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


• 60% of the participants are mini installations: Emissions < 25,000 CO₂eq / year.
• 75% of the emissions are emitted by large installations: Emissions > 500,000 CO₂eq / year.
• 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.
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.

Total Entities in Dataset: 12,245 Firms

- Phase 1: 8,486 Firms
- Phase 2: 9,245 Firms
- Phase 3: 8,919 Firms

**Venn Diagram:**

- \( P_1 \cap (P_2 \cap P_3) \) \( n = 748 \)
- \( P_1 \cap P_3 \) \( n = 5,837 \)
- \( P_1 \cap P_2 \cap P_3 \) \( n = 5,473 \)
- \( (P_1 \cap P_2) \setminus P_3 \) \( n = 1,901 \)
- \( P_2 \setminus (P_1 \setminus P_3) \) \( n = 677 \)
- \( (P_1 \cap P_3) \setminus P_2 \) \( n = 364 \)
- \( P_3 \setminus (P_1 \cap P_2) \) \( n = 1,888 \)
- \( (P_2 \cap P_3) \setminus P_1 \) \( n = 1,194 \)
- \( P_1 \cap P_2 \) \( n = 1,901 \)
- Total Entities: 12,245 Firms
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.

\( ab_{it} = a_{it} - s_{it} + \text{purch}_{it} - \text{sales}_{it} \):

- Annual Balance = Allocated Allowances – Surrendered Allowances – Sales + Purchases
- In case of no trade, the allocation position is equal to the annual balance.

\( \text{Banking firm}_i = \sum_{t=1}^{n} ab_{it} \):
- Banked allowances at the end of phase I expired.
- Banked allowances at the end of phase II could be carried over to phase III.
• 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.
Binary choice model using panel data:
\( y_{it} = 1 \) if firm \( i \) conducts at least one trade in period \( t \)

- \( \text{Prob}(y_{it} = 1 \mid x_{it}, z_i, \eta_i) = \Phi(x'_{it}\beta + z'_i\gamma + \eta_i + \varepsilon_{it}) \)

  - \( x_{it} \) are the entity-specific time-varying variables such as the logarithm of the yearly allocation position.
  - \( \eta_i \) are entity-specific unobserved time-constant effects such as firm culture, management behavior or firm-specific technology.
  - \( z_i \) are entity specific time-invariant observed characteristics, such as sector affiliation, country and size.
  - Following Mundlak (1978) \( \eta_i = \bar{x}'_i\delta + \alpha_i \) 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

- \( P(\text{yes}_t = 1 \mid x_{it}, \bar{x}_i, z_i, \alpha_i) = \Phi(x'_{it}\beta + \bar{x}'_i\delta + z'_i\gamma + \alpha_i + \varepsilon_{it}) \)
### Propensity to Trade: Results and Discussion I:

Panel Probit Estimation Results for pi, pII & pIII & for all ps’

