The impact of unilateral climate policy with endogenous plant location and market size asymmetry

Francesca Sanna-Randaccio
Sapienza Università di Roma

Roberta Sestini
Sapienza Università di Roma

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Purpose of the paper

The paper analyses the impact of unilateral climate policy on the international location strategies of firms in emission intensive sectors, and on the welfare of the area implementing the policy.

Debates:

- Carbon Leakage
- Pollution Haven Hypothesis

Carbon Leakage

Definition

If a policy aimed to limit emissions in a region is the direct cause of an increase in emission outside the region (see EU Directive 2009/29/EC)

Carbon Leakage Rate

IPCC 2007 AR4, Ch. 11, p. 665 "Carbon leakage is defined as the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries".

Carbon Leakage

Combines two related sensitive issues

- the effectiveness of mitigation policy (**emission leakage**)
- the impact on competiveness and job losses **(job leakage**)

Several **channels** via which carbon leakage:

1) via trade flows
2) via FDI (i.e. relocation of production abroad)
3) via the fossil fuel price channel

1) and 2): competitiveness driven carbon leakage channels

Importance of the FDI channel (relocation-driven carbon leakage)

Industry Position on Unilateral Climate Policy

EU ETS third trading period (2013-2020)

Example: **EU Cement Industry**

Study by the Boston Consulting Group (November 2008):

Project conclusions: with full auctioning of allowances by 2020 offshoring between 80% and 100% of EU clinker production.

US: Waxman-Markey (HR 2454) and Kerry-Boxer (S1733)

Example: **American Chemistry Council**, 2009

"..unilateral climate change policy has the potential to drive manufacturing production, jobs and GHG emission to overseas markets..."

Formal Literature on FDI and Environmental Policy

	Exogenous Env Policy One Country	**Exogenous Env Policy** Two Countries	**Endogenous Env Policy** One Country	**Endogenous Env Policy** Two Countries
Exogenous Location One Firm				
Exogenous Location Two Firms			Cole et al (2006)	Bayindir-Upmann (2003)** Kayalica & Lahiri (2005)+
Endogenous Location One Firm		Motta & Thisse (1994)		Markusen et al (1995) Rauscher (1995)- Hoel (1997)**
Endogenous Location Two Firms		Markusen et al.(1993) Markusen (1997)	Ikefujuji et al. (2010)	Ulph & Valentini (2001)+

Notes: ** Integrated markets, no transport costs
+ Third country model, no transport costs
- No transport costs

Drawbacks of Recent Models on FDI and Environmental Policy

- Do not distinguish between different forms of production relocation. Only total relocation considered.
- Transport costs (trade costs) ignored
- Symmetric regions
- Local pollution

Stylized Facts

- Fixed Plant Costs

Mani and Wheeler (1997) Dirty Industry in the World Economy, 1960-1995

- Transport Costs

Mc Kinsey (2006) EU ETS Review

- Asymmetries in Market Size

European Economy 298 (2007) Unilateral Carbon constraint on EI industries

US Interagency Report (2009) The Effects of H.R. 2454 on EITE Industries

Cement Industry

- Large **capital start-up costs** estimated by McKinsey (2006) to amount to 120 million Euro for a 1 million ton plant

- Average operating time of a clinker plant: 30 years

- Characterized by **high transport costs** as compared to unit value.

- In 2006 **trade** of cement and clinker (the primary input to cement) represented **only 7%** of world cement consumption

