Industry Compensation under Relocation Risk: A Firm-level Analysis of the EU Emissions Trading System

Ulrich Wagner
Universidad Carlos III de Madrid

joint with Mirabelle Muûls, Laure de Preux, and Ralf Martin

5th Atlantic Workshop on Energy and Environmental Economics, Isla de la Toja
June 26, 2012

Regulation and Relocation Risk

> *"If [the financial transaction tax] really happened, we would have to move our business to New York or Singapore or Hong Kong. Our business would continue. [It is] just sad it wouldn't continue in London."*

BBC interview with Michael Spencer, Group Chief Executive Officer of leading financial transactions company ICAP, available online at http://www.bbc.co.uk/news/business-16990025.

The Case for Industry Compensation

- Relocation of regulated firms to non-regulated jurisdictions has undesirable consequences from government's p.o.v.
  - loss of jobs, taxable profits etc.
  - *"carbon leakage"*: evasion of regulated emissions
- Politicians keen to prevent relocation ("protect international competitiveness")
- Implications for policy design:
  - Lobbying for exemptions undermines policy objectives (e.g. European carbon taxes)
  - Efficiency cost of compensation changes the ranking of different policy instruments (Bovenberg, Goulder & Gurney 2005 *RAND*; Bovenberg, Goulder & Jacobsen, 2008, *JPubE*)
- If the sole aim of compensation is to prevent relocation, how much should be offered, and to whom?

Industry Compensation in the EU ETS

- Cap-and-trade system for stationary sources (power generation, industrial emitters) in 30 countries. *Largest "carbon pricing experiment" worldwide*
- Trading Phase III, 2013-2020: Shift from grandfathering to auctioning of permits in manufacturing.
- Industry has sucessfully lobbied to be exempt from permit auctions
- European Commission (EC) will exempt industries deemed at risk of relocation to prevent offshoring of jobs and carbon leakage
- Compensation offered in the form of free emission permits

Optimal compensation under relocation risk

- Goal: Assess the efficiency gap and distributional effects of EC proposal
- Key ingredient: New firm-level measure of relocation propensity in response to future carbon pricing, based on interviews with managers
  - Match with microdata on performance and carbon emissions

Main Results

- No evidence that permit auctions will lead to exodus of firms
- EC criteria give rise to
  - overly generous compensation
  - unequal treatment of countries
  - highly unequal distribution of subsidies per job
- Simple fix of EC criteria for exempting sectors from auctioning could generate 6.7 bn Euros in permit revenue p.a.
- Firm level: Optimal permit allocation
  - reduces risk of job loss by two thirds and
  - leads to more equal distribution of subsidies per job

How does climate policy affect the propensity to relocate?

⇒ Talk to managers

Telephone interview method (Bloom & van Reenen, *QJE* 2007)

- large N – move beyond case studies
- open question, answers scored on a grid [1-5] by trained interviewer
- avoid common types of survey bias
  - double blind
  - double scoring
  - analyst rotation and extensive noise controls

How does climate policy affect the propensity to relocate?

$\Rightarrow$ Talk to managers

Telephone interview method (Bloom & van Reenen, *QJE* 2007)

- large N – move beyond case studies
- open question, answers scored on a grid [1-5] by trained interviewer
- avoid common types of survey bias
  - double blind
  - double scoring
  - analyst rotation and extensive noise controls

How does climate policy affect the propensity to relocate?

$\Rightarrow$ Talk to managers

Telephone interview method (Bloom & van Reenen, *QJE* 2007)

- large N – move beyond case studies
- open question, answers scored on a grid [1-5] by trained interviewer
- avoid common types of survey bias
  - double blind
  - double scoring
  - analyst rotation and extensive noise controls

How does climate policy affect the propensity to relocate?

$\Rightarrow$ Talk to managers

Telephone interview method (Bloom & van Reenen, *QJE* 2007)

- large N – move beyond case studies
- open question, answers scored on a grid [1-5] by trained interviewer
- avoid common types of survey bias
  - double blind
  - double scoring
  - analyst rotation and extensive noise controls

Basic Statistics

- Interviewed 770 managers in 6 European countries
- Random sampling from all medium-sized manufacturing firms in ORBIS data base (balance sheet data)
- Oversampled ETS firms at random from the ETS register (CITL)

Table: Interview response rates by country

	# of Interviews	# of Firms Interviewed	# of ETS Firms Interviewed	# of Non ETS Firms Interviewed	Total Firms Contacted	Refused	Response Rate
Belgium	134	131	85	46	178	47	0.74
France	141	140	92	48	238	98	0.59
Germany	139	138	95	43	337	199	0.41
Hungary	69	69	37	32	90	21	0.77
Poland	78	78	57	21	140	62	0.56
UK	209	205	63	142	468	264	0.44
Total	770	761	429	332	1451	691	0.52

Vulnerability Score

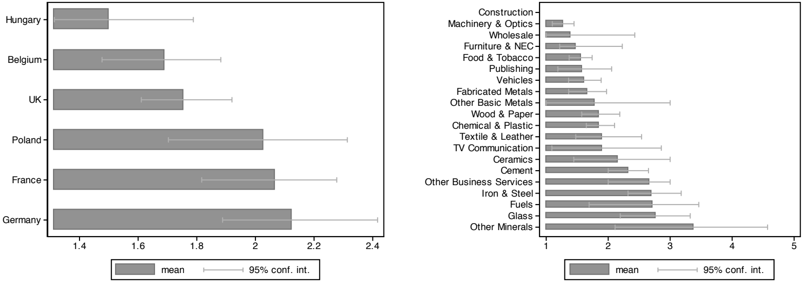
"Do you expect that government efforts to put a price on carbon emissions will force you to outsource parts of the production on this business site in the foreseeable future, or to close down completely?"

