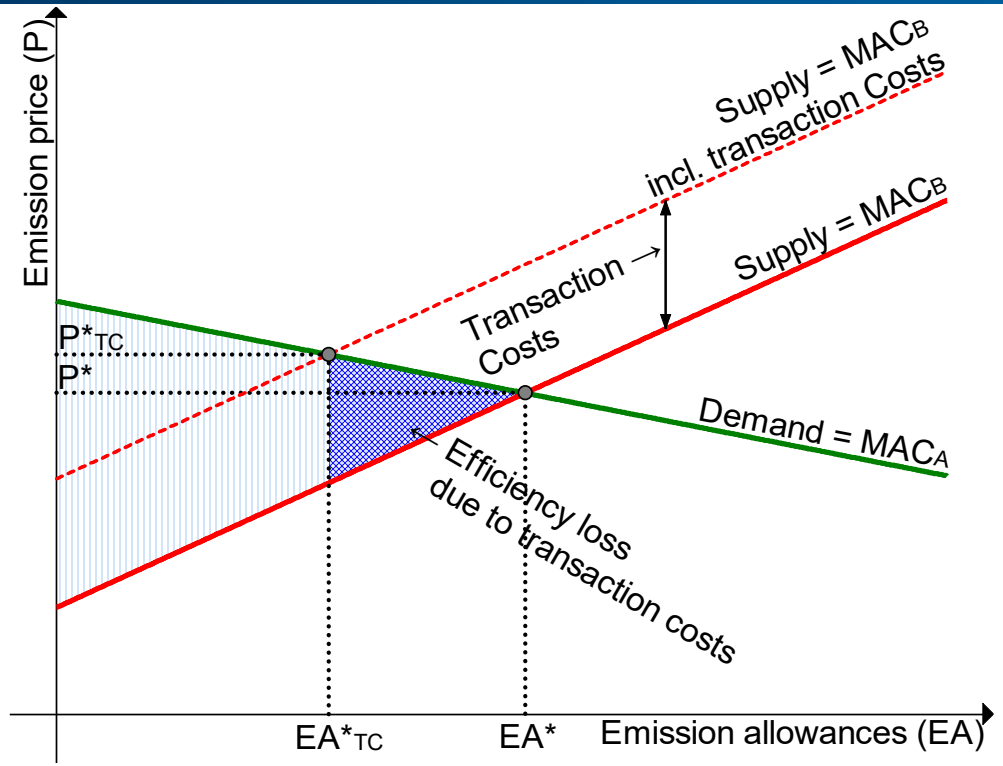
Compliance Years

- Compared to the first year of a phase as baseline year, every year that followed shows an increase in the propensity to trade ☺.