The model

Firm 1 chooses

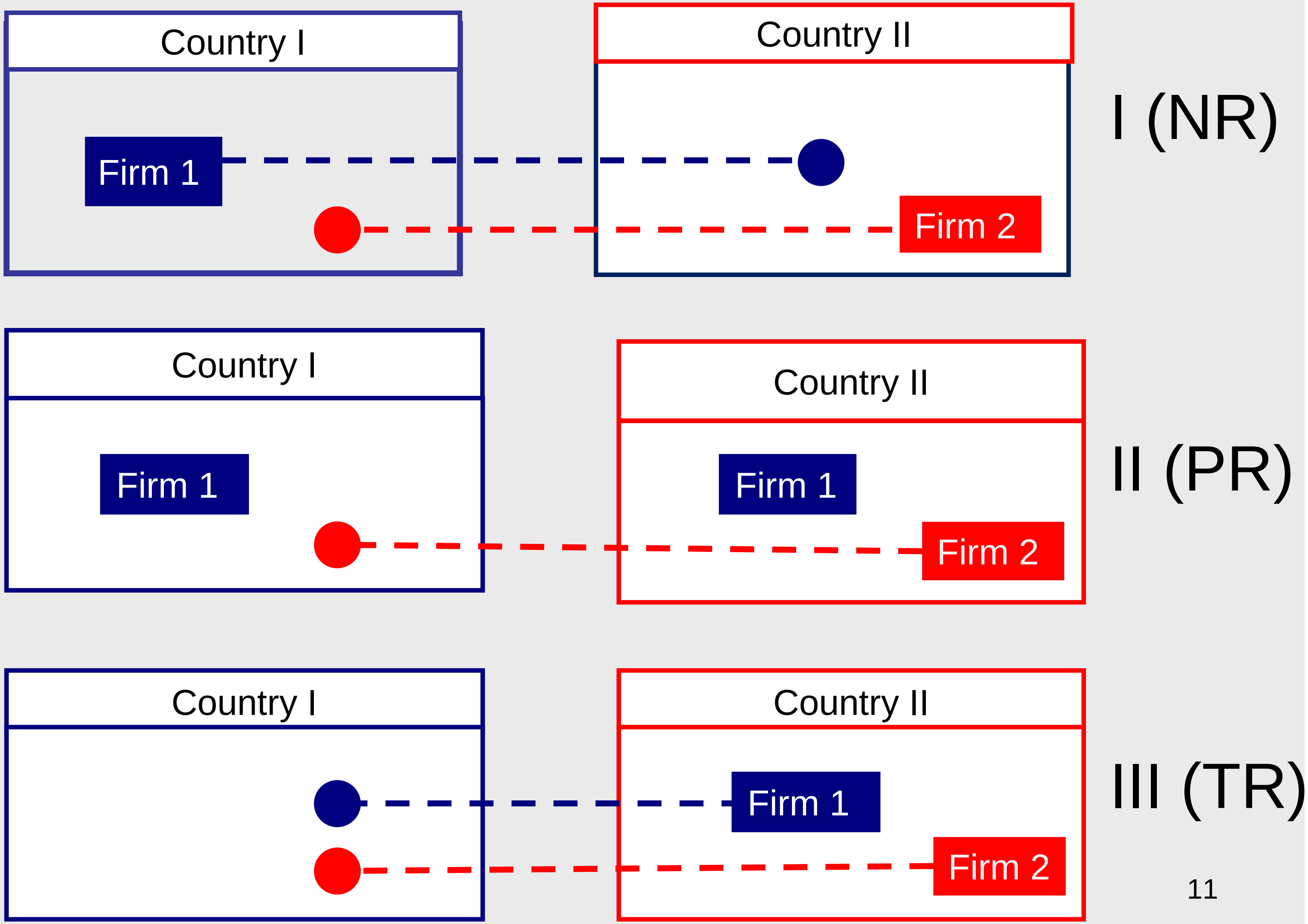
MODE OF FOREIGN EXPANSION

$$S_1 = \{NR, PR, TR\}$$

The two firms decide

SALES IN EACH MARKET

Country I introduces a pollution tax $t_I > t_{II}$



Two countries and two firms: country I introduces $t_I > t_{II}$

I: No relocation (NR)

$$\pi_1^{NR} = (a_I - b_I q_{1,I} - b_I q^e_{2,I})q_{1,I} + (a_{II} - b_{II} q_{1,II} - b_{II} q^e_{2,II})q_{1,II} - cq_{1,I}$$
$$-(c+s)q_{1,II} - t_I(q_{1,I} + q_{1,II}) - F - G_{1,h}$$

II: Partial relocation (PR)

$$\pi_1^{PR} = (a_I - b_I q_{1,I} - b_I q^e_{2,I})q_{1,I} + (a_{II} - b_{II} q_{1,II} - b_{II} q^e_{2,II})q_{1,II} - c(q_{1,I} + q_{1,II})$$
$$-t_I q_{1,I} - t_{II} q_{1,II} - F - G_{1,h} - G_{1,f}$$

III: Total relocation (TR)

$$\pi_1^{TR} = (a_I - b_I q_{1,I} - b_I q^e_{2,I})q_{1,I} + (a_{II} - b_{II} q_{1,II} - b_{II} q^e_{2,II})q_{1,II} - (c+s)q_{1,I}$$
$$-cq_{1,II} - t_{II}(q_{1,I} + q_{1,II}) - F - G_{1,f}$$