Scoring:

- Low(1): No impact of this kind
- Mid(3): Significant reduction (>10%) in production or employment due to outsourcing
- High(5): Complete close-down

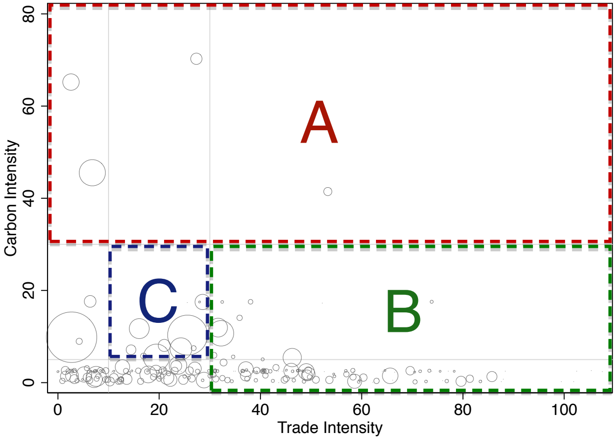
Distribution of vulnerability score

Figure: Average vulnerability score by country and industry



- Overall risk is low but some sectors are at risk
- ask me about validity checks in the Q&A

Exemption groups



- A. High Carbon Intensity >30%
- B. High Trade Intensity (TI) > 30% (and not A)
- C. Intermediate Carbon and Trade Intensity:

CI is correlated with vulnerability, but not TI

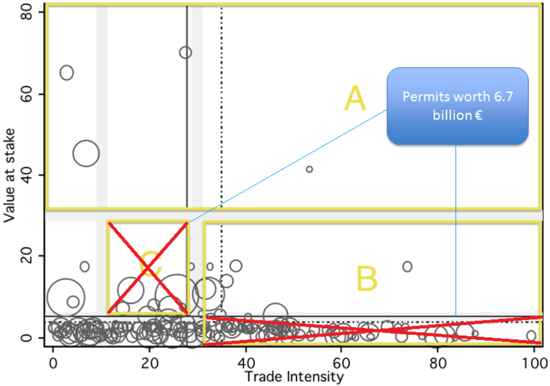
	(1)	(2)	(3)	(4)	(5)
	Vulnerability Score (VS)				
Sectoral Trade Intensity (TI)	-0.012		0.050	0.051	0.097
	(0.092)		(0.112)	(0.096)	(0.117)
Carbon Intensity (CI)		0.229***	0.454**	0.292***	0.473***
		(0.063)	(0.215)	(0.090)	(0.114)
TI X TI			-0.037		
			(0.037)		
CI X CI			0.007		
			(0.074)		
TI X CI			0.059	0.086	0.063
			(0.106)	(0.091)	(0.134)
Weights	no	no	no	no	employment
Observations	392	392	392	392	392

No threshold effects of exemption criteria

	(1)	(2)	(3)	(4)	(5)
		Vulnerability Score		Vulnerability Score>2	
CI>30 (A)	1.032***	1.015***	1.996***	0.714***	1.704***
	(0.303)	(0.312)	(0.523)	(0.242)	(0.448)
TI>30 ∩ CI<30 (B)	0.225				
	(0.258)				
10<TI<30 ∩ 5<CI<30 (C)	0.122	0.139	0.358	0.105	0.271
	(0.248)	(0.240)	(0.241)	(0.233)	(0.292)
B ∩ CI>5		0.596*	1.031***	0.500**	1.267***
		(0.316)	(0.322)	(0.252)	(0.417)
B ∩ CI<5		-0.053	0.056	-0.059	0.121
		(0.243)	(0.329)	(0.233)	(0.389)
Constant	1.623***	1.572***	1.426		
	(0.516)	(0.523)	(0.912)		
Weights	no	no	employment	no	employment
Observations	392	392	392	392	392

but TI sectors are vulnerable if at least moderately carbon intensive

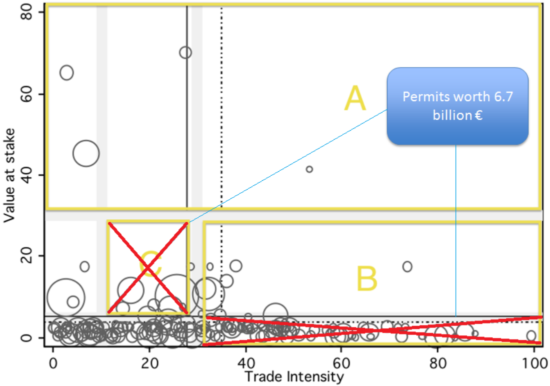
Improvement 1: Exempt only sectors with a significant impact



- NOT exempting C and B ∩ CI<5 would NOT increase relocation risk
- could raise an additional €6.7 bn p.a. in auction revenues

$$\Delta Revenue = \Delta\left(CO_2 \text{ share not exempt}\right) \cdot \left(CO_2\right)_{Manufacturing} \cdot P_{CO_2}$$

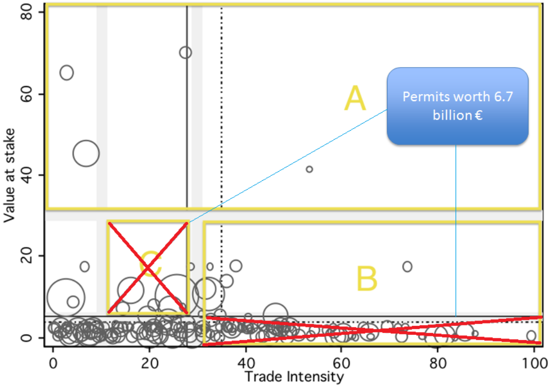
Improvement 1: Exempt only sectors with a significant impact