EU ETS phases

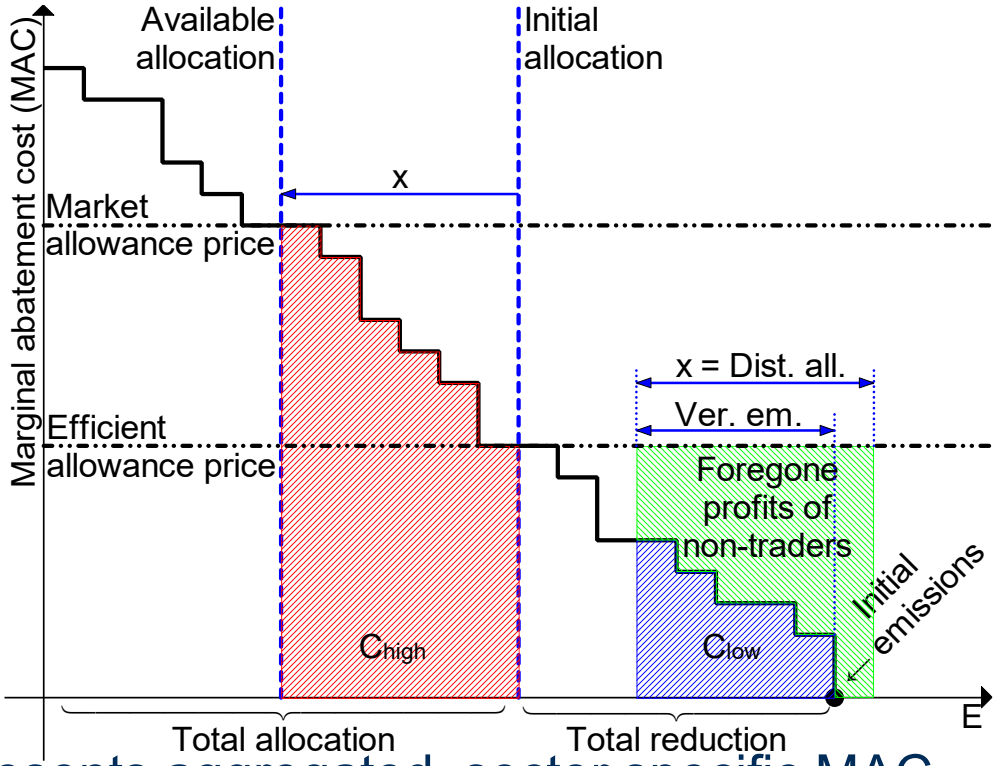
- Compared to phase I as baseline, phase II and especially phase III the propensity to trade is higher than in the baseline phase ☺.

Emissions Trading in a World with Trading Costs: The Welfare Loss due to the Existence of Trading Costs



- EA* is the efficient outcome of allowance trading between firm B and firm A.
- Firm B faces increasing marginal abatement costs (MAC) and constant trading costs.
- As a result, the price received by the seller (firm B) is lower and the price paid by the buyer (firm A) is higher than the price without transaction costs P*.
- The traded volume is lower than the efficient trading level leading to an efficiency loss (Stains, 1995).

Emissions Trading in a World with Trading Costs: Foregone Earnings of non-selling Allowance Surpluses



- The stair curve represents aggregated, sector specific MAC.
- Firms with low MACs are allocated more allowances than verified emissions (Stains>0).
- The efficient allowance price would equalize MACs. Firms with low marginal abatement costs would sell their surplus to firms with high MACs.
- If over allocated firms do not sell their allocation surplus, they face foregone earnings. Foregone earnings of the non-trading decision can be seen as a proxy for trading costs.

An alternative Approach to estimate Foregone Earnings of non-trading Entities as a Proxy for Trading Costs I

Steps to estimate the causal effect of the non-trading decision of firms with long positions by matching treatment and control group by PSM:

- Step 1: Extract firms with positive net allocation through the whole phase I / phase II & III
- Step 2: Treatment group: Non-traders with positive net allocation
  Control group: Traders with at least one allowance sale and no purchase
- Step 3: Define outcome variable per firm i for phase I and phase II &III:

$$\%\ of\ unsold\ allowances\ of\ firm\ i\ summed\ over\ t = \sum \frac{annual\ balance\ of\ firm\ i}{allocated\ allowances\ to\ firm\ i}$$

- Step 4: By propensity score matching, every treatment unit is matched to its counterfactual control unit, using baseline control variables such as log(size), log(allocation-emissions), sector, country
  $P(y_i = 1 \mid \mathbf{x}_i) = \Phi(\mathbf{x'}_i\boldsymbol{\beta} + \varepsilon_i)$; $y_i = 1$ for treatment group, $y_i = 0$ for control group
- Step 5: Calculate the causal effect of the non-trading decision:

$$\Delta\ Percentage\ of\ unsold\ allocation\ of\ firm\ i = pua_{itreated} - pua_{icontrol}$$

- Step 6: $Hypothetical\ foregone\ earnings\ of\ firm\ i = \Delta pua_i \cdot \sum Allocation_{it} \cdot price_t$
- Step 7: Calculate the total opportunity costs (o.c.), the o.c. per year grouped by size, the o.c. per allowance and the o.c. as a percentage of all allocated allowances.