Four scenarios

The full symmetry scenario

$(a_I = a_{II},\ b_I = b_{II})$ $G_{1,h} = G_{1,f}$ $G_{1,h}$ not sunk

The market size asymmetry scenario

$(a_I > a_{II},\ b_I < b_{II})$ $G_{1,h} = G_{1,f}$ $G_{1,h}$ not sunk

The plant costs asymmetry scenario

$(a_I = a_{II},\ b_I = b_{II})$ $G_{1,h} = 0$ $G_{1,h}$ sunk

The full asymmetry scenario

$(a_I > a_{II},\ b_I < b_{II})$ $G_{1,h} = 0$ $G_{1,h}$ sunk

The market size asymmetry scenario: $(a_I > a_{II},\ b_I < b_{II})$

(with plant costs symmetry)

if $s < (t_I - t_{II})$ (low transport costs) relocation is total

if $s > (t_I - t_{II})$ (high transport costs) unaltered market structure possible

$\hat{\pi}_1^{NR} > \hat{\pi}_1^{TR}$ iff

$$\frac{4}{9}\left\{ s\left[\frac{(a_I - c - t_I)}{b_I} - \frac{(a_{II} - c - t_I)}{b_{II}}\right] - (t_I - t_{II})\left[\frac{(a_I - c - t_I)}{b_I} + \frac{(a_{II} - c - s - t_I)}{b_{II}}\right] + \frac{s^2}{b_{II}}\right\} > 0 \quad \text{(I)}$$

$\hat{\pi}_1^{NR} > \hat{\pi}_1^{PR}$ iff

$$G_{1,f} > \frac{4}{9}\left[\frac{s + (t_I - t_{II})}{b_{II}}\right](a_{II} - c - s - t_I) \quad \text{(II)}$$

The market size asymmetry scenario: $(a_I > a_{II},\ b_I < b_{II})$

$$\frac{\partial(\hat{\pi}_1^{NR} - \hat{\pi}_1^{TR})}{\partial s} = \frac{4}{9}\left\{\left[\frac{(a_I - c - t_I)}{b_I} - \frac{(a_{II} - c - t_I)}{b_{II}}\right] + \frac{t_I - t_{II}}{b_{II}} + \frac{2s}{b_{II}}\right\} > 0 \qquad \text{(III)}$$

$$\frac{\partial(\hat{\pi}_1^{NR} - \hat{\pi}_1^{PR})}{\partial s} = -\frac{4}{9}\left[\frac{a_{II} - c - 2s - 2t_I + t_{II}}{b_{II}}\right] < 0 \qquad \text{(IV)}$$

The full asymmetry scenario: $G_{1,f} > G_{1,h} = 0$

$$\hat{\pi}_1^{NR} - \hat{\pi}_1^{TR} = \frac{4}{9}\left\{ s\left[\frac{A_I}{b_I} - \frac{A_{II}}{b_{II}}\right] - (t_I - t_{II})\left[\frac{A_I}{b_I} + \frac{B_{II}}{b_{II}}\right] + \frac{s^2}{b_{II}} \right\} + (G_{1,f} - G_{1,h}) \qquad \text{(V)}$$

Market asymmetry

Unilateral climate policy

Lower competition

Plant cost asymmetry

$$\hat{\pi}_1^{PR} - \hat{\pi}_1^{TR} = \frac{4}{9b_I}\left[s - (t_I - t_{II})\right](a_I - c - t_I)$$

$$\hat{\pi}_1^{NR} - \hat{\pi}_1^{PR} = G_{1,f} - \frac{4}{9}\left[\frac{s + (t_I - t_{II})}{b_{II}}\right](a_{II} - c - s - t_I)$$

Impact of unilateral climate policy on the local firm's location strategy

	$s < (t_I - t_{II})$	$s > (t_I - t_{II})$
Full symmetry	Total R	No R* Partial R Total R
Market size asymmetry	Total R	No R Partial R Total R
Plant costs asymmetry	No R Total R	No R Partial R
Market size & plant costs asymmetry	No R Total R	No R Partial R