- NOT exempting C and B ∩ CI<5 would NOT increase relocation risk
- could raise an additional €6.7 bn p.a. in auction revenues

$$\Delta Revenue = \Delta \left(CO_2 \text{ share not exempt} \right) \cdot \left(CO_{2\,Manufacturing} \right) \ldots$$

Improvement 1: Exempt only sectors with a significant impact



- NOT exempting C and B ∩ CI<5 would NOT increase relocation risk
- could raise an additional €6.7 bn p.a. in auction revenues

$$\Delta Revenue = \Delta\left(CO_2 \text{ share not exempt}\right) \cdot \left(CO_2\right)_{Manufacturing} \cdot AF \cdot P_{CO_2}$$

Improvement 2: Use TI with less developed countries

	(1)	(2)	(3)
		Vulnerability Score	
Sectoral Carbon Intensity (CI)	0.234***	0.547***	0.551***
	(0.060)	(0.169)	(0.166)
Sectoral Trade Intensity (TI)	0.376**	0.695***	1.454***
with LESS developed countries	(0.164)	(0.232)	(0.245)
TI with LEAST developed countries	-0.228***	-0.422***	-0.740***
	(0.076)	(0.157)	(0.174)
TI with Developed non-EU countries	0.117	-0.216	-0.593***
	(0.125)	(0.243)	(0.219)
TI with EU countries	-0.229**	-0.411***	-0.680***
	(0.114)	(0.143)	(0.190)
Quadratic terms	no	yes	yes
Interaction terms	no	yes	yes
Weights	no	no	employment
Observations	389	389	389

- use same thresholds, but only TI will less developed countries instead of overall TI
- could raise an additional €2.8 bn p.a. in auction revenues

Improvement 2: Use TI with less developed countries

	(1)	(2)	(3)
	Vulnerability Score		
Sectoral Carbon Intensity (CI)	0.234***	0.547***	0.551***
	(0.060)	(0.169)	(0.166)
Sectoral Trade Intensity (TI)	0.376**	0.695***	1.454***
with LESS developed countries	(0.164)	(0.232)	(0.245)
TI with LEAST developed countries	-0.228***	-0.422***	-0.740***
	(0.076)	(0.157)	(0.174)
TI with Developed non-EU countries	0.117	-0.216	-0.593***
	(0.125)	(0.243)	(0.219)
TI with EU countries	-0.229**	-0.411***	-0.680***
	(0.114)	(0.143)	(0.190)
Quadratic terms	no	yes	yes
Interaction terms	no	yes	yes
Weights	no	no	employment
Observations	389	389	389

- use same thresholds, but only TI will less developed countries instead of overall TI
- could raise an additional €2.8 bn p.a. in auction revenues

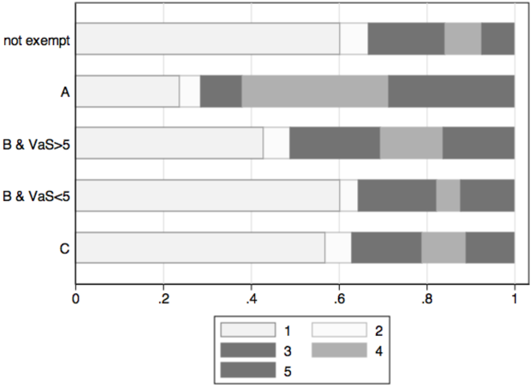
Improvement 2: Use TI with less developed countries

	(1)	(2)	(3)
		Vulnerability Score	
Sectoral Carbon Intensity (CI)	0.234***	0.547***	0.551***
	(0.060)	(0.169)	(0.166)
Sectoral Trade Intensity (TI)	0.376**	0.695***	1.454***
with LESS developed countries	(0.164)	(0.232)	(0.245)
TI with LEAST developed countries	-0.228***	-0.422***	-0.740***
	(0.076)	(0.157)	(0.174)
TI with Developed non-EU countries	0.117	-0.216	-0.593***
	(0.125)	(0.243)	(0.219)
TI with EU countries	-0.229**	-0.411***	-0.680***
	(0.114)	(0.143)	(0.190)
Quadratic terms	no	yes	yes
Interaction terms	no	yes	yes
Weights	no	no	employment
Observations	389	389	389

- use same thresholds, but only TI will less developed countries instead of overall TI
- could raise an additional €2.8 bn p.a. in auction revenues

Within-group heterogeneity calls for firm-level exemptions

Figure: Distribution of vulnerability score by category



For given amount of free permits, relocation is profitable if

$$\pi_i^{domestic}(permits_i) < \underbrace{\pi_i^{abroad} - cost_i^{relocation}}_{\epsilon_i \sim \Phi_i(\cdot)}$$

Firm i's contribution to aggregate relocation risk

$$risk_i(permits_i) = \underbrace{\Phi_i\left[-\pi_i(permits_i)\right]}_{\text{relocation propensity}} \cdot \underbrace{\left[\alpha Jobs_i + (1-\alpha) Emissions_i\right]}_{\text{relocation damage}} \quad 0 \leq \alpha \leq 1.$$

- Minimize Risk:

$$\min_{\{permits_i \geq 0\}} \sum_{i=1}^{n} risk_i(permits_i) \text{ s.t. } \sum_i permits_i \leq permit\ constraint.$$

- Minimize Cost:

$$\min_{permits_i \geq 0} \sum_{i=1}^{n} permits_i \text{ s.t. } \sum_{i=1}^{n} risk_i(permits_i) \leq risk\ constraint$$

Optimality condition: No additional job/ton of carbon can be saved by shifting the last free permit from one firm to another.

