Imperial College London

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# EU Emission Trading and Aluminium Imports

## Evidence for Carbon Leakage

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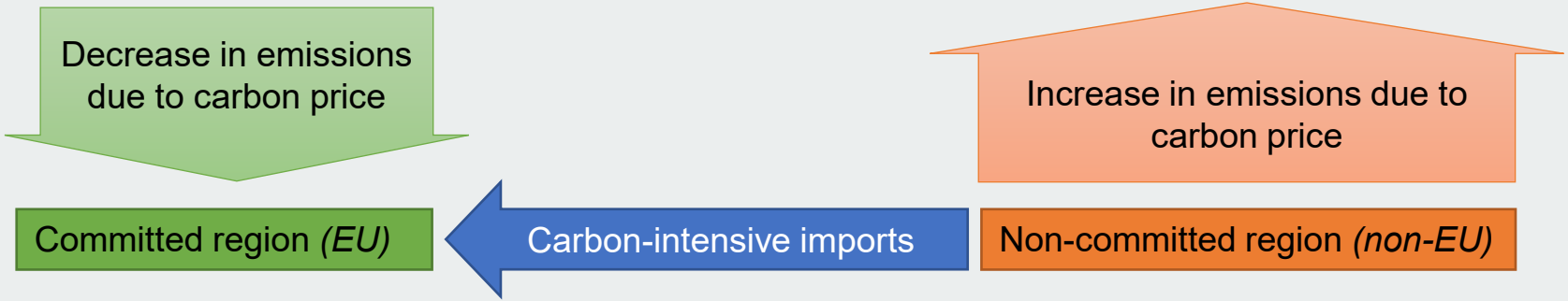
# Introduction: Carbon Leakage

Carbon leakage is the increase in a regions emissions caused by another regions climate policy

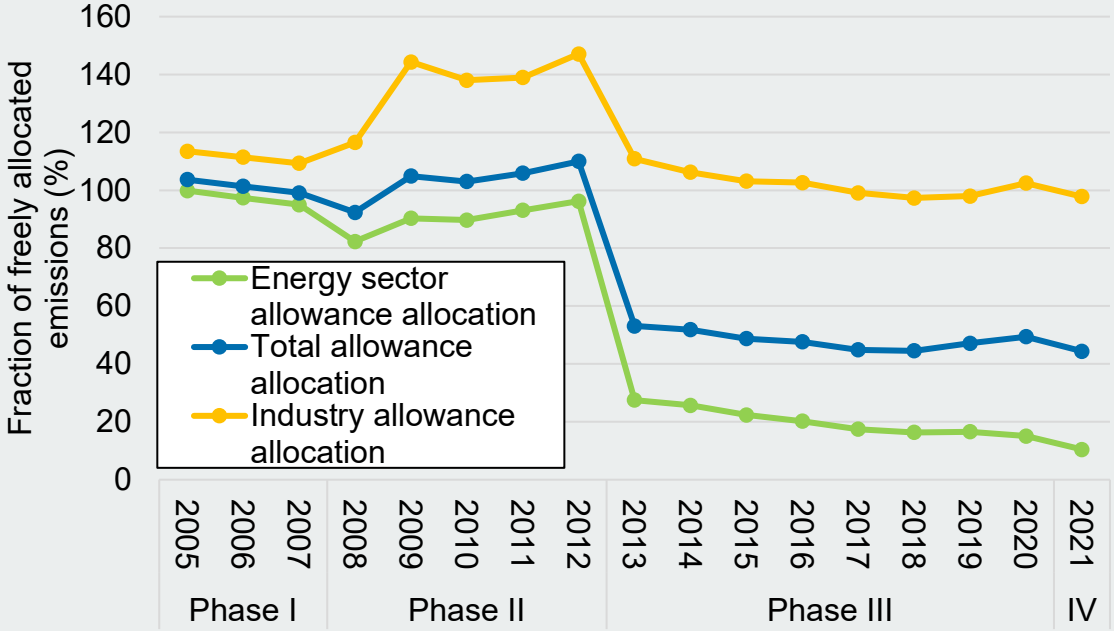
$$\textit{Carbon leakage rate} = \frac{\text{Increase in Emissions in non-committed region}}{\text{Decrease in emissions in committed region}}$$