Long Term: Full symmetry; Market size asymmetry

Short/Medium Term: Plant costs asymmetry; Market size & plant costs asymmetry

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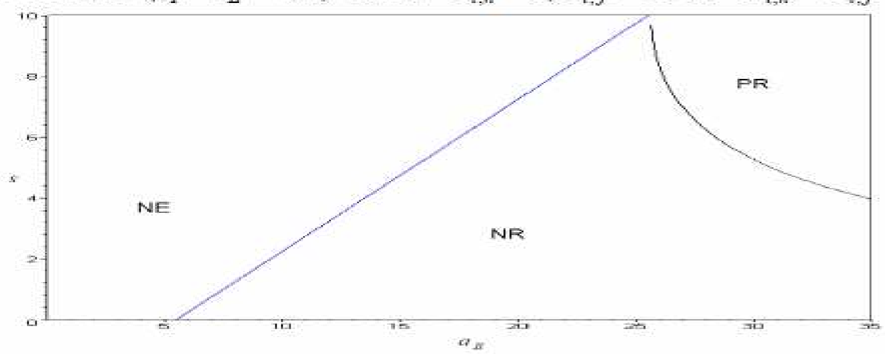
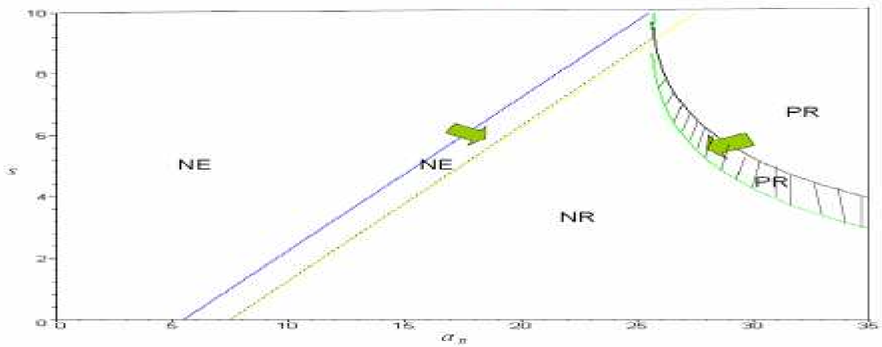
Impact of unilateral climate policy

(regions drawn for $a_I = 36,\ b_I = 2,\ b_{II} = 3,\ c = 5,\ t_{II} = 0.5,\ F = 10$)

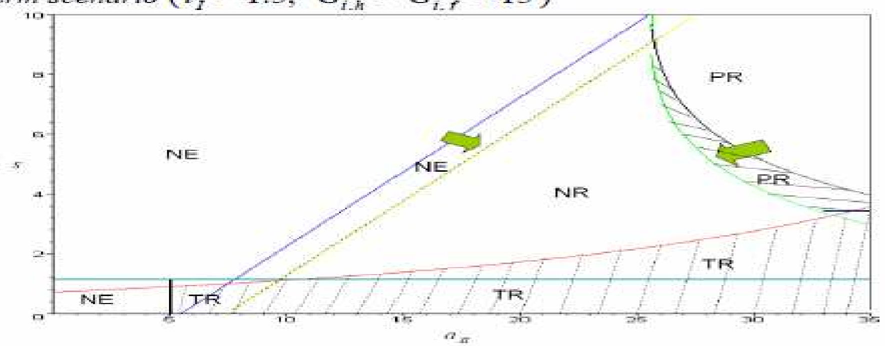
1.a *Baseline scenario* ($t_I = t_{II} = 0.5$; *either* $G_{i,h} = 0, G_{i,f} = 15$ *or* $G_{i,h} = G_{i,f} = 15$)



1.b *Short /medium-term scenario* ($t_I = 1.5$; $G_{i,h} = 0$, $G_{i,f} = 15$)



1.c *Long-term scenario* ($t_I = 1.5$; $G_{i,h} = G_{i,f} = 15$)



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Impact of Unilateral Climate Policy