For given amount of free permits, relocation is profitable if

$$\pi_i^{domestic}(permits_i) < \underbrace{\pi_i^{abroad} - cost_i^{relocation}}_{\epsilon_i \sim \Phi_i(\cdot)}$$

Firm i's contribution to aggregate relocation risk

$$risk_i(permits_i) = \underbrace{\Phi_i\left[-\pi_i(permits_i)\right]}_{\text{relocation propensity}} \cdot \underbrace{\left[\alpha Jobs_i + (1-\alpha) Emissions_i\right]}_{\text{relocation damage}} \quad 0 \leq \alpha \leq 1.$$

- Minimize Risk:

$$\min_{\{permits_i \geq 0\}} \sum_{i=1}^{n} risk_i(permits_i) \text{ s.t. } \sum_i permits_i \leq permit\ constraint.$$

- Minimize Cost:

$$\min_{permits_i \geq 0} \sum_{i=1}^{n} permits_i \text{ s.t. } \sum_{i=1}^{n} risk_i(permits_i) \leq risk\ constraint$$

Optimality condition: No additional job/ton of carbon can be saved by shifting the last free permit from one firm to another.

For given amount of free permits, relocation is profitable if

$$\pi_i^{domestic}(permits_i) < \underbrace{\pi_i^{abroad} - cost_i^{relocation}}_{\epsilon_i \sim \Phi_i(\cdot)}$$

Firm i's contribution to aggregate relocation risk

$$risk_i(permits_i) = \underbrace{\Phi_i\left[-\pi_i(permits_i)\right]}_{\text{relocation propensity}} \cdot \underbrace{\left[\alpha Jobs_i + (1-\alpha)Emissions_i\right]}_{\text{relocation damage}} \quad 0 \leq \alpha \leq 1.$$

- Minimize Risk:

$$\min_{\{permits_i \geq 0\}} \sum_{i=1}^{n} risk_i(permits_i) \text{ s.t. } \sum_i permits_i \leq permit\ constraint.$$

- Minimize Cost:

$$\min_{permits_i \geq 0} \sum_{i=1}^{n} permits_i \text{ s.t. } \sum_{i=1}^{n} risk_i(permits_i) \leq risk\ constraint$$

Optimality condition: No additional job/ton of carbon can be saved by shifting the last free permit from one firm to another.

For given amount of free permits, relocation is profitable if

$$\pi_i^{domestic}(permits_i) < \underbrace{\pi_i^{abroad} - cost_i^{relocation}}_{\epsilon_i \sim \Phi_i(\cdot)}$$

Firm i's contribution to aggregate relocation risk

$$risk_i(permits_i) = \underbrace{\Phi_i\left[-\pi_i(permits_i)\right]}_{\text{relocation propensity}} \cdot \underbrace{\left[\alpha Jobs_i + (1-\alpha)Emissions_i\right]}_{\text{relocation damage}} \quad 0 \leq \alpha \leq 1.$$

- Minimize Risk:

$$\min_{\{permits_i \geq 0\}} \sum_{i=1}^{n} risk_i(permits_i) \text{ s.t. } \sum_i permits_i \leq permit\ constraint.$$

- Minimize Cost:

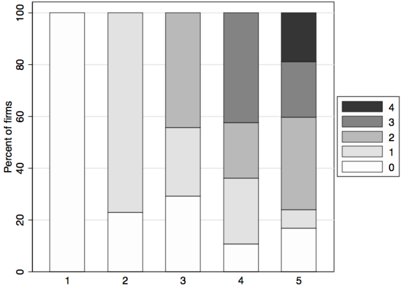
$$\min_{permits_i \geq 0} \sum_{i=1}^{n} permits_i \text{ s.t. } \sum_{i=1}^{n} risk_i(permits_i) \leq risk\ constraint$$

Optimality condition: No additional job/ton of carbon can be saved by shifting the last free permit from one firm to another.

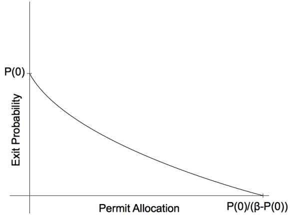
Numerical Solution

- deal with corner solutions
    - use dynamic programming in the cross section of firms
- marginal relocation probability $\Phi_i(\cdot)$:

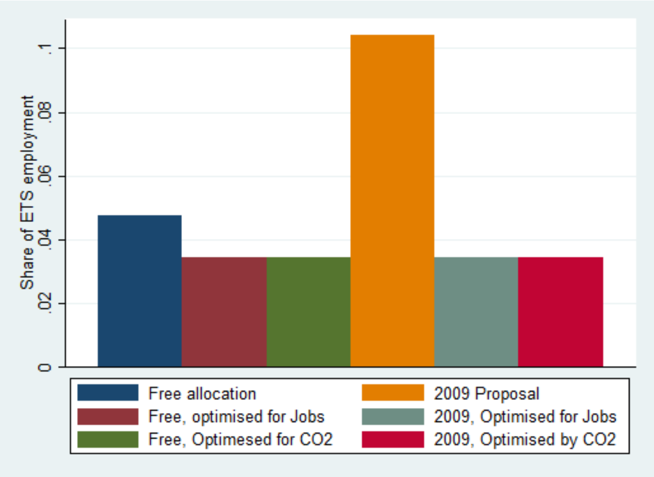
ask respondents how score changes with free allowance for 80% of emissions $\Rightarrow$



