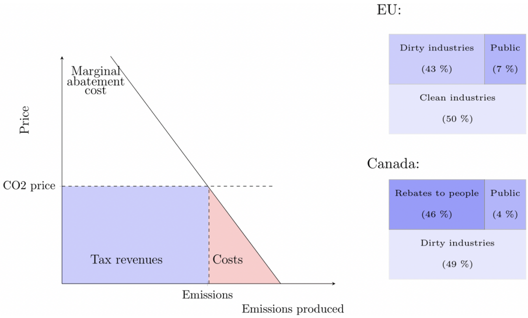
# Global Externalities, Local Policies, and Firm Selection

# Introduction

# Distribution and carbon pricing

It routinely goes unnoticed that a realistic price on carbon typically reallocates wealth by multiple factors more than what abatement costs: If carbon price sets the total harm from unabated pollution at 100, and 20 of this is abated, then carbon price leads to transfers that are 8/10 of the total harm. This redistribution comes in many forms: between governments and individuals, governments and firms, firms and individuals, and special interests and governments[1]




[1]Link to sources *(here)* and *(and here)*

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> *"In theory [EU ETS] provides a cheap and efficient means to limit greenhouse gas reductions within an ever-tightening cap, but in practice it has rewarded major polluters with windfall profits"*
>
> –Carbon Market Watch (2013)

# The concern in the news

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## '£1bn windfall' from carbon trade

By Roger Harrabin
BBC News environment correspondent

**Power firms could make a £1bn windfall profit from the EU Carbon Emissions Trading Scheme, it is claimed.**

Under Labour emissions have gone up by more than 2%

The windfall is likely because many firms have benefited from increases in electricity prices brought about by the scheme without needing to make any extra investment in return.

Peter Bedson, from IPA Consulting, confirmed to BBC News that the profit could reach £1bn.

Environmental pressure groups have called the news a scandal.

Part of the problem, Mr Bedson said, was that firms had been given, free-of-charge, the carbon emissions permits on which the scheme is based. This, he explained, was like the government giving energy firms free money.

The WWF pressure group has demanded a windfall tax to re-direct the profits into energy conservation.

The Conservatives said it was an example of government incompetence.

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**Travel and transport**
Guardian Environment Network

# Airlines could net £1.6bn windfall from EU carbon trading scheme, report says

US analysis suggests inclusion of aviation in European emissions trading scheme could financially benefit airlines, rather than harm them

Arthur Neslen for EurActiv, part of the Guardian Environment Network

Wednesday 11 January 2012 10.28 GMT

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US airlines have opposed the EU's move to charge carriers for carbon emissions, but a new report suggest the scheme could actually benefit the airlines. Photograph: DE MALGLAIVE E./GAMMA/Gamma-Rapho via Getty Images

Far from damaging US airlines, the EU's Emissions Trading System (ETS) could deliver it a €2 billion windfall profit, according to a new report by a US Federal Aviation Administration-funded group of academics.

Bill Hemmings, the aviation spokesman for the European environmental pressure group Transport and Environment, said that it "called seriously into question" air industry claims that the ETS would leave them out of pocket.

"On the contrary, their real costs will probably be covered by being able to pass them on to passengers with minimal impact on their businesses," Hemmings told EurActiv.

"The fact that this US government-funded report says they could make windfall profits leaves us unsympathetic to their cries that the ETS will cost them billions."

The Guardian, 2012

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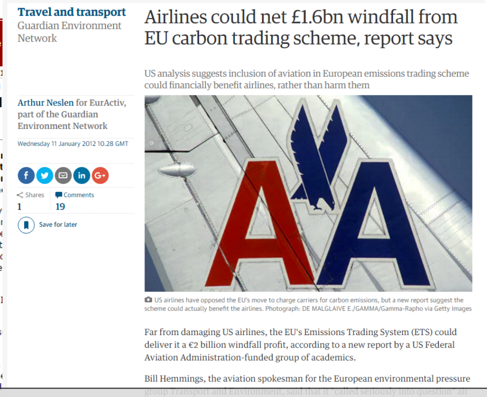

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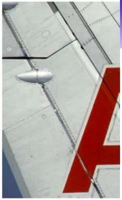

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## EU Industry Got $27 Billion Carbon Plan Windfall, Study Says

by Ewa Krukowska
March 15, 2016, 12:01 AM GMT+1 *Updated on* March 15, 2016, 5:59 PM GMT+1

- Companies profited from free permits, CE Delft reports
- Iron and steel producers benefitted the most from ETS program

European Union industry landed a 24-billion-euro ($26.7 billion) windfall from an emissions cap-and-trade program that was intended to moderate emissions by putting a price on pollution, according to an environmental consultancy.