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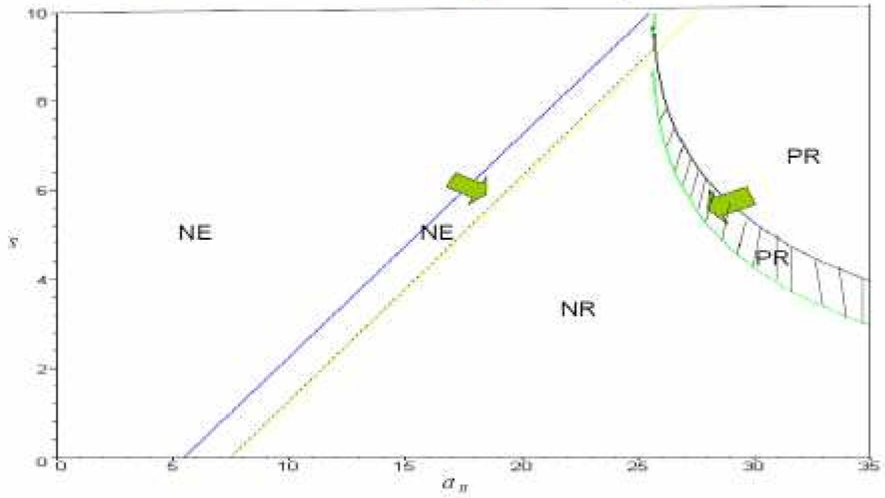
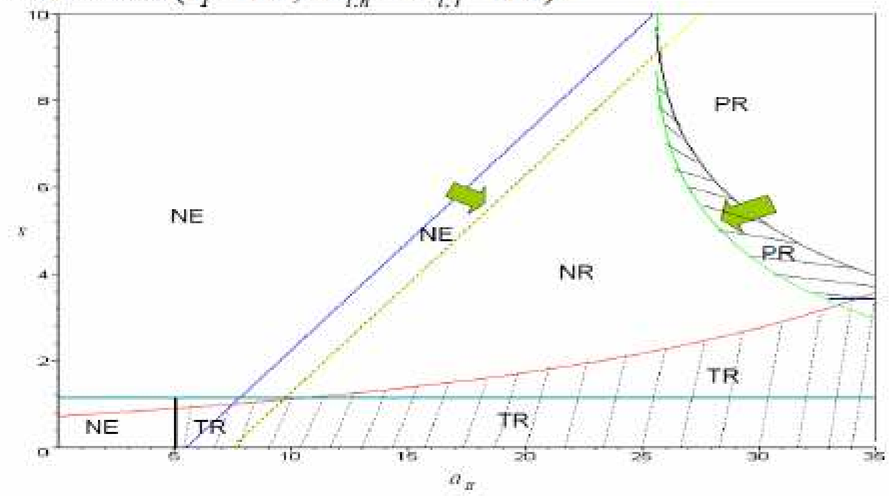


1.c *Long-term scenario* $(t_I = 1.5;\ G_{i,h} = G_{i,f} = 15)$



Welfare impact of unilateral climate policy

$$\hat{W}_I^n = C\hat{S}_I^n + \hat{\pi}_1^n + \hat{T}_I^n - \frac{\gamma_I}{2}(Q_W^n)^2 \qquad \text{(VI)}$$

$$(\hat{W}_I^n - \tilde{W}_I) \qquad n \in \{NR, PR, TR\}$$

Job leakage is a function of the fall in domestic production

$$J\hat{L}^{NR} = -\varphi(\hat{Q}^{NR}_{I,p} - \tilde{Q}_{I,P}) = \varphi\left[\frac{2(t_I - t_{II})}{3b_I} + \frac{2(t_I - t_{II})}{3b_{II}}\right] \quad \text{(VII)}$$

$$J\hat{L}^{PR} = -\varphi(\hat{Q}^{PR}_{I,p} - \tilde{Q}_{I,P}) = \varphi\left[\frac{2(t_I - t_{II})}{3b_I} + \frac{(a_{II} - c - t_{II} - 2s)}{3b_{II}}\right] \quad \text{(VIII)}$$

$$J\hat{L}^{TR} = -\varphi(\hat{Q}^{TR}_{I,p} - \tilde{Q}_{I,P}) = \varphi\left[\frac{(a_I - c - t_{II} + s)}{3b_I} + \frac{(a_{II} - c - t_{II} - 2s)}{3b_{II}}\right] \quad \text{(IX)}$$

$$J\hat{L}^{NR} < J\hat{L}^{PR} < J\hat{L}^{TR}$$

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Environmental effectiveness (and thus the emission leakage) assessed in terms of the impact on the global level of emissions

$$(\hat{Q}_W^{NR} - \tilde{Q}_W) = -\left[\frac{t_I - t_{II}}{3b_I} + \frac{t_I - t_{II}}{3b_{II}}\right] < 0 \qquad \text{(X)}$$

$$(\hat{Q}_W^{PR} - \tilde{Q}_W) = -\left(\frac{t_I - t_{II}}{3b_I}\right) + \frac{s}{3b_{II}} \qquad \text{(XI)}$$

$$(\hat{Q}_W^{TR} - \tilde{Q}_W) = -\frac{s}{3b_I} + \frac{s}{3b_{II}} < 0 \qquad \text{(XII)}$$