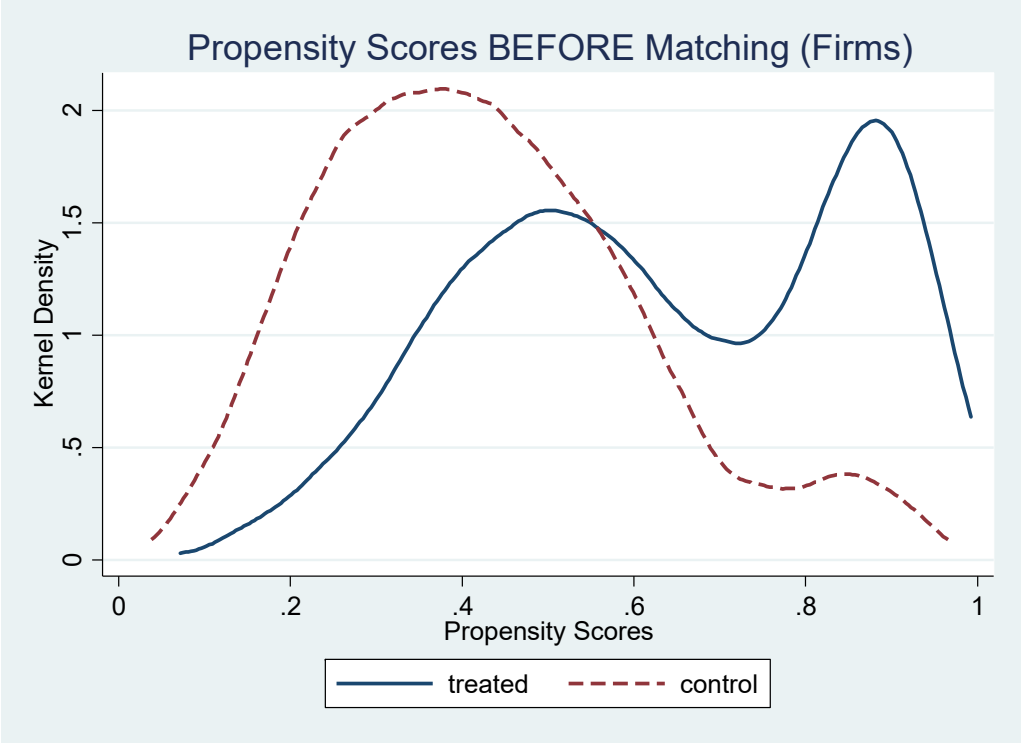
An alternative Approach to estimate Foregone Earnings of non-trading Entities as a Proxy for Trading Costs II

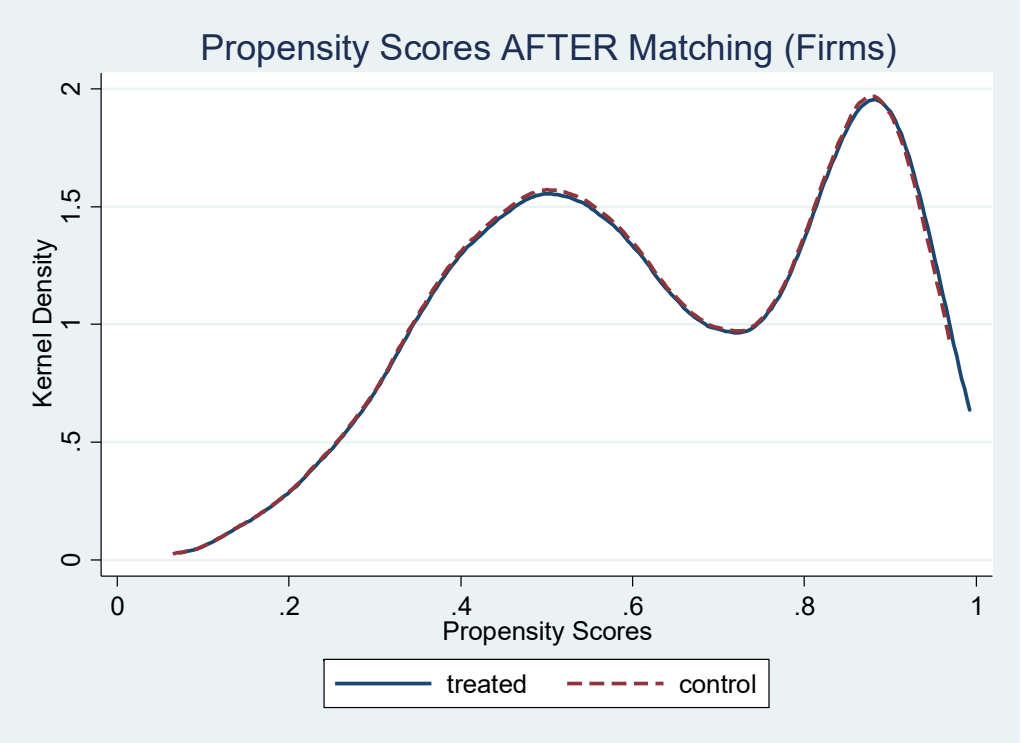
Propensity Score Matching by nearest neighbor: Phase I