fit to logistic distribution



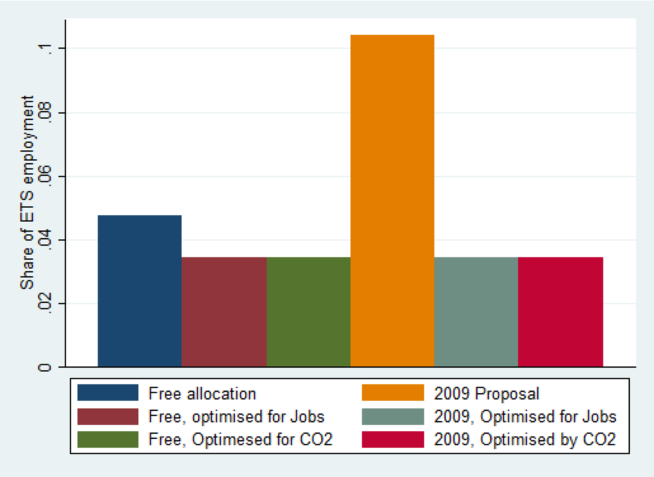
Minimize job loss s.t. fixed amount of free permits



Optimal allocation reduces risk to ETS manufacturing jobs from 10.6% to 3.5%

(from 2.1% to 0.76% of *total* EU manufacturing jobs)

Minimize job loss s.t. fixed amount of free permits



Optimal allocation reduces risk to ETS manufacturing jobs from 10.6% to 3.5%
(from 2.1% to 0.76% of *total* EU manufacturing jobs)

Which countries gain?

Table: % Change in free permits: EC proposal vs. counterfactuals

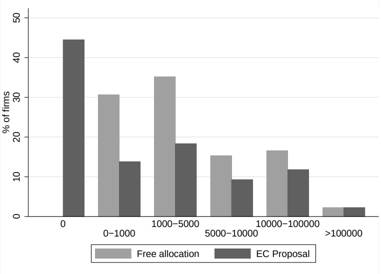
	Belgium	France	Germany	Hungary	Poland	UK
Counterfactual						
Proportional reduction	2.6	-1.3	-0.0	-6.8	2.7	-1.1
Minimal job risk	12.2	-12.4	48.1	9.2	14.1	-17.3
Minimal carbon risk	5.1	-7.4	43.7	-6.5	-2.5	-10.2

- Need a model that justifies non-uniform permit allocations because looking at raw data doesn't control for differences in relocation risk.
- Relevant benchmark is the optimal allocation across firms.
- Germany and Belgium gain
- France and UK lose

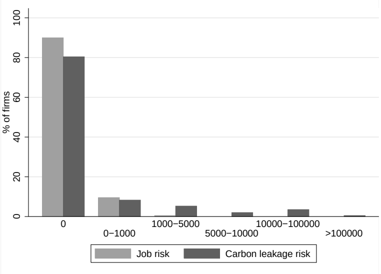
Distribution of subsidies per job

Optimal allocation mitigates excessive inequality

Reference scenarios



Minimal cost scenarios



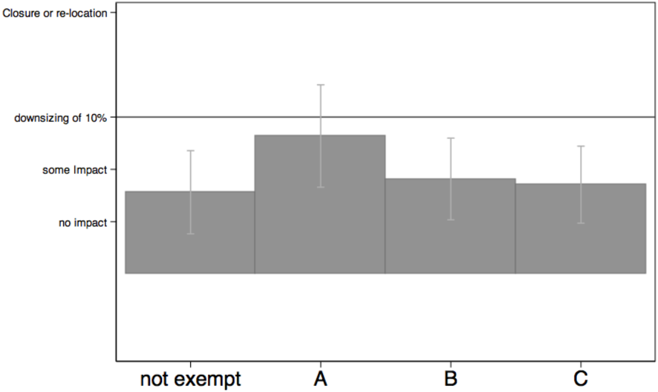
Conclusions

- If industry compensation is based on extensive-margin response to regulation, relocation risk should be be equalized across firms
- EC's trade intensity criterion has little to say about relocation risk across sectors
- €6.7 bn could be raised through a simple modification of the EC criteria without increasing relocation risk
- Allocation of free permits at the firm level is more efficient and reduces excessive per-job subsidies to individual firms

External data sources

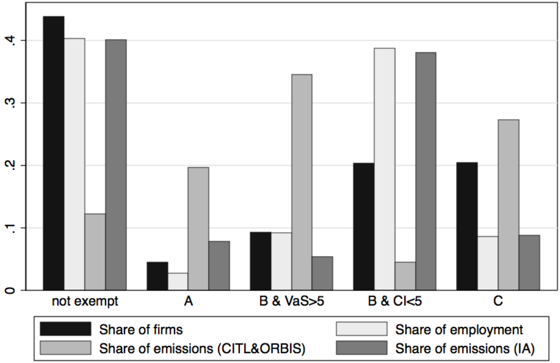
Emissions	Official registry of the EU ETS: Community Independent Transaction Log (CITL)
Performance	ORBIS database provides balance-sheet data on all firms
Trade	use PRODCOM and EUROSTAT sources to calculate sector level trade intensities.
Matching	Interview sample: 429 EU ETS firms, hand-matched to ORBIS and CITL. Full sample: Based on Calel and Dechezlepretre (2012), match 75% of CITL installations to 4,254 firms in ORBIS