# Introduction: Literature on EU ETS

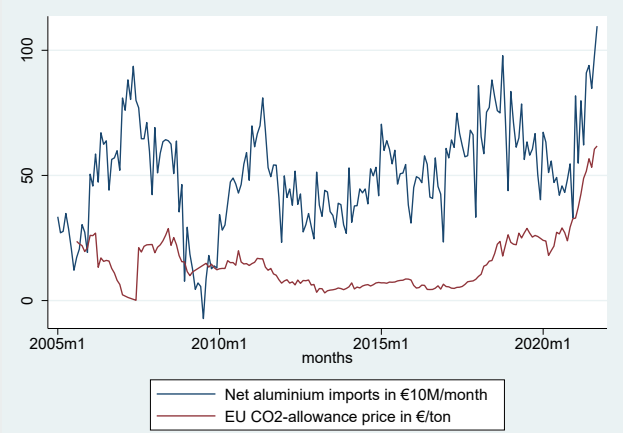
| Study | Industry | Period | Leakage rate | Approach |
|---|---|---|---|---|
| Antimiani et al. (2016) | Multi-sectoral | 2010 – 2050 | 16 – 49% | CGE (GDynE) |
| Böhringer et al. (2017) | Multi-sectoral | 2011 | 17 – 20% | CGE (GTAP) |
| Demailly & Quirion (2006) | Cement | 2005 – 2011 | 50% | Spatial Model |
| Kuik & Hofkes (2010) | Cement & Steel | 2005 – 2008 | 2% – 35% | CGE (GTAP-E) |
| Gerlagh & Kuik (2014) | Multi-sectoral | 2007 – 2020 | -1% – 10% | CGE (GTAP-E) |
| Alexeeva-Talebi et al. (2012) | Metals & Minerals | 2004 – 2020 | 10% – 15% | CGE (PACE) |
| Branger et al (2016) | Cement & Steel | 2005 – 2012 | No short run evidence | ARIMA + Prais-Winsten |
| Reinaud (2008) | Aluminium | 2005 – 2006 | Not significant | Prais-Winsten |
| Sartor (2012) | Aluminium | 2005 – 2011 | No evidence | Johansen cointegr. |
| Naegele & Zaklan (2019) | Multi-sectoral | 2004 – 2011 | No evidence | Panel Data |
| Healy et al. (2018) | Cement & Aluminium | 2000 – 2016 | No evidence | Panel Data |
| Boutabba & Lardic (2017) | Cement & Steel | 2005 – 2015 | Negligible | Rolling cointegr. |

# Introduction: Allowance Allocation & Aluminium Sector




- Since phase III, power stations buy most their allowances in auctions
- Industry continues to receive them for free
- Aluminium mostly emits indirectly, thereby being at risk of carbon leakage while paying indirectly for allowances

# Hypothesis and Empirical Model




Hypothesis: Aluminium Imports ~ Allowance price

$$N_t = \beta_0 + \beta_{1,i}\, log(E_t) \times P_i + \beta_2 log(I_t) + \beta_{3,j} M_j + \varepsilon_t$$

$N_t$ : Monthly Net Aluminium Imports (€)

$E_t$ : Avg. Monthly EU ETS Allowance Price (€)

$I_t$ : Monthly EU Industrial Output Index (based on 2010: 100)

$P_i$ : Dummy for each phase of the EU ETS (I – IV)

$M_j$ : Dummy for months of the year (1 – 12)

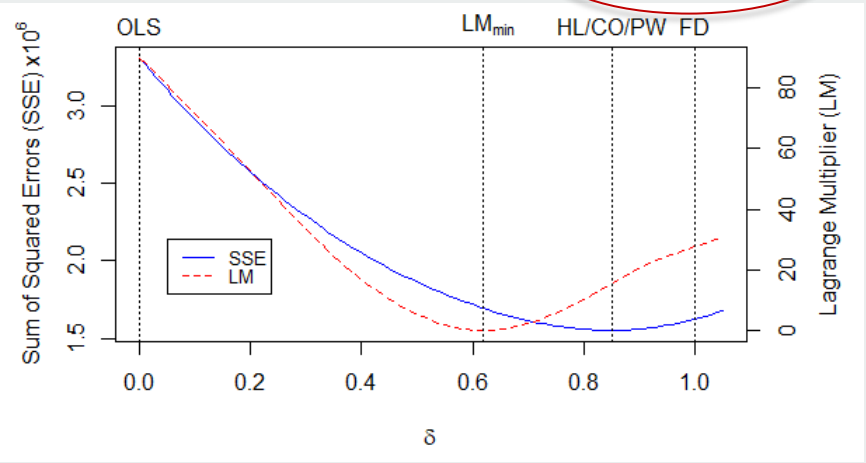
→ Breusch-Godfrey test indicates autocorrelated residuals