Dep. Variable: Treatment (yes/no) VARIABLES	Logit Phase I
Log(1 + Emissions)	0.206**
	(0.0359)
Log(1 + Total Position)	-0.516**
	(0.0418)
Constant	2.541**
	(0.366)
Observations	2,875
Sector Controls	YES
Country Controls	YES
Pseudo R-squared	0.171

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

Treatment assignment	Off support	On support	Total
Untreated	0	1,327	1,327
Treated	16	1,532	1,548
Total	16	2,859	2,875





An alternative Approach to estimate Foregone Earnings of non-trading Entities as a Proxy for Trading Costs III

Results Phase I

- About one third of the participating firms in phase I never engaged in trading, although facing permanent allocation surplus.
- Counterfactual-analysis reveals foregone earnings of 168 million € per trading year (= 4.08 €/Unit)
- As expected, smaller entities face higher opportunity costs of trading.
- Since banking allowances to phase II was not possible, not selling allowances was not the best strategy. This indicates that in phase I, all that these firms wanted was to be compliant and not to engage in trading activities. These firms precepted the opportunity costs of trading to be prohibitively high.

Size Category	Opportunity Cost (Euros)	Opportunity Cost/Year (Euros)	Banked allowances (Units)	Opportunity Cost/Allowance (Euros)
Mini (0 < emissions < 25kt CO_2-eq)	87,340,891	29,113,630	12,182,759	7.17
Small (25 < emissions < 50kt CO_2-eq)	40,041,815	13,347,272	6,947,915	5.76
Medium (50 < emissions < 500kt CO_2-eq)	183,355,395	61,118,465	39,021,349	4.70
Large (emissions > 500kt CO_2-eq)	194,521,307	64,840,436	65,658,542	2.96
Total	505,259,408	168,419,803	123,810,565	4.08
Opportunity Costs as a Percentage of the market value of the total allocated allowances	0.3437%			