Regression coefficients on different category dummies



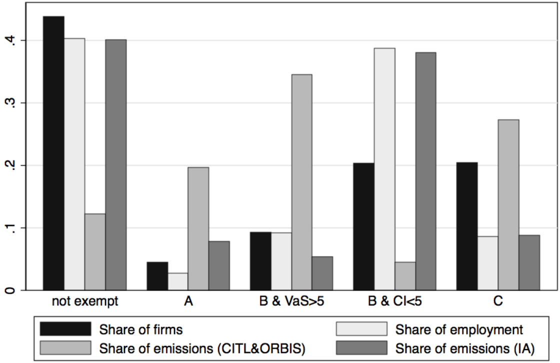
Significant downsizing only in very carbon intensive sectors (A)

Share of firms, employment and emissions in different categories



- NOT exempting C and B & VaS<5 could raise €7 bn p.a.
- Heterogeneity within groups: could do better by defining exemptions at the firm level

Share of firms, employment and emissions in different categories



- NOT exempting C and B & VaS<5 could raise €7 bn p.a.
- Heterogeneity within groups: could do better by defining exemptions at the firm level

Optimality condition

The first-order condition for an interior solution is given by

$$\Phi' \left[-\pi_i(q_i)\right] \frac{\partial \pi_i(q_i)}{\partial q_i} \left[\alpha Jobs_i + (1-\alpha) Emissions_i\right] = \lambda \qquad \forall i. \tag{1}$$

Equalize *marginal* damage from relocation across firms

Free permits should *not necessarily* be allocated to the firms with the highest propensity to relocate Φ. Optimality requires the regulator to equalize, across firms, the reduction in expected job losses and carbon leakage brought about by the last free permit allocated to each firm.

Solving for optimal allocations

Corner solutions $\Rightarrow$ use dynamic programming in the cross section of firms

- For fixed (arbitrary) ordering of firms write the Bellman equation as

$$V_i\left(s_i\right) = \min_{0 \leq q_i \leq s_i} \Phi\left[-\pi_i(q_i)\right]\left[\alpha l_i + (1-\alpha)e_i\right] + V_{i+1}\left(s_i - q_i\right)$$

  - s_i: stock of permits when reaching firm i in the sequence and
  - $V_{i+1}\left(s_i - q_i\right)$: value of leaving $s_i - q_i$ permits to remaining firms in the sequence.

Dual program: Allocate a fixed pie of relocation risk so as to minimize total permits

- Invert $r(q_i)$ to get $q_i = \pi_i^{-1}\left[-\Phi_i^{-1}\left(\frac{r_i}{\alpha l_i + (1-\alpha)e_i}\right)\right]$, $(\Phi_i(-\pi_i(\cdot))$ strictly monotonic in $q_i)$
- Rewrite the dual program

$$\min_{\{r_i \geq 0\}} \sum_{i=1}^{n} \pi_i^{-1}\left[-\Phi_i^{-1}\left(\frac{r_i}{\alpha l_i + (1-\alpha)e_i}\right)\right] \text{ s. t. } \left(\sum_i r_i \leq \bar{R}\right).$$

Solving for optimal allocations

Corner solutions $\Rightarrow$ use dynamic programming in the cross section of firms

- For fixed (arbitrary) ordering of firms write the Bellman equation as

$$V_i\left(s_i\right) = \min_{0 \leq q_i \leq s_i} \Phi\left[-\pi_i(q_i)\right]\left[\alpha l_i + (1-\alpha) e_i\right] + V_{i+1}\left(s_i - q_i\right)$$

  - s_i: stock of permits when reaching firm i in the sequence and
  - $V_{i+1}\left(s_i - q_i\right)$: value of leaving $s_i - q_i$ permits to remaining firms in the sequence.

Dual program: Allocate a fixed pie of relocation risk so as to minimize total permits

- Invert $r(q_i)$ to get $q_i = \pi_i^{-1}\left[-\Phi_i^{-1}\left(\frac{r_i}{\alpha l_i + (1-\alpha) e_i}\right)\right]$, $\left(\Phi_i\left(-\pi_i(\cdot)\right)\right)$ strictly monotonic in q_i)
- Rewrite the dual program

$$\min_{\{r_i \geq 0\}} \sum_{i=1}^{n} \pi_i^{-1}\left[-\Phi_i^{-1}\left(\frac{r_i}{\alpha l_i + (1-\alpha) e_i}\right)\right] \text{ s. t. } \left(\sum_i r_i \leq \bar{R}\right).$$

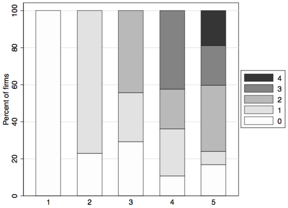
Marginal impact of free permits on relocation risk

1. *"Do you expect that government efforts to put a price on carbon emissions will force you to outsource parts of the production on this business site in the foreseeable future, or to close down completely?"*
2. *"How would your answer to the previous question change if you received a free allowance for 80% of your current emissions?"*

Scoring:

- Low(1): No impact of this kind
- Mid(3): Significant reduction (>10%) in production or employment due to outsourcing
- High(5): Complete close-down

score change with 80% free



Firm-specific relocation propensity

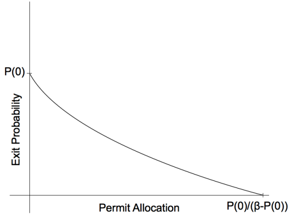
- Linear approximation to profit function: $\pi_i(q_i) = a_{0i} + a_{1i} q_i$
- Logistic relocation probability $\Pr(y_i = 1 | q_i)$

$$= \Phi_i\left(-\pi_i(q_i)\right) = \frac{1}{1 + \exp\left(\beta_{0i} + \beta_{1i} q_i\right)_i}$$

where $\beta_{0i} \equiv \frac{a_{i0} + \mu_\epsilon}{\sigma_\epsilon}$ and $\beta_{1i} \equiv \frac{a_{1i}}{\sigma_\epsilon}$.