# Serial Correlation Remedy Procedures

Assume: $\varepsilon_t = \delta\varepsilon_{t-1} + u_t \quad \rightarrow \quad u_t = \varepsilon_t - \delta\varepsilon_{t-1}$

$Y_t = \beta_0 + \beta X_t + \varepsilon_t \quad \rightarrow \quad Y_t - \delta Y_{t-1} = (1-\delta)\beta_0 + \beta_1(X_t - \delta X_{t-1}) + \varepsilon_t - \delta\varepsilon_{t-1}$

- Cochrane-Orcutt (CO): $\varepsilon_t \sim \delta\varepsilon_{t-1}$
- Prais-Winsten (PW): $\varepsilon_t \sim \delta\varepsilon_{t-1}$
- First Differences (FD): $\delta = 1$
- Hildreth-Lu (HL): minimise SSE
- Lagrange-Multiplier Minimisation ($LM_{min}$): optimise Breusch-Godfrey



# Regression results

- Phase IV shows a significant correlation between allowance price and net aluminium imports in 3 regressions
- The First-Differences regression shows no impact of the EU industrial output on imports → this indicates that it "overcorrected"

Net Aluminium Imports (€MM)

| | OLS ($\delta = 0$) | $LM_{min}$ ($\delta = 0.63$) | CO/PW/HL ($\delta \approx 0.85$) | First Diff. ($\delta = 1$) |
|---|---|---|---|---|
| $log(I_t)$ | 24.388*** | 14.523*** | 6.072* | 3.214 |
| | (2.012) | (2.842) | (3.306) | (3.376) |
| $log(E_t)$ × Phase I | −40.323*** | −2.034 | 9.010 | 9.613 |
| | (14.499) | (16.829) | (16.879) | (16.468) |
| $log(E_t)$ × Phase II | −23.874* | −12.968 | −5.365 | −4.191 |
| | (14.119) | (20.827) | (27.753) | (30.477) |
| $log(E_t)$ × Phase III | −0.941 | 22.293 | 27.468 | −52.969 |
| | (14.625) | (21.402) | (33.209) | (55.236) |
| $log(E_t)$ × Phase IV | 72.836*** | 112.159*** | 120.431*** | 12.523 |
| | (13.287) | (20.833) | (34.559) | (62.071) |
| Constant | −1,963.425*** | −441.270*** | −116.304** | −104.645*** |
| | (205.980) | (109.455) | (55.123) | (23.686) |
| Observations | 200 | 199 | 199 | 199 |
| $R^2$ | 0.663 | 0.577 | 0.573 | 0.585 |
| Adjusted $R^2$ | 0.633 | 0.540 | 0.535 | 0.548 |
| Resid. Std. Error (df = 182) | 134.759 | 96.220 | 92.372 | 94.381 |
| F Statistic (df = 16; 182) | 22.384*** | 15.505*** | 15.261*** | 16.006*** |
| *Note:* | | | | *p<0.1; **p<0.05; ***p<0.01 |

# Results

Cap reduction that leads to a price increase of 1%

$$\frac{\Delta N_t}{Cost_{Alu}} \times CI_{Alu}$$

Committed region *(EU)* ← Carbon-intensive imports ← Non-committed region (Non-EU)

$\Delta E_t = +1\%$

$\Delta N_t = +€1.12MM$

$$\textit{Carbon leakage rate} = \frac{\frac{\Delta N_t}{Cost_{Alu}} \times CI_{Alu}}{\text{Cap reduction that leads to a price increase of 1\%}}$$

## Conclusion

- Empirical literature is unable to back-up model-based predictions of carbon leakage from the EU ETS
- The Aluminium sector is unique because it emits mostly indirectly
- A novel autocorrelation procedure is deployed on the monthly data
- In phase IV, a 1%-increase in price caused a €1.12MM rise in imports

## Next Steps

- Relate allowance price increases to cap reduction to estimate CLR
- Proper statistical scrutiny for the newly deployed method ($LM_{min}$)
- Deal with inaccuracies: EU ≠ EEA
- More research in the EU Aluminium sector is needed to empirically quantify carbon leakage in EUETS:

  →ARIMA, Cointegration, Diff-in-diff

# Thanks for listening!

Questions?