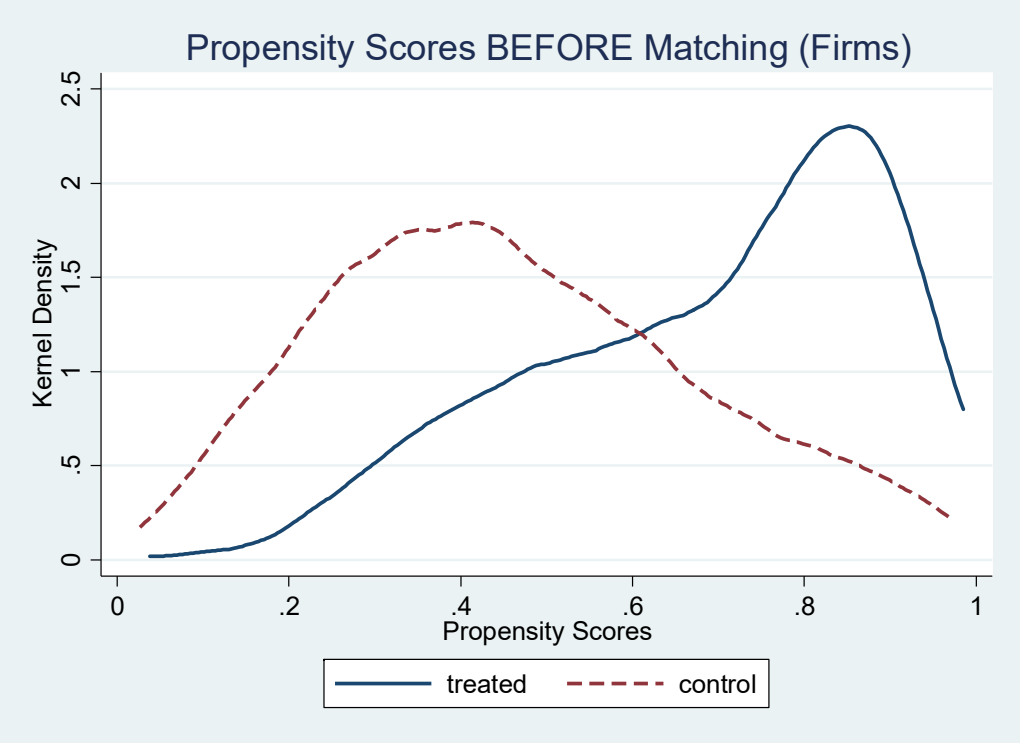
An alternative Approach to estimate Foregone Earnings of non-trading Entities as a Proxy for Trading Costs IV

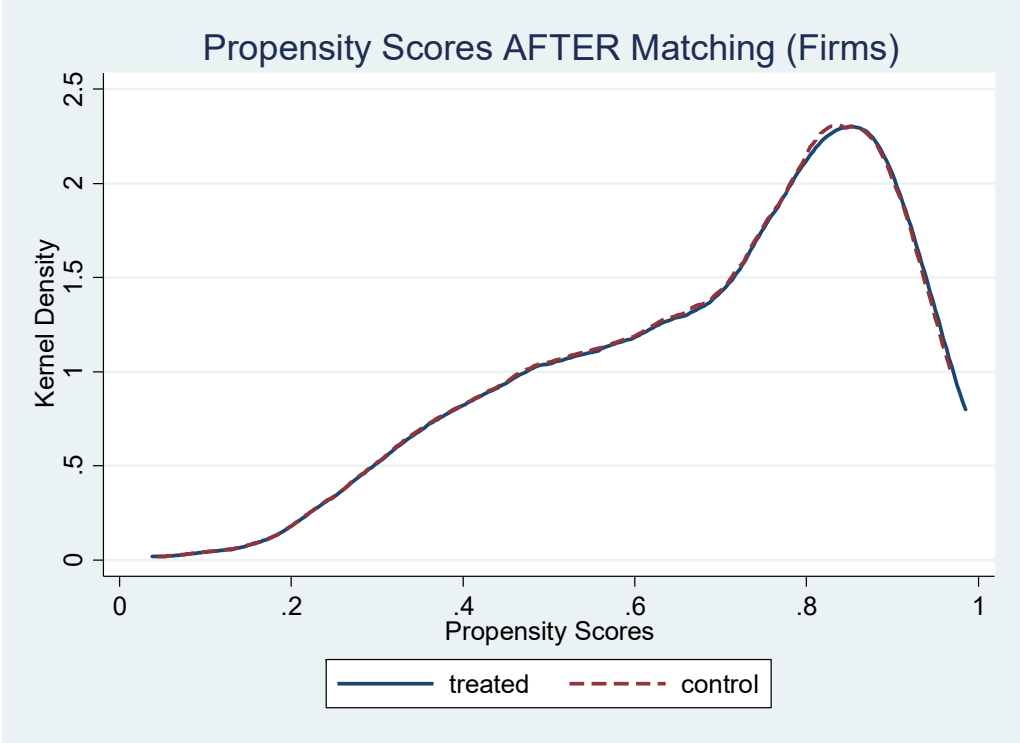
Propensity Score Matching by nearest neighbor: Phases II & III