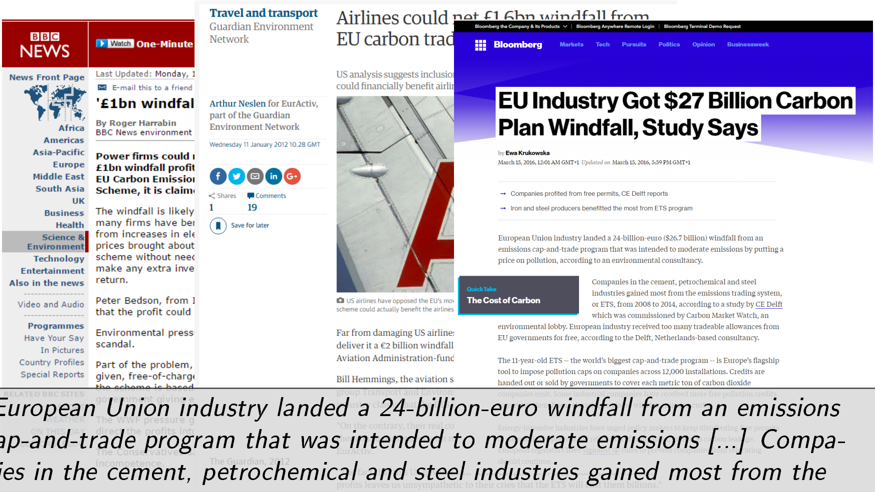
QuickTake
**The Cost of Carbon**

Companies in the cement, petrochemical and steel industries gained most from the emissions trading system, or ETS, from 2008 to 2014, according to a study by CE Delft which was commissioned by Carbon Market Watch, an environmental lobby. European industry received too many tradeable allowances from EU governments for free, according to the Delft, Netherlands-based consultancy.

The 11-year-old ETS -- the world's biggest cap-and-trade program -- is Europe's flagship tool to impose pollution caps on companies across 12,000 installations. Credits are handed out or sold by governments to cover each metric ton of carbon dioxide companies emit. Some industrial companies have received more free pollution credits to prevent them from relocating to places with lax emission curbs.

Energy-intensive industries have urged policy makers to keep distributing free permits to companies to prevent the relocation of companies, known as carbon leakage. European regulators have signaled rules to prevent companies from relocating should continue.

# The concern in the news




*"European Union industry landed a 24-billion-euro windfall from an emissions cap-and-trade program that was intended to moderate emissions [...] Companies in the cement, petrochemical and steel industries gained most from the emissions trading system."*

–Bloomberg, 2016

# Introduction

Having a price on all emissions is not enough but the distribution of costs matters too: The propensity to relocate as a function of compensations varies across industries; some types of firms are more footloose than others.

- some firms can do more at home than others and are thus more valuable to keep: Transfers from scarce public funds should reach those firms first
- However, information on the ease of relocation and options available to firms are inherently private by nature
- Regulated industries fiercely lobby for compensations, emphasizing the cost of regulation and easiness to relocate production to other countries

Again, the central challenge for the policies is to achieve the distributional and efficiency goals through policies, including transfers, under privately held information

# Analysis

# Transfers and private information

We focus now on how the transfers should be used in two situations

1. Budget is not a problem: Mechanisms that solve the information problem – Groves mechanisms
2. Funds are scarce: Mechanisms with a budget – we focus on screening mechanisms

## First case: Budget balance not required

To illustrate the theme, let us first consider a public project such as a bridge to be financed jointly by the agents. There are free-riding incentives since no agent can be excluding from using the bridge after it has been built. We want to design a mechanism that collects information about how the agents value the bridge and how much each agent has to pay.