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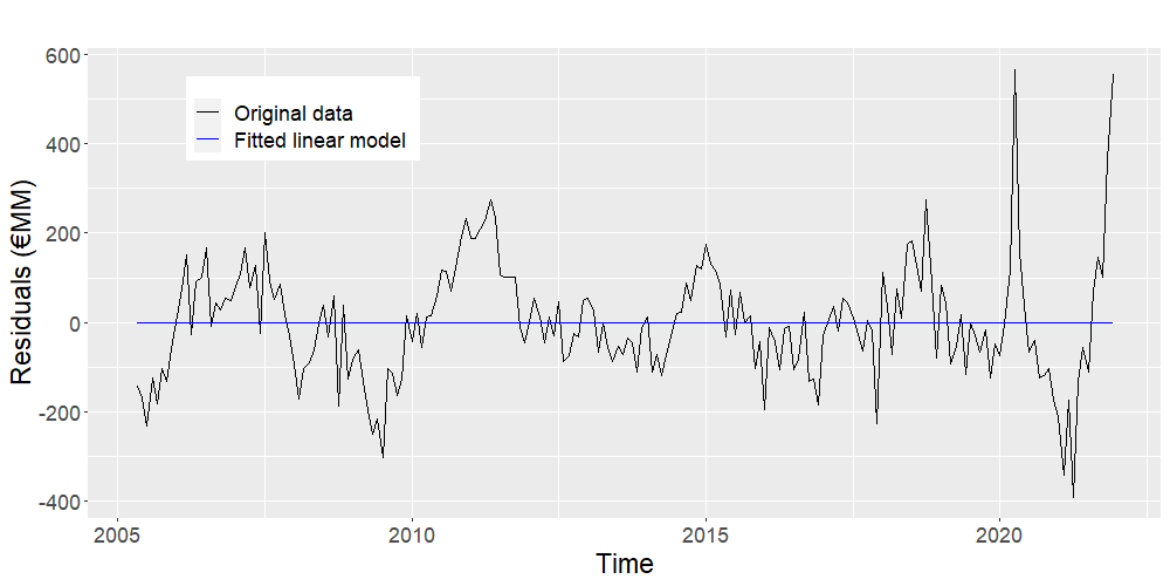
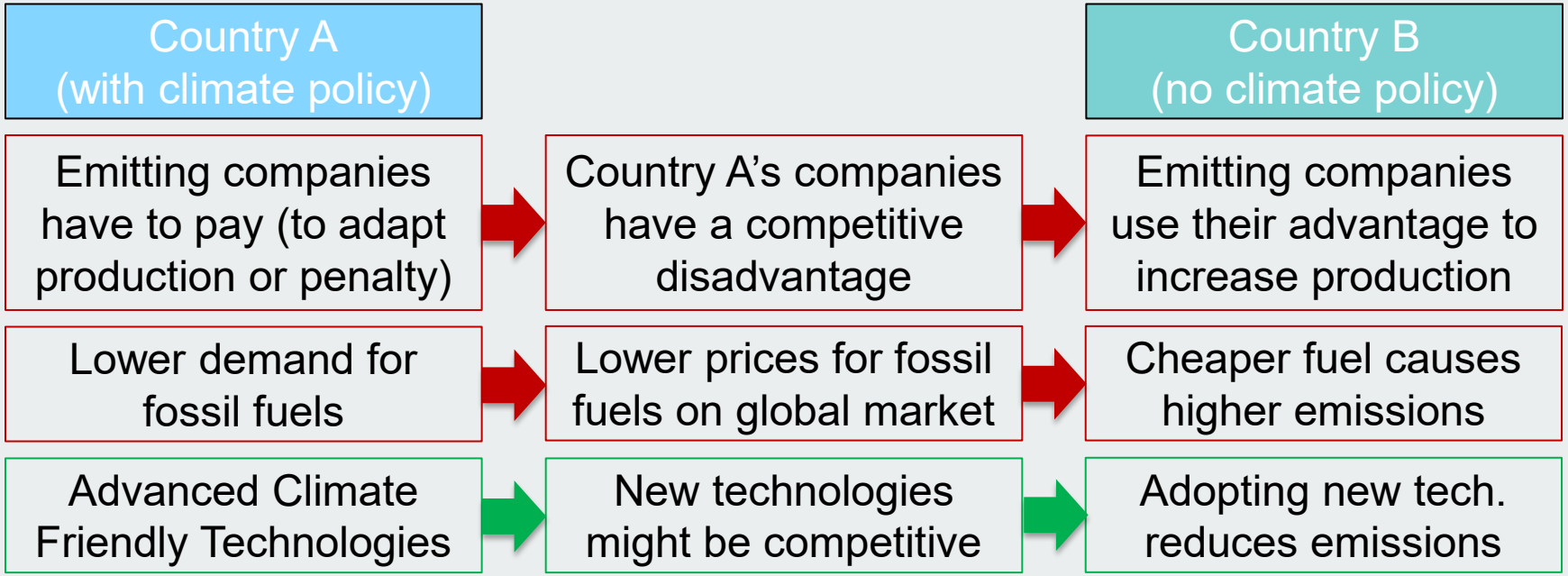
# Autocorrelated Residuals