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(1 + Allocation Position)</td>
<td>-0.0204**</td>
<td>0.00850**</td>
<td>-0.0048**</td>
<td>-0.00468**</td>
<td>-0.0206**</td>
<td>0.0255**</td>
</tr>
<tr>
<td>(0.00237)</td>
<td>(0.00165)</td>
<td>(0.00182)</td>
<td>(0.000887)</td>
<td>(0.000979)</td>
<td>(0.00101)</td>
<td></td>
</tr>
<tr>
<td>Log(1 + Lag Banking)</td>
<td>-0.00578**</td>
<td>0.00802**</td>
<td>-0.0176**</td>
<td>0.00307**</td>
<td>-0.00991**</td>
<td>0.0246**</td>
</tr>
<tr>
<td>(0.00210)</td>
<td>(0.00149)</td>
<td>(0.00223)</td>
<td>(0.000887)</td>
<td>(0.000998)</td>
<td>(0.00109)</td>
<td></td>
</tr>
<tr>
<td>N. of Installations</td>
<td>0.0245**</td>
<td>0.140**</td>
<td>0.121*</td>
<td>0.0246**</td>
<td>0.0356**</td>
<td>0.0444**</td>
</tr>
<tr>
<td>(0.00390)</td>
<td>(0.00289)</td>
<td>(0.00302)</td>
<td>(0.00121)</td>
<td>(0.00129)</td>
<td>(0.00131)</td>
<td></td>
</tr>
<tr>
<td>Is Subsidiary Company = 1</td>
<td>0.0339</td>
<td>0.0406</td>
<td>0.0635</td>
<td>0.1030</td>
<td>0.0465</td>
<td>0.3067</td>
</tr>
<tr>
<td>(0.00682)</td>
<td>(0.00581)</td>
<td>(0.00581)</td>
<td>(0.00253)</td>
<td>(0.00258)</td>
<td>(0.00259)</td>
<td></td>
</tr>
<tr>
<td>Is Subsidiary = 0</td>
<td>0.305*</td>
<td>-0.0364</td>
<td>-0.0258*</td>
<td>0.0265**</td>
<td>0.0261**</td>
<td>0.216**</td>
</tr>
<tr>
<td>(0.0483)</td>
<td>(0.0308)</td>
<td>(0.0322)</td>
<td>(0.0192)</td>
<td>(0.0192)</td>
<td>(0.0203)</td>
<td></td>
</tr>
<tr>
<td>Size Category = 2, Small (25 &lt; emissions &lt; 50 kt CO2-eq)</td>
<td>0.414**</td>
<td>0.186**</td>
<td>0.537**</td>
<td>0.458**</td>
<td>0.396**</td>
<td>0.306**</td>
</tr>
<tr>
<td>(0.0445)</td>
<td>(0.0294)</td>
<td>(0.0329)</td>
<td>(0.0183)</td>
<td>(0.0183)</td>
<td>(0.0194)</td>
<td></td>
</tr>
<tr>
<td>Size Category = 3, Medium (50 &lt; emissions &lt; 500 kt CO2-eq)</td>
<td>0.738**</td>
<td>0.737**</td>
<td>1.128**</td>
<td>0.988**</td>
<td>0.606**</td>
<td>0.619**</td>
</tr>
<tr>
<td>(0.0709)</td>
<td>(0.0463)</td>
<td>(0.0621)</td>
<td>(0.0303)</td>
<td>(0.0303)</td>
<td>(0.0304)</td>
<td></td>
</tr>
<tr>
<td>Size Category = 4, Large (emissions &gt; 500 kt CO2-eq)</td>
<td>0.305**</td>
<td>0.354**</td>
<td>0.258**</td>
<td>0.269**</td>
<td>0.255**</td>
<td>0.216**</td>
</tr>
<tr>
<td>(0.0483)</td>
<td>(0.0308)</td>
<td>(0.0322)</td>
<td>(0.0192)</td>
<td>(0.0192)</td>
<td>(0.0203)</td>
<td></td>
</tr>
</tbody>
</table>

### 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 idiosyncratic error term and the Mundlak term.
- 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."}

### Data Source:
European Union Transaction Log.
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 😊.
• 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).
• 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.
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:
  \[
  \% \text{ of unsold allowances of firm } i \text{ summed over } t = \sum \text{annual balance of firm } i \text{ allocated allowances to firm } i
  \]
- **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
  \[
P(y_i = 1 \mid x_i) = \Phi(x'_i \beta + \epsilon_i); y_i = 1 \text{ for treatment group, } y_i = 0 \text{ for control group}
  \]
- **Step 5:** Calculate the causal effect of the non-trading decision:
  \[
  \Delta \text{Percentage of unsold allocation of firm } i = pu_{a_{\text{treated}}} - pu_{a_{\text{control}}}
  \]
- **Step 6:** Hypothetical foregone earnings of firm $i$ = $\Delta pu_i \cdot \sum \text{Allocation}_{it} \cdot price_t$
- **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