- $U(x_i, z) = z \times x_i + t_i,\ i = 1, ..., n$
- $z \in \{0, 1\}$ so that $z = 1$ if the bridge is built, and $t_i$ is the money transfer for agent $i$
- $c > 0$ is the cost of undertaking the project
- Efficient allocation rule must satisfy: build only if the valuations exceed the cost,

$$z^*(x) = \begin{cases} 1 \text{ if } \sum_{i=1}^{n} x_i \geq c \\ 0 \text{ otherwise} \end{cases}$$

But agents have incentives to hide their private benefits in the hope that others pay the costs

# Groves mechanism: public project

One mechanism that implements the above outcome:

$$t_j(\hat{x}) = \begin{cases} \sum_{i \neq j} \hat{x}_i - c \text{ if } \sum_{i=1}^{n} \hat{x}_i \geq c \\ 0 \text{ otherwise} \end{cases}$$

$$x^*(\hat{x}) = \begin{cases} 1 \text{ if } \sum_{i=1}^{n} \hat{x}_i \geq c \\ 0 \text{ otherwise} \end{cases}$$

Why? Agent $j's$ payoff is

$$\begin{cases} x_j + \sum_{i \neq j} \hat{x}_i - c \text{ if } \sum_{i=1}^{n} \hat{x}_i \geq c \\ 0 \text{ otherwise} \end{cases}$$

which is maximized by truth telling, $\hat{x}_j = x_j$ (regardless of $\hat{x}_{-j}$).

# Groves mechanism: lessons

- In generalized Groves mechanism, the agent gets her/his true contribution to the overall surplus as a net payoff. Transfers of this form make this mechanism a pivotal mechanism, or Vickrey-Clarke-Groves (VCG) mechanism.
- transfers are not budget-balanced.
- Groves schemes are essentially only mechanisms that imply truthful revelation in dominant stategies.
- if there is a need to search for balanced budgets, then dominant-stategy equilibrium is too demanding equilibrium concept.

# Second case: public funds are scarce

- For global problems, some firms can do more at home than others and are thus more valuable to keep: Transfers from scarce public funds should reach those firms first.
  - because firms' available options are privately known, the policies must incentivize right firms to self-select the desired action

Plan

1. we first solve this screening problem
2. apply to the data by Martin et al. (AER, 2014)

Based on "Global externalities, local policies, and firm selection", Ahlvik&Liski, (the Journal of the European Economic Association)

# Set-up

- Units of interest are firms/plants, emission reduction $x = [0, 1]$, transfer $t \in \mathbb{R}$

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- We follow Rochet and Stole (2002, ReStud):
  - Direct revelation mechanism conditional on staying: firms reporting $\hat{\beta}$, receive $t = T(\hat{\beta})$ and reduce $x = X(\hat{\beta})$:

$$C(\beta, \hat{\beta}) = \beta X(\hat{\beta}) - T(\hat{\beta})$$

  - Relocation modelled as an indirect mechanism where the firm leaves if the cost of regulation exceeds the relocation cost:

$$C(\beta, \hat{\beta}) > \theta$$

  - This mechanism at home $M_i(\beta)$, but we allow another abroad $M_j(\beta)$.

# Set-up

- Policy-maker's problem

$$\max_{X_i(\beta),T(\beta)} \int_{\underline{\beta}}^{\overline{\beta}} \Big( \underbrace{\gamma}_{\text{(i)}} + \underbrace{DX_i(\beta)}_{\text{(ii)}} - \underbrace{C_i(\beta)}_{\text{(iii)}} \Big) \underbrace{\phi_i(C(\beta),\beta)}_{\text{(iv)}} - \underbrace{\phi_j(C(\beta),\beta)DX_j(\beta)}_{\text{(v)}} - \underbrace{(1+\lambda)T(\beta)}_{\text{(vi)}} \, d\beta$$