- Autocorrelated errors violate the Gauss-Markov assumptions
- Breusch-Godfrey test confirms autocorrelation

# Graphic


Country A (with climate policy)
Country B (no climate policy)
Emitting companies have to pay (to adapt production or penalty)
Country A's companies have a competitive disadvantage
Emitting companies use their advantage to increase production
Lower demand for fossil fuels
Lower prices for fossil fuels on global market
Cheaper fuel causes higher emissions
Advanced Climate Friendly Technologies
New technologies might be competitive
Adopting new tech. reduces emissions

# Serial Correlation Remedy Procedures

$$Y_t = \beta_0 + \beta X_t + \varepsilon_t$$

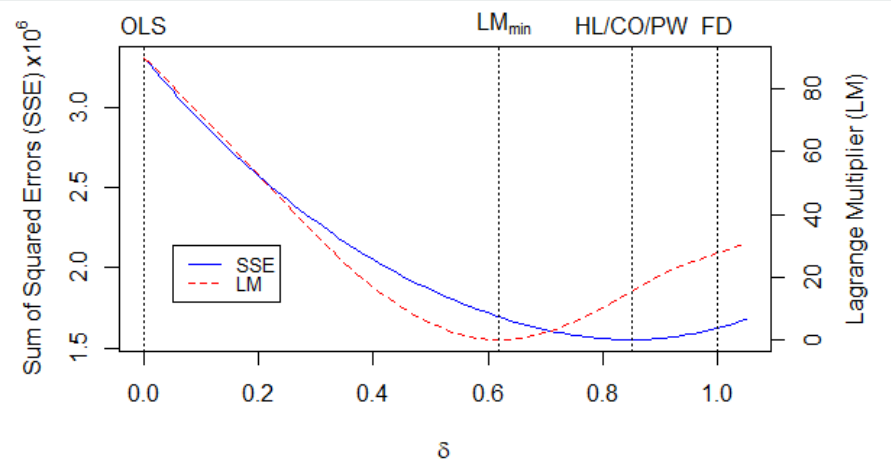
- Assume: $\varepsilon_t = \delta \varepsilon_{t-1} + u_t$

  → $u_t = \varepsilon_t - \delta \varepsilon_{t-1}$

$$Y_t - \delta Y_{t-1} = (1-\delta)\beta_0 + \beta(X_t - \delta X_{t-1}) + u_t$$

- $\delta$ can be estimated by regressing $\varepsilon_t$ & $\varepsilon_{t-1}$ (Cochrane-Orcutt/Prais-Winsten)
- $\delta$ can also be chosen to minimise Sum of Squared Errors (Hildreth-Lu)
- We propose minimising the Lagrange Multiplier of Breusch-Godfrey ($LM_{min}$)