Dep. Variable: Treatment (yes/no) VARIABLES	Logit Phase II / III
Log(1 + Emissions)	0.190**
	(0.0611)
Log(1 + Total Position)	-0.505**
	(0.0662)
Constant	4.182**
	(1.018)
Observations	607
Sector Controls	YES
Country Controls	YES
Pseudo R-squared	0.185

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

Treatment assignment	Off support	On support	Total
Untreated	0	245	245
Treated	3	359	362
Total	3	604	607





An alternative Approach to estimate Foregone Earnings of non-trading Entities as a Proxy for Trading Costs V

Results Phase II & III

- Non-participating firms with permanent allocation surplus in phase II & III are a minority of about 5%.
- Counterfactual-analysis reveals foregone earnings of 6.4 million € per trading year (= 4.95 €/Unit)
- The average opportunity costs of smaller entities are lower in phase II and III.
- However, the dataset ends in 2014. Allowances do not expire. They can be banked.
- Since the sample is very small (359 entities), it is not representative for the average participant in phase II und III
- Trading allowances is now widely accepted, especially since auctioning was introduced.

Size Category	Opportunity Cost (Euros)	Opportunity Cost/Year (Euros)	Banked allowances (Units)	Opportunity Cost/Allowance (Euros)
Mini (0 < emissions < 25kt CO_2-eq)	21,925,902	3,132,272	5,425,068	4.04 (7.17)
Small (25 < emissions < 50kt CO_2-eq)	6,850,302	978,615	1,554,867	4.41 (5.76)
Medium (50 < emissions < 500kt CO_2-eq)	15,727,748	2,246,821	2,017,132	7.80 (4.70)
Large (emissions > 500kt CO_2-eq)	-		-	- (2.96)
Total	44,503,951	6,357,707	8,997,067	4.95 (4.08)
Opportunity Costs as a Percentage of the market value of the total allocated allowances	0.0076%			

Synopsis of the Opportunity Costs of trading Allowances

Phase I

- The opportunity costs of non-trading are as expected. Small emitters face higher costs/allowance than larger firms (size measured by the emissions volume).
- The opportunity costs are relatively high compared to other studies, since they cover only firms which explicitly forgo selling their allowances.

Phase II & III

- The remaining non-traders face, on average, higher opportunity costs/allowance.
- The reason for this might be that these 5% of firms which do not sell their allocation surplus are very risk averse und prefer banking excess allowances.
- Direct comparison between phase I and phases II & III is to be taken with caution. Many institutional changes favor trading.

Conclusion and Outlook

Conclusion

- Trading allowances is going to be normal for most firms.
- The aim of trading allowances of most of the firms is still to be compliant at the end of a compliance cycle in order not to pay the fine.
- The cap which is reduced every trading year, as well as auctioning instead of free allocations increase the allowance prices and therefore the opportunity costs of not the engaging in trading activities. This is positive for the propensity of trading.
- Trading costs, measured as foregone earnings of not selling excess allowances, are decreasing. However, there are still firms that do not sell excess allowances.