(i) Direct benefits of a firm staying
(ii) Benefits of reductions
(iii) Cost to firm $\beta$ at home $i$, i.e., $C_i(\beta) = \beta X_i(\beta) - T_i(\beta)$
(iv) Mass of firms staying when $C(\beta) = C_i(\beta) - C_j(\beta)$
(v) Mass of moving firms and benefits, if any
(vi) Total transfer $T(\beta) = T_i\phi_i + T_j\phi_j$, with cost of public funds $\lambda > 0$

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(vi) Total transfer $T(\beta) = T_i\phi_i + T_j\phi_j$, with cost of public funds $\lambda > 0$

- Such that:
  - Incentive compatibility holds

$$\beta = \arg\min_{\hat{\beta}} C_i(\beta, \hat{\beta}) \text{ for all } \beta$$

  - The mass of firms with type $\beta$ that stay is given by

$$\phi_i(C(\beta),\beta) = \Big(1 - G(C(\beta)|\beta)\Big) f(\beta)$$

The **welfare effect of relocation** is the change in social welfare at $i$ when a firm of type $c$ relocates to $j$:

$$\Delta(\beta) = -\Big(\gamma + D\big(X_i(\beta) - X_j(\beta)\big) - C_i(\beta) - (1+\lambda)\big(T_i(\beta) - T_j(\beta)\big)\Big)$$

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- if a firm cuts emissions in neither regime ($X_i = 0, X_j = 0$), there is no "leakage"
- a firm that cuts emissions only when staying ($X_i > 0, X_j = 0$) creates surplus $D - \beta$
- if a firm cuts the same in both countries ($X_i = 1, X_j = 1$), no effect on the global externality but the firm's social value still depends on its costs $\beta$. All else equal, preference to keep the low cost firms.

# Optimal local mechanism when $T_j = 0$ and $X_j = 0$

The other location is a pollution haven

**Lemma**

***(Two-part tariff)*** *Optimal local mechanism $M_i(\beta)$ sets two constants $(T_i^*, \beta_i^*)$:*

$$\begin{cases} T_i(\beta) = T_i^*, & X_i(\beta) = 1 \quad \text{for } \beta \le \beta_i^* \\ T_i(\beta) = T_i^* - \beta_i^*, & X_i(\beta) = 0 \quad \text{for } \beta > \beta_i^*. \end{cases} \tag{1}$$

All get a base compensation (could be a tax), and polluters pay a price.

- a market interpretation follows
- distributions can describe sectors; we may run the mechanism separately for each sector

# Set-up

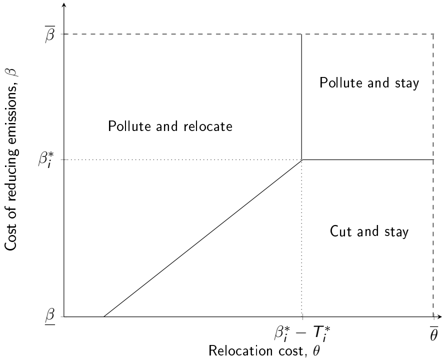



Figure: Graphical illustration of the two-dimensional type space in the local mechanism.

# Setting the base transfer

Define *marginal surplus* $MS(C(\beta),\beta) \equiv \Delta(\beta)\phi_i'(C(\beta),\beta) - \lambda\phi_i(C(\beta),\beta)$. Compensating more incentivizes firms to stay and surplus $\Delta\phi_i'$ is gained, but this increases the mass of firms receiving compensations $-\lambda\phi_i$. These marginal surpluses from all firms,

$$\mu(\underline{\beta},\overline{\beta}) = \int_{\underline{\beta}}^{\overline{\beta}} MS(C(\beta),\beta)d\beta,$$

guide the optimal base transfer, $T_i^* \Rightarrow \mu(\underline{\beta},\overline{\beta}) = 0$.

# Setting the emissions price

The externality price $\beta_i^*$ is set by the trade-off

$$\Big(D - (1+\lambda)\beta_i^*\Big)\phi_i(C(\beta_i^*), \beta_i^*) = \mu(\beta_i^*, \overline{\beta})$$

and $\mu(\underline{\beta}, \beta_i^*) = -\mu(\beta_i^*, \overline{\beta})$.