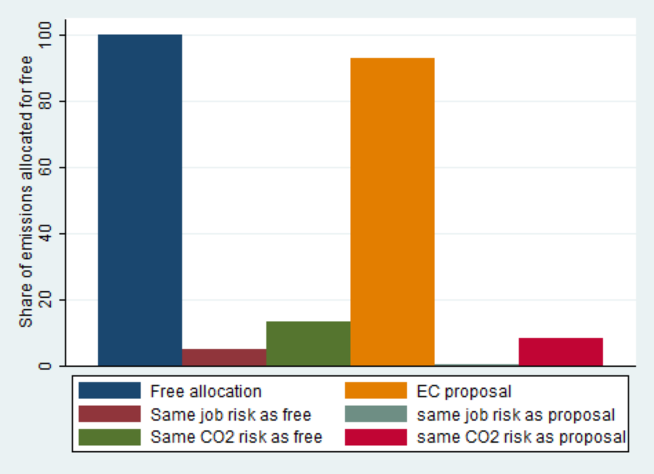
- Back out β_0, β_1 using reported $\Phi_i(0)$ and $\Phi_i(0.8 \cdot e_i)$ where

Score	1	2	3	4	5
$\Phi(\cdot)$	0.01%	5%	10%	55%	99%



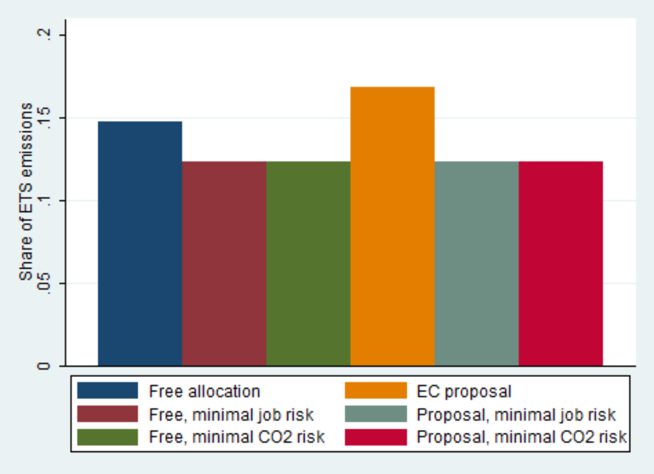
Minimize cost

Minimize amount of free permits s.t. given relocation risk



Share of permits allocated for free

Minimize carbon leakage s.t. fixed amount of free permits



Share of CO_2 at risk of leaking to non-EU countries

Sample representativeness

	(1) Turnover	(2) Employment	(3) Capital
A. All firms			
Firm contacted	-0.0322	-0.0794	0.172
	(0.0786)	(0.0611)	(0.108)
EU ETS firm	2.031***	1.452***	2.530***
	(0.095)	(0.080)	(0.145)
Number of observations	118,874	107,830	113,771
Number of firms	12,322	12,921	118,874
R-squared	0.511	0.364	12322
B. Contacted firms			
Firm granted interview	-0.0983	-0.0373	0.0443
	(0.118)	(0.0957)	(0.150)
EU ETS firm	2.044***	1.547***	2.540***
	(0.124)	(0.107)	(0.160)
Number of observations	26,114	23,933	25,815
Number of firms	1,373	1,420	1,297
R-squared	0.659	0.589	0.618

Notes: Regressions in panel A are based on the set of manufacturing firms with more than 50 employees contained in ORBIS for the six countries covered by the survey. Each column shows the results from a regression of the ORBIS variable given in the column head on a dummy variable indicating whether a firm was contacted or not and a dummy variable indicating whether a firm was taking part in the EU ETS at the time of the interviewing. Panel B shows analogous regressions for the set of contacted companies and with an indicator for whether an

Internal Validity

Vulnerable firms have less market power and more non-EU competitors

Table: Correlations between vulnerability score and other survey variables

	(1) All firms	(2) EU ETS firms
Cost pass-through (%)	-0.107***	-0.109*
Share of non-EU competitors (%)	0.141***	0.135**
Non-EU competitors	0.02	-0.06
Total competitors	0.02	-0.14
Share of sales exported to non EU (%)	-0.08	-0.03
Customers are other businesses (D)	0.105***	0.166***
Multinational firm (D)	0.01	-0.06
CC related products (S)	0.01	0.01
CC related product innovation (S)	-0.02	-0.04
CC related process innovation (S)	0.132***	0.108*
Energy monitoring (S)	0.169***	0.179***
Greenhouse gas monitoring (S)	0.168***	0.1
Energy consumption targets (S)	0.074*	0
Greenhouse gas targets (S)	0.207***	0.160***
Enforcement of targets (S)	0.120***	0.1
Employment	0.02	-0.06
EU ETS firm (D)	0.623***	