Welfare impact of a unilateral climate policy if NR

- World emissions fall
- Consumer aggregate welfare $(AC\hat{S}_I^{NR} = C\hat{S}_I^{NR} + \hat{T}_I^{NR} - (\gamma_I/2)(Q_W^{NR})^2)$ rises although consumer surplus narrowly defined falls.
- Firm 1 global profits fall

$(\hat{W}_I^{NR} - \tilde{W}_I) > 0 \quad iff$ (Given $(a_I > a_{II},\ b_I = b_{II} = b)$)

$$2\gamma_I(4a_I + 4a_{II} - 8c - 2t_I - 6t_{II} - 4s) > b(6a_I + 2a_{II} - 8c + 7t_I + 9t_{II} - 4s) \quad \text{(XIII)}$$

A positive net impact requires that a high importance is assigned by the national community to the environmental damage (i.e. a high value of γ_I).

Welfare impact of a unilateral climate policy if PR

- World emissions may rise (iff $\frac{s}{t_I - t_{II}} > \frac{b_{II}}{b_I}$)
- Sign of impact on consumer aggregate welfare is undetermined

$(\hat{W}_I^{PR} - \tilde{W}_I) < 0 \quad if$ (Given $(a_I > a_{II},\ b_I = b_{II} = b)$)

$$\left[3t_I(2A_I + t_I) - 8s(A_{II} - s)\right] + \gamma_1\left[(s - t_I)(4A_I + 4A_{II} - t_I - 3s)\right] > 0 \quad \text{(XIV)}$$

A high value of γ_I enhances the negative effect on welfare (since with $(b_I = b_{II} = b)$ world pollution increases).

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Welfare impact of a unilateral climate policy if TR

- World emissions fall (or unchanged if $(b_I = b_{II} = b)$)

- Aggregate consumer welfare is likely to fall as **the carbon tax revenue decreases** due to all production being relocated

- The overall effect on welfare, when $(b_I = b_{II} = b)$ and thus $(\hat{D}_I^{TR} - \tilde{D}_I) = 0$, is negative.

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Conclusions

When considering the impact of unilateral climate policy:

1)Fear of TR highly exaggerated in the short/medium term (i.e. when domestic plant costs are sunk). With HTC (most likely scenario) TR cannot be an optimal strategy.

2)However, if the asymmetry in climate policy is expected to persist over the long run and the market asymmetry is limited, TR may be the equilibrium also with high transport costs. This however requires stable expectations as to future market conditions and regulatory regime.

3) In the short/medium-term, if there is a location strategy shift, it will take the form of PR. With limited market asymmetry, the global level of pollution may rise. However, the stricter pollution measures are likely only to accelerate a decision which would be taken in any case later on.

4) An unilateral climate policy leading to NR may rise welfare. This requires that the society’s assessment of the disutility of pollution is high. On the other hand, the net effect on welfare is likely to be negative when the policy leads to partial or total relocation.

5) Carbon leakage provisions, aiming to discourage producers from relocating abroad, have been mainly designed to deter TR, which instead appears to be less likely than PR (e.g. the “border tax adjustment”).

6) An area implementing an unilateral climate policy should enjoy a large market asymmetry (which implies a small size of the non-cooperating area) to prevent relocation. Furthermore, it should avoid fixing the carbon price too high, in order not to fall in the low transport cost scenario which supports the TR outcome.

Future research agenda

- MNEs and the international transfer of low-carbon technologies.