# Serial correlation results




- Minimising the sum of squared errors (HL) leads to a similar result as the error regression estimation (CO/PW) → $\delta \approx 0.85$
- The newly proposed $LM_{min}$ procedure yields a significantly different result that with better LM → $\delta = 0.63$
- New procedure should be interpreted with care

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# Carbon border adjustment mechanism (CBAM)

- Passed by EU parliament in May 23
- Aims to reduce carbon leakage


FINANCIAL TIMES

EU's trading partners accuse bloc of protectionism over carbon tax plan


EURACTIV The Capitals The Brief Ukraine Intelligence

Agrifood Economy Energy & Environment Global Europe Health Politics Technology Transport

World's poorest should not pay for climate action while EU industry pollutes for free

- What is carbon leakage?
- What estimates of carbon leakage are there for the EU ETS?
- Why is the Aluminium sector especially suited for improving those estimates?

# Research Aim

Hypothesis: The ETS allowance price positively impacts net aluminium imports

- The impact is expected to occur indirectly via the electricity price
- Is there a significant correlation and what is the magnitude of the effect?

# Carbon border adjustment mechanism (CBAM)

- Passed by EU parliament in May 23
- Will gradually enter enforcement between October 23 and January 25
- Extension to the EU Emission Trading System (EU ETS) to cover emissions embodied in imports

  → prevent carbon leakage


**Africa sees new wall in EU's carbon border scheme [Business Africa]**

# Outline

1. Carbon leakage
2. Existing Literature for the EU ETS
3. Empirical Model
4. Autocorrelation
5. Results
6. Conclusion and Next Steps

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# Carbon border adjustment mechanism (CBAM)




# Outline

1. Introduction
   I. What is carbon leakage?
   II. Existing Literature on EU ETS
   III. The Aluminium Sector
2. Methodology
   I. Empirical Model
   II. Autocorrelation
3. Results
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[BUCH] Going beyond default intensities in an EU carbon border adjustment mechanism

M Mehling, RA Ritz - 2020 - JSTOR


**Africa sees new wall in EU's carbon border scheme [Business Africa]**

FINANCIAL TIMES

EU's trading partners accuse bloc of protectionism over carbon tax plan

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Agrifood | Economy | Energy & Environment | Global Europe | Health | Politics | Technology | Transport

**World's poorest should not pay for climate action while EU industry pollutes for free**

# Serial Correlation Test and Remedy Procedures

Breusch-Godfrey Test

- The lagged error terms are added to the regression
- The Lagrange Multiplier (LM) is computed to assess whether any of the added terms is significant

Remedy Procedures:

- First-order autocorrelated errors: $\varepsilon_t = \delta\varepsilon_{t-1} + u_t$
- Change regression from $Y_t = \beta_0 + \beta X_t + \varepsilon_t$ to:

$$Y_t - \delta Y_{t-1} = (1-\delta)\beta_0 + \beta(X_t - \delta X_{t-1}) + \varepsilon_t - \delta\varepsilon_{t-1}$$

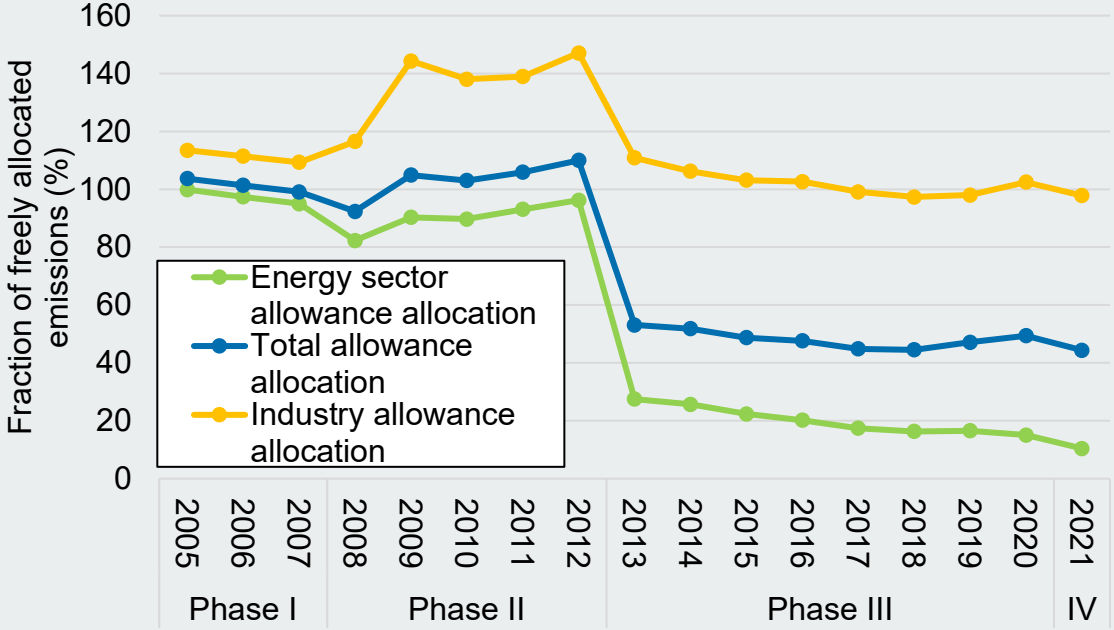
$$\rightarrow \varepsilon_t - \delta\varepsilon_{t-1} = u_t$$