External Validity

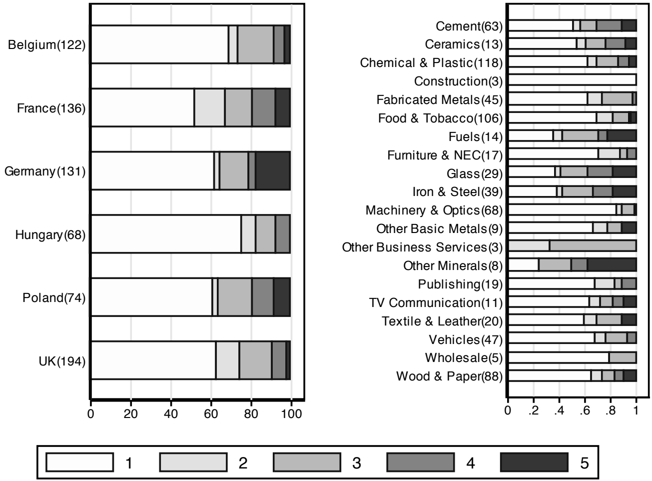
Firms in sectors with high vulnerability are more sensitive to energy prices

$$\triangle \log(emp)_{isct} \quad = \quad \beta_0 + \beta_1 HI_s + \beta_2 \triangle p^e_{sct} + \beta_3 \triangle p^e_{sct} \cdot HI_s + \lambda_{ct} + HI_s \cdot \lambda_{ct} + \Delta\epsilon_{it}$$

- HI_s: indicator that sector s is above the median vulnerability score (VS)
- p^e_{sct}: log energy price in sector s in country c and year t,

	(1)	(2)	(3)	(4)	(5)	(6)
	Δln(Employment)					
	European Union			OECD		
Δln(Energy price)*(High VS)	-0.057***	-0.242***	-2.426***	-0.052***	-0.237***	-1.763***
	(0.009)	(0.041)	(0.320)	(0.008)	(0.033)	(0.242)
Δln(Energy price)	0.035***	0.065***	1.354***	0.034***	0.039***	0.694***
	(0.006)	(0.013)	(0.265)	(0.005)	(0.013)	(0.200)
High VS	-0.007	-0.180**	-1.066***	0.070	0.030	-0.172***
	(0.024)	(0.080)	(0.157)	(0.071)	(0.051)	(0.061)
Number of firms	93,831	93,831	93,831	129,867	129,867	129,867
Number of observations	407,905	407,905	407,905	516,128	516,128	516,128
R-squared (OLS and 1st stage)	0.039	0.727	0.718	0.034	0.695	0.682
Method	OLS	IV (1 lag)	IV (2 lags)	OLS	IV (1 lag)	IV (2 lags)

Vulnerability score averages



The EC criteria for exempting sectors from permit auctions

A. High Carbon Intensity (CI)

$$CI = \frac{\text{direct} + \text{indirect emissions of } CO_2[t]}{\text{gross value added}\,[€]} \cdot \frac{€30}{t} > 30\%$$

B. High Trade Intensity (TI)

$$TI = \frac{\text{exports non EU} + \text{imports non EU}}{\text{turnover EU} + \text{imports non EU}} > 30\%$$

C. Intermediate CI and TI

$$5\% < CI \leq 30\% \quad \cap \quad 10\% < TI \leq 30\%$$

The EC criteria for exempting sectors from permit auctions

A. High Carbon Intensity (CI)

$$CI = \frac{\text{direct + indirect emissions of } CO_2[t]}{\text{gross value added } [€]} \cdot \frac{€30}{t} > 30\%$$

B. High Trade Intensity (TI)

$$TI = \frac{\text{exports non EU} + \text{imports non EU}}{\text{turnover EU} + \text{imports non EU}} > 30\%$$

C. Intermediate CI and TI

$$5\% < CI \leq 30\% \quad \cap \quad 10\% < TI \leq 30\%$$

The EC criteria for exempting sectors from permit auctions

A. High Carbon Intensity (CI)

$$CI = \frac{\text{direct} + \text{indirect emissions of } CO_2[t]}{\text{gross value added } [€]} \cdot \frac{€30}{t} > 30\%$$

B. High Trade Intensity (TI)

$$TI = \frac{\text{exports non EU} + \text{imports non EU}}{\text{turnover EU} + \text{imports non EU}} > 30\%$$

C. Intermediate CI and TI

$$5\% < CI \leq 30\% \quad \cap \quad 10\% < TI \leq 30\%$$

Minimal cost allocation vs. actual and proposed allocations

Minimize cost holding fixed relocation risk

	Free allocation			EC proposal		
Program	Actual	Minimal cost		Actual	Minimal cost	
Risk constraint	-	Jobs	CO_2	-	Jobs	CO_2
Firm allocation	100.0	17.1	26.1	92.6	0.3	21.0
Sector allocation	100.0	28.1	27.6	92.6	15.3	26.0

Shares of emissions exempted from auctioning

	Impact Assessment Direct Emissions data	CITL EU ETS/ORBIS data
Current EU criteria (A, B and C)	72.3%	84.8%
A and B & CI>5	32.9%	48.9%
A, B and C – but TI is with less developed countries	51.7%	73.9%
Total emissions from non-power sectors (Million tons of CO_2 equ.)	833.98	748.19

Make optimal allocation operational

- Risk minimization program

$$\min_{\beta_J,\beta_E} \sum_{i=1}^{n} risk_i \left(\frac{Jobs_i^{\beta_J} \cdot Emissions_i^{\beta_E}}{\sum_i Jobs_i^{\beta_J} \cdot Emissions_i^{\beta_E}} \cdot permit\ constraint \right).$$

- Optimal weights: $\beta_{jobs} = 20\%$, $\beta_{emissions} = 80\%$
- Resulting job risk is close to that under the unconstrained optimal allocation (3.6% vs 3.5%)