- left: marginal social gain from increasing the threshold for cuts, $\beta_i^*$
- right: marginal surplus from all firms that do not cut $\beta > \beta_i^*$

# Optimal local mechanism: benchmark of immobile firms

Suppose firms cannot move

**Theorem**

***(Local Mechanism)*** *Optimal $M_i(\beta)$ is characterized by $(T_i^*, \beta_i^*)$ where*

*(i) Set $\theta = \overline{\theta}$ for all (immobile firms), $T_i^* = \beta_i^* - \overline{\theta} \equiv T_B$*

$$\beta_i^* = \frac{D}{1+\lambda} - \frac{\lambda}{1+\lambda} \frac{F(\beta_i^*)}{f(\beta_i^*)} \equiv \beta_B < \beta_P$$

where $\beta_P = \frac{D}{1+\lambda}$ is Pigouvian price. Classical result (Lewis, Rand 1996, etc.)

- tax away the outside option
- distort the emissions price downwards: this allows raising the base tax to all firms.

# Optimal local mechanism: moving firms, the main case

**Theorem**

***(Local Mechanism)*** *Optimal $M_i(\beta)$ is characterized by $(T_i^*, \beta_i^*)$ where*

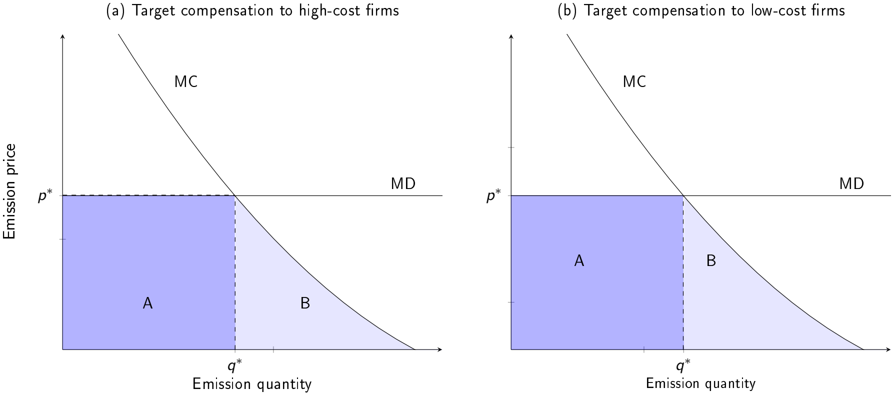
*(ii) Allow for $\theta \in (-\infty, \overline{\theta}]$ (mobile firms),*

$$\beta_i^* = \frac{D}{1+\lambda} - \frac{\mu(\beta_i^*, \overline{\beta})}{(1+\lambda)\phi_i(C(\beta_i^*), \beta_i^*)} > \beta_B.$$

where $\mu$ is a measure of marginal surplus of moving firms.

- Certain elasticity assumptions imply that even $\beta_i^* > \beta_p$ holds
- Similar upward distortion never arises in standard random participation models (Rochet & Stole, 2002; Lehmann et al., QJE 2014)

# Intuition for the result



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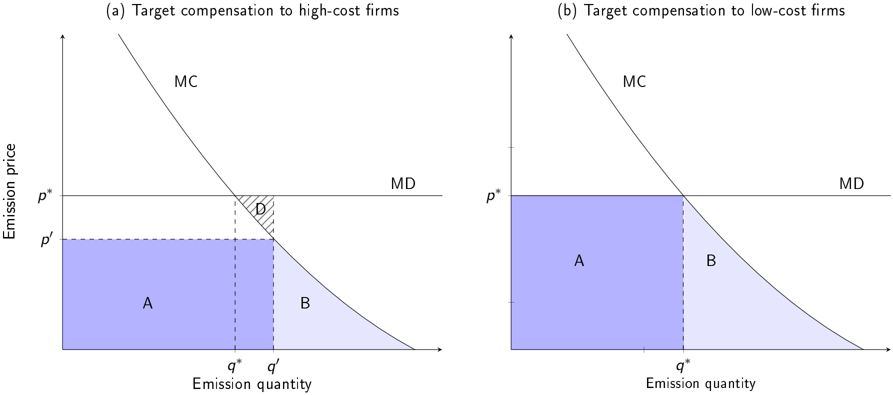