- $\delta$ can be estimated by regressing $\varepsilon_t$ against $\varepsilon_{t-1}$ (Cochrane-Orcutt & Prais-Winsten)
- $\delta$ can also be chosen to minimise SSE (Hildreth-Lu)
- This work proposes choosing $\delta$ to minimise the LM

# Carbon border adjustment mechanism (CBAM)

- Extension to the EU Emission Trading System (EU ETS) to cover emissions embodied in imports
- It was officially passed as a law by the EU parliament in May 2023
- The CBAM will gradually enter enforcement between October 2023 and January 2025

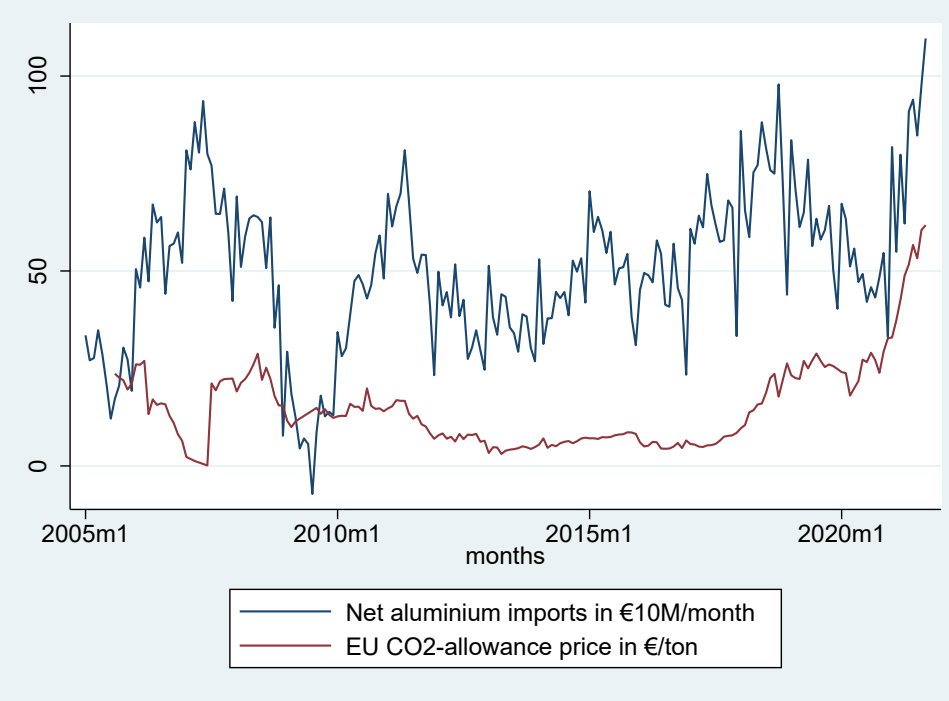
# Allowance allocation in the EU ETS




- Since phase III, the power sector acquires most allowances in auctions while industry receives them for free
- Aluminium mostly emits indirectly, thereby being at risk of carbon leakage while paying indirectly for allowances

# Research Aim

- The hypothesis is that an increased EU allowance price will increase costs of domestically producing aluminium
- This will in turn increase Aluminium imports
- We should be able to observe a correlation between allowance price and imports



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