- Climate policy and international trade policy

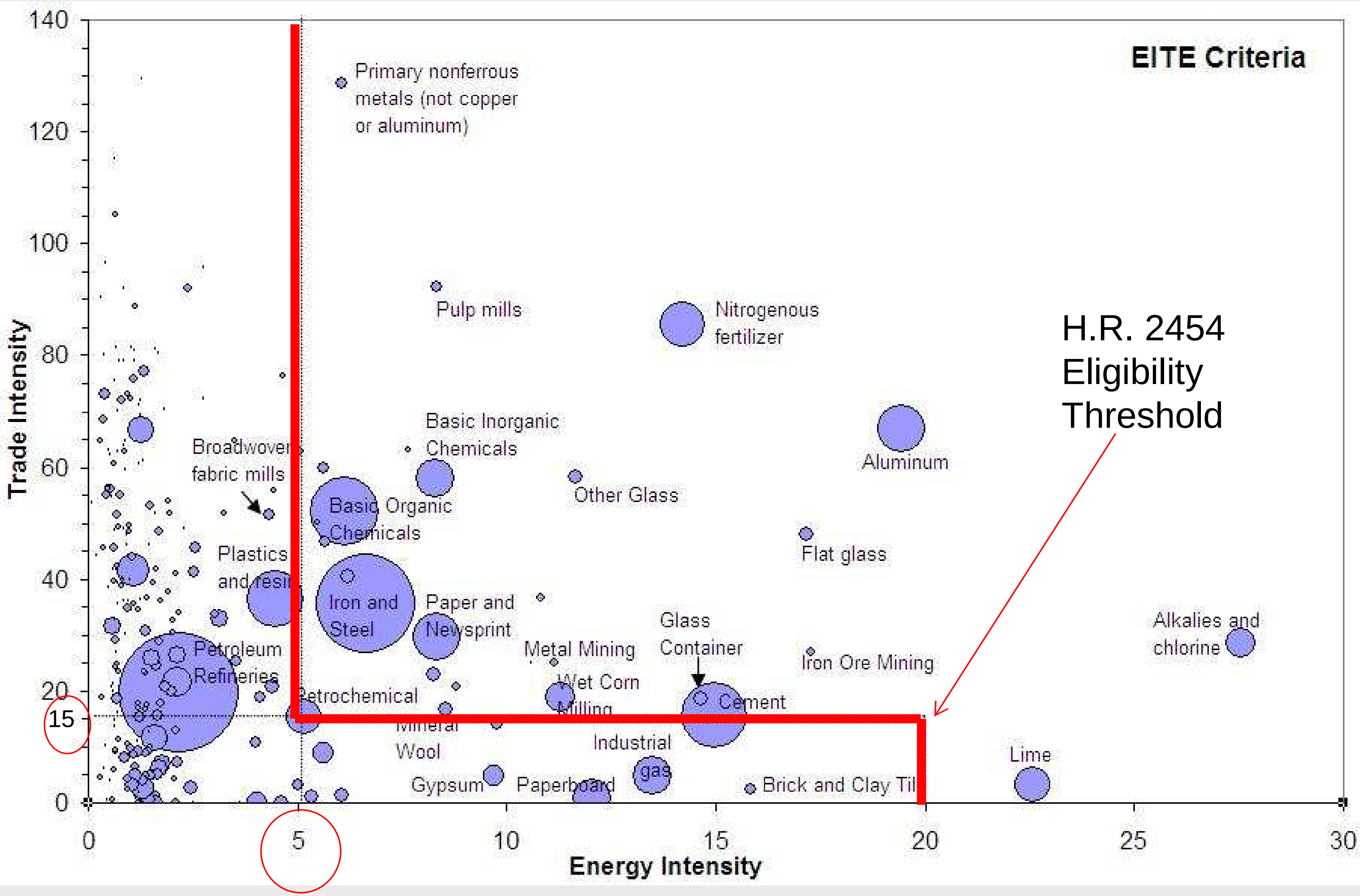
US Climate Policy (Waxman-Markey bill) Criteria for Identifying EITE Industries

1) Energy intensity* (or Carbon Intensity**) ≥5%
   and Trade Intensity*** ≥ 15 % **or**

2) Energy intensity (or Carbon Intensity) ≥ 20% regardless of trade intensity

*E**nergy intensity:** energy expenditures / the value of domestic production.
****GHG intensity**: total GHG emissions (including indirect emissions) times **$20 per ton of emissions** / the value of the industry's domestic production.
***T**rade intensity:** value of its exports + imports / the value of its domestic production and imports

US EITE Criteria: Sectors by NAICS Code (6-digit level)



Source: Bradbury, World Resources Institute

US: two measures to address emission leakage and competitiveness impact

- **Output-based allocations (or rebates)** to EITE. Freely allocate (or rebate) allowances to EITE on a continuously updating output-based formula (guaranteed to 2025; phased out by 2035).

- **Border taxes** on imports starting in 2020 if international negotiations and actions are not sufficient and allowance rebates do not fully compensate affected industries .

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EU Climate Policy
Criteria for identifying sectors exposed to a significant risk of carbon leakage (EU Directive 2009/29/EC):

1) Additional Costs due to the Directive* as a proportion of gross value added ≥ 5% **and** Trade Intensity >15 % (10a (15)) **or**

2) Additional Costs due to the Directive as a proportion of gross value added ≥ 30% (10a (16a)) **or**