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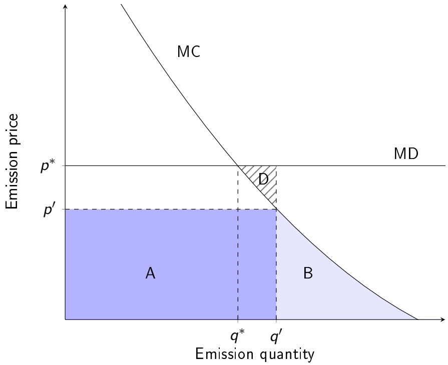
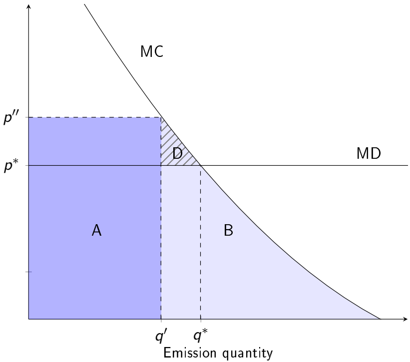
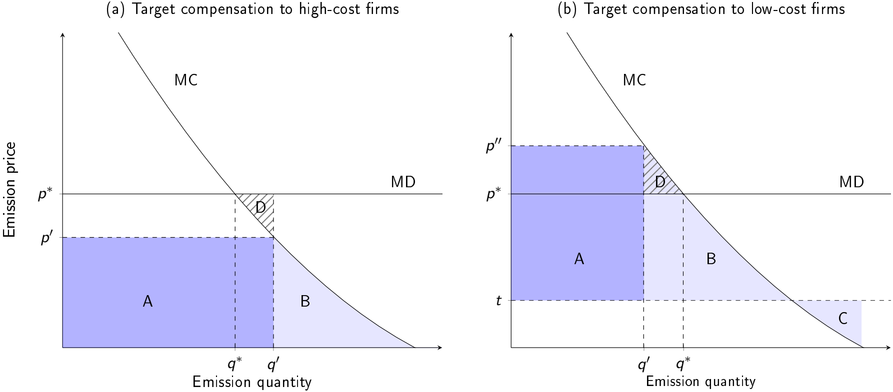
(a) Target compensation to high-cost firms




(b) Target compensation to low-cost firms



# Intuition for the result



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# Discussion II: literature

- **Vast literature on carbon leakage**: Markusen et al. (1993), Motta and Thisse (1994), Ulph (1994), Hoel (1996), Ulph and Valentini (1997), Kuik and Gerlagh (2003), Böhringer (2004), Babiker (2005), Bernard and Vielle (2009), Kuik and Hofkes (2010), Clò (2014), Costantini et al. (2011), Fisher and Fox (2012), Meunier et al. (2014), Schmidt and Heitzig (2014), Martin et al. (2014)...

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> "[E]fficiency requires that payments be distributed across firms so as to equalize **marginal relocation probabilities, weighted by the damage caused by relocation**. We formalize this fundamental economic logic [...]"
>
> Martin et al., 2014, AER

# Discussion II

- **Environmental policy under private information**: Kwerel (1977), Dasgupta et al. (1980), Montero (2000,2006), Spulber (1988), Kim and Chang (1993), Lewis (1996), Meunier et al. (2016), Martimort and Sand-Zantman (2015)
- **Self-selection model with random participation**: Rochet and Stole (2002), Lehmann et al. (2014)
- **Use of exclusions in other contexts**: Norman (2004), Hellwig (2005), Baron and Myerson (1982), Armstrong (1996)

# Quantification: EU ETS

The idea:

- calibrate the relocation distribution $G$ to the firm-level survey data of Martin et al. (2014).
- calibrate abatement cost distribution $F$ to Böhringer et al (2014)
- $\gamma$ is based on emissions-weighted average earnings before investment and tax (EBIT) per unit of pollution, expressed as EUR/tCO2
- The social cost of public funds is $\lambda = .6$
- $D = 40 EUR/tCO_2$ from Nordhaus (2017)