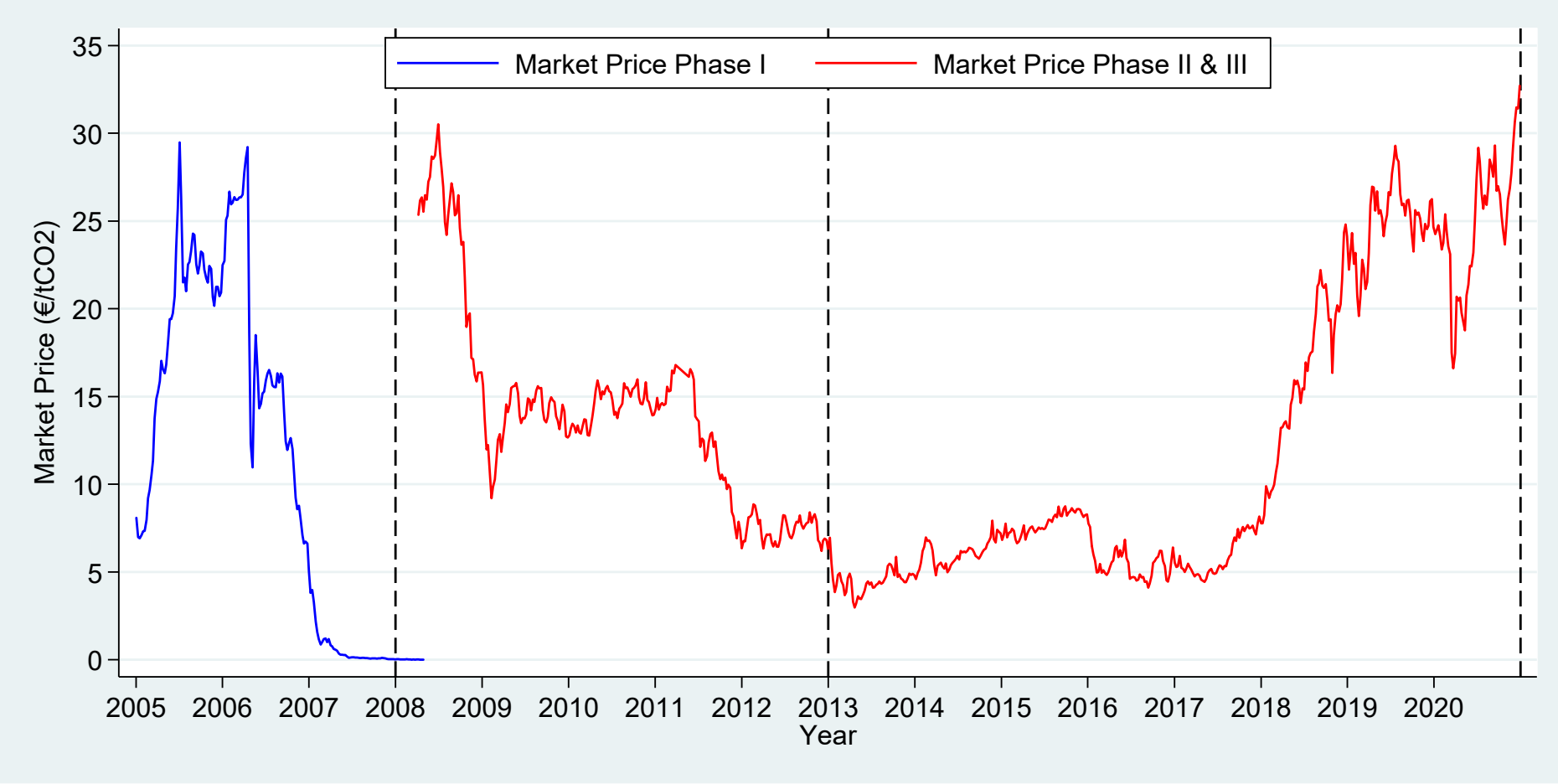
Challenge

- Linking EUTL data on an annual basis is a drawback.
- Data with individual transaction and price data on a daily basis might compensate this drawback (big data) and open a clearer insights into the trading behavior.

Outlook

- Sector analysis over the compete EU ETS could reveal in-depth insights in the behavior of sectors.

Evolution of the EU ETS Allowance Price in phase I, II and III



- Note: The vertical dashed lines indicate the three trading phases of the EU ETS. Data Sources: Ember-Coal to clean energy production (https://ember-climate.org).

End of the Presentation

Thank you very much for your attention.

Thomas Leu