3) Trade Intensity >30 % (10a (16b)) regardless of EI

* Based on an average carbon price of €30/tCO_2

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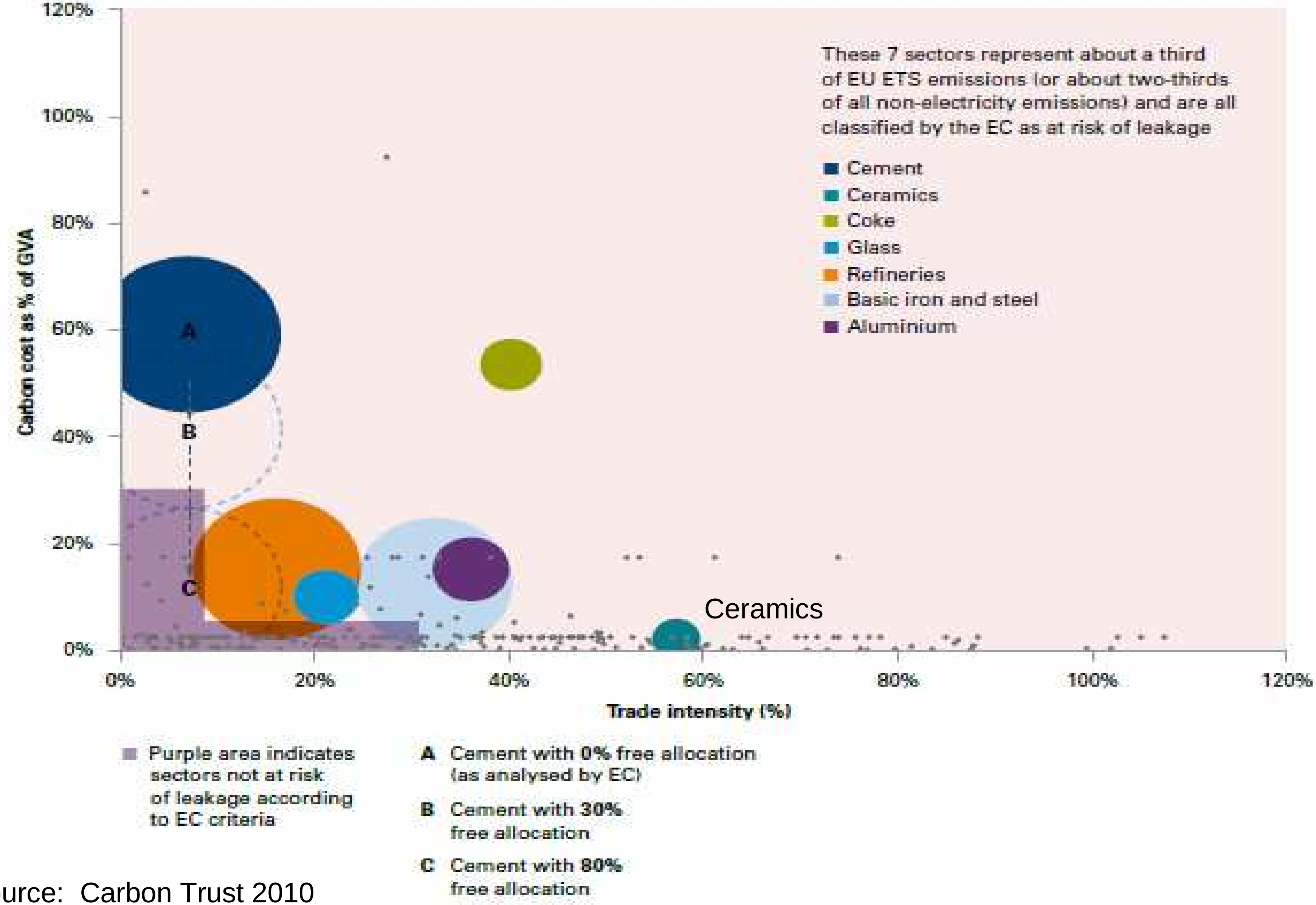
EC classification of sectors at risk of carbon leakage



Source: Carbon Trust 2010

EU provisions for sectors exposed to carbon leakage

- In 2013 - 2020, 100% free allocation of allowances (on a product specific ex-ante benchmarks basis). Predetermined amount of allowances for each unit of the good (historical production).

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Trade off between addressing carbon leakage concerns and distortion of carbon price signal

- EU adopted a wide definition (151 NACE-4 sectors out of 258 examined). Free allocation less impact on carbon price but less effective in addressing leakage.

- However EU new entrant reserve and closure rules allow allocation to vary with production capacity. Furthermore different trading periods.

- US adopted a stricter criteria (44 six-digit sectors out of 500 examined). However OBR is an output subsidy which reduces the price signal.

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