# Descriptives

Table 1: Descriptive statistics of the data used

| | Total emissions in 2015 ($MtCO_2$)[1] | EBIT per emissions (€/$tCO_2$)[2] | Relocation probability[2] 0% compensation | Relocation probability[2] 80% compensation | No. firms[2] | Parameters[3] Mean | Parameters[3] Variance |
|---|---|---|---|---|---|---|---|
| Cement | 113.8 | 32.73 | 0.46 | 0.20 | 46 | 27.98 | 716.6 |
| Iron and Steel | 120.6 | 80.52 | 0.60 | 0.21 | 25 | 20.38 | 363.3 |
| Chemical and Plastic | 74.9 | 177.96 | 0.24 | 0.06 | 64 | 41.26 | 525.3 |
| Wood and Paper | 27.1 | 89.31 | 0.14 | 0.03 | 61 | 53.05 | 672.9 |
| Glass | 18.2 | 120.56 | 0.14 | 0.05 | 24 | 65.32 | 1389.8 |
| Aggregate | 354.6 | 88.49 | 0.42 | 0.15 | 220 | 30.08 | 591.0 |

[1]Data from EEA (2017), [2]Data from Martin *et al.* (2014a), [3]Mean and variance of standard distribution, calibrated separately for each sector. Aggregate is calculated based on the sum (columns 1-5) and emission-weighted averages (columns 2-4) of individual sectors, and by calibrating a distribution based on relocation probabilities (columns 6-7).

# Optimal local mechanism

Table 2: Optimal mechanism for the EU ETS sectors

| | Implementation of the mechanism | | | Implied emission reductions | | |
|---|---|---|---|---|---|---|
| | Base compensation (€/t$CO_2$) | Local $CO_2$ price (€/t$CO_2$) | Global $CO_2$ price (€/t$CO_2$) | Local reductions (Mt$CO_2$) | Global reductions (Mt$CO_2$) | Emission leakage (Mt$CO_2$) |
| Panel A - Local mechanism | | | | | | |
| Cement | 12.7 | 23.4 | - | 25.60 | - | 4.41 |
| Iron and Steel | 27.2 | 21.4 | - | 28.09 | - | 0.96 |
| Chemical and Plastic | 20.3 | 21.3 | - | 17.68 | - | 0.29 |
| Wood and Paper | 4.2 | 22.0 | - | 6.45 | - | 0.28 |
| Glass | 6.3 | 22.8 | - | 4.42 | - | 0.26 |
| | | | | 82.24 | - | 6.20 |

# Optimal local mechanism

Panel B: restriction of one price in all sectors

Table 2: Optimal mechanism for the EU ETS sectors

| | Implementation of the mechanism | | | Implied emission reductions | | |
|---|---|---|---|---|---|---|
| | Base compensation (€/$tCO_2$) | Local $CO_2$ price (€/$tCO_2$) | Global $CO_2$ price (€/$tCO_2$) | Local reductions ($MtCO_2$) | Global reductions ($MtCO_2$) | Emission leakage ($MtCO_2$) |
| Panel A - Local mechanism | | | | | | |
| Cement | 12.7 | 23.4 | - | 25.60 | - | 4.41 |
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| Glass | 6.3 | 22.8 | - | 4.42 | - | 0.26 |
| | | | | 82.24 | - | 6.20 |
| Panel B - Uniform-price mechanism | | | | | | |
| Cement | 11.7 | 22.1 | - | 24.14 | - | 4.23 |
| Iron and Steel | 27.8 | 22.1 | - | 29.08 | - | 0.97 |
| Chemical and Plastic | 21.0 | 22.1 | - | 18.38 | - | 0.29 |
| Wood and Paper | 4.2 | 22.1 | - | 6.47 | - | 0.28 |
| Glass | 5.8 | 22.1 | - | 4.28 | - | 0.26 |
| | | | | 82.35 | - | 6.03 |