<table>
<thead>
<tr>
<th>Treatment assignment</th>
<th>Off support</th>
<th>On support</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>0</td>
<td>1,327</td>
<td>1,327</td>
</tr>
<tr>
<td>Treated</td>
<td>16</td>
<td>1,532</td>
<td>1,548</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>2,859</td>
<td>2,875</td>
</tr>
</tbody>
</table>

Dep. Variable: Treatment (yes/no)
VARIABLES Logit Phase I

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Log(1 + Emissions)</th>
<th>(0.0359)</th>
<th>Log(1 + Total Position)</th>
<th>(-0.516** (0.0418)</th>
<th>Constant</th>
<th>2.541** (0.366)</th>
</tr>
</thead>
</table>

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

Propensity Scores BEFORE Matching (Firms)

Propensity Scores AFTER Matching (Firms)
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.

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Opportunity Cost (Euros)</th>
<th>Opportunity Cost/Year (Euros)</th>
<th>Banked allowances (Units)</th>
<th>Opportunity Cost/Allowance (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini (0 &lt; emissions &lt; 25kt CO₂-equivalent)</td>
<td>87,340,891</td>
<td>29,113,630</td>
<td>12,182,759</td>
<td>7.17</td>
</tr>
<tr>
<td>Small (25 &lt; emissions &lt; 50kt CO₂-equivalent)</td>
<td>40,041,815</td>
<td>13,347,272</td>
<td>6,947,915</td>
<td>5.76</td>
</tr>
<tr>
<td>Medium (50 &lt; emissions &lt; 500kt CO₂-equivalent)</td>
<td>183,355,395</td>
<td>61,118,465</td>
<td>39,021,349</td>
<td>4.70</td>
</tr>
<tr>
<td>Large (emissions &gt; 500kt CO₂-equivalent)</td>
<td>194,521,307</td>
<td>64,840,436</td>
<td>65,658,542</td>
<td>2.96</td>
</tr>
<tr>
<td>Total</td>
<td>505,259,408</td>
<td>168,419,803</td>
<td>123,810,565</td>
<td>4.08</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Logit Phase II / III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(1 + Emissions)</td>
<td>0.190** (0.0611)</td>
</tr>
<tr>
<td>Log(1 + Total Position)</td>
<td>-0.505** (0.0662)</td>
</tr>
<tr>
<td>Constant</td>
<td>4.182** (1.018)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dep. Variable: Treatment (yes/no)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment assignment</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Untreated</td>
</tr>
<tr>
<td>Treated</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

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

Propensity Scores BEFORE Matching (Firms)
Propensity Scores AFTER Matching (Firms)
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.

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Opportunity Cost (Euros)</th>
<th>Opportunity Cost/Year (Euros)</th>
<th>Banked allowances (Units)</th>
<th>Opportunity Cost/Allowance (Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini (0 &lt; emissions &lt; 25kt CO₂-equivalent)</td>
<td>21,925,902</td>
<td>3,132,272</td>
<td>5,425,068</td>
<td>4.04 (7.17)</td>
</tr>
<tr>
<td>Small (25 &lt; emissions &lt; 50kt CO₂-equivalent)</td>
<td>6,850,302</td>
<td>978,615</td>
<td>1,554,867</td>
<td>4.41 (5.76)</td>
</tr>
<tr>
<td>Medium (50 &lt; emissions &lt; 500kt CO₂-equivalent)</td>
<td>15,727,748</td>
<td>2,246,821</td>
<td>2,017,132</td>
<td>7.80 (4.70)</td>
</tr>
<tr>
<td>Large (emissions &gt; 500kt CO₂-equivalent)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- (2.96)</td>
</tr>
<tr>
<td>Total</td>
<td>44,503,951</td>
<td>6,357,707</td>
<td>8,997,067</td>
<td>4.95 (4.08)</td>
</tr>
<tr>
<td>Opportunity Costs as a Percentage of the market value of the total allocated allowances</td>
<td>0.0076%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 and 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

• 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 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).
Thank you very much for your attention.

Thomas Leu