# Optimal local mechanism

## Panel C: incentivize also moving firms

Table 2: Optimal mechanism for the EU ETS sectors

| | Implementation of the mechanism | | | Implied emission reductions | | |
|---|---|---|---|---|---|---|
| | Base compensation (€/t$CO_2$) | Local $CO_2$ price (€/t$CO_2$) | Global $CO_2$ price (€/t$CO_2$) | Local reductions (Mt$CO_2$) | Global reductions (Mt$CO_2$) | Emission leakage (Mt$CO_2$) |
| Panel A - Local mechanism | | | | | | |
| Cement | 12.7 | 23.4 | - | 25.60 | - | 4.41 |
| Iron and Steel | 27.2 | 21.4 | - | 28.09 | - | 0.96 |
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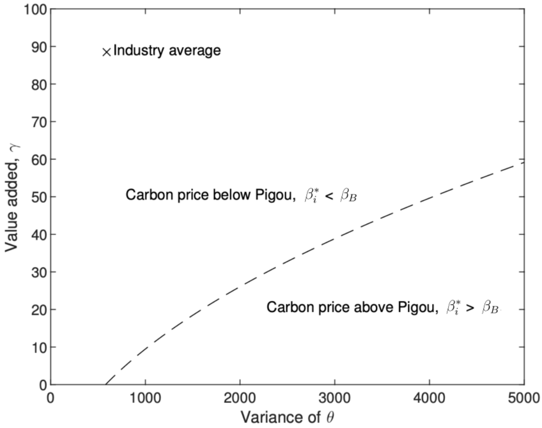
| Wood and Paper | 4.2 | 22.0 | - | 6.45 | - | 0.28 |
| Glass | 6.3 | 22.8 | - | 4.42 | - | 0.26 |
| | | | | 82.24 | - | 6.20 |
| Panel B - Uniform-price mechanism | | | | | | |
| Cement | 11.7 | 22.1 | - | 24.14 | - | 4.23 |
| Iron and Steel | 27.8 | 22.1 | - | 29.08 | - | 0.97 |
| Chemical and Plastic | 21.0 | 22.1 | - | 18.38 | - | 0.29 |
| Wood and Paper | 4.2 | 22.1 | - | 6.47 | - | 0.28 |
| Glass | 5.8 | 22.1 | - | 4.28 | - | 0.26 |
| | | | | 82.35 | - | 6.03 |
| Panel C - Global mechanism | | | | | | |
| Cement | 12.0 | 23.0 | 7.5 | 24.83 | 1.08 | 3.60 |
| Iron and Steel | 27.1 | 21.3 | 3.3 | 28.06 | 0.05 | 0.92 |
| Chemical and Plastic | 20.3 | 21.3 | 1.6 | 17.68 | 0.01 | 0.28 |
| Wood and Paper | 4.1 | 22.0 | 4.1 | 6.43 | 0.02 | 0.27 |
| Glass | 6.2 | 22.7 | 6.2 | 4.40 | 0.03 | 0.24 |
| | | | | 81.40 | 1.19 | 5.31 |

# Quantification: summary

- The optimal $CO_2$ prices are differentiated between sectors and varies between 21.3-23.4 €/t$CO_2$
- The impact of leakage is quantitatively significant: the effective $CO_2$ price is substantially elevated, by $17 - 29$ per cent compared to the benchmark level where leakage was assumed away, 18.2 €/t$CO_2$
- Higher local prices translate into larger global emission reductions: if all the sectors considered would be immobile by assumption, the total emission reductions would be 72.69 Mt$CO_2$.
- For all the sectors the emissions price falls short of the Pigouvian benchmark (25 €/t$CO_2$). When would it be higher? Next figure.

# When does the externality price exceed the Pigouvian level?




Notes: The Figure depicts the results from a simulation that finds the parameters for which the optimal carbon price exceeds or falls below the socially optimal level. The social cost of carbon is 25 €/t$CO_2$ and the social cost of public funds is $\lambda = .6$. The emissions-weighted industry average value for the value added is $\gamma = 88.7$ and the variance is 591.0.

# Conclusions

- Forms' available options are privately known, the policies must incentivize right firms to self-select the desired action and location
  - This selection effect calls for higher externality prices, not lower
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  - Carbon tax rebates
  - Possibility to use international or domestic offsets
  - Exclusion from regulation
- Future empirical work should focus on
  - Correlation between abatement and relocation costs
  - Destination countries and their regulation levels