"Carbon Taxes and Border Tax Adjustments: Might Industrial Organization Matter?"

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Seminar: University of Guanajuato

Guanajuato, Mexico

March 2, 2012

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Trade and Climate Policy

With no international carbon price, domestic climate policy may affect *competitiveness* of domestic firms

Non-universal application of climate policies also creates potential for *carbon leakage*

Provisions for border tax adjustments (BTAs) on energy-intensive imports in US and EU climate legislation

Border tax adjustments (BTAs) for domestic taxes legal under WTO/GATT rules, as long as they have *neutral* impact on trade

Competitiveness

Competitiveness and carbon leakage typically linked in policy debate, but former is harder to define

Typically thought of in terms of market share and/or firms' profits – a function of market structure, technology and behavior of firms (WTO/UNEP, 2009)

Appropriate to analyze climate policy and BTAs in context of *strategic trade theory* and environmental policy (Conrad, 1993; Barrett, 1994)

If firms earn above normal profits, climate policy may shift rents between domestic and foreign firms

Which Industries?

Steel, aluminum, chemicals, paper and cement (Houser *et al*., 2009; Monjon and Quirion, 2010)

Appropriate to assume upstream and downstream sectors are imperfectly competitive:

> **Electricity generation now typically modeled as oligopolistic, e.g., Fowlie (2009)**
>
> **Carbon leakage also modeled in oligopolistic setting, e.g., steel (Ritz, 2009)**

Apply McCorriston and Sheldon's (2005) model of successive oligopoly to BTAs and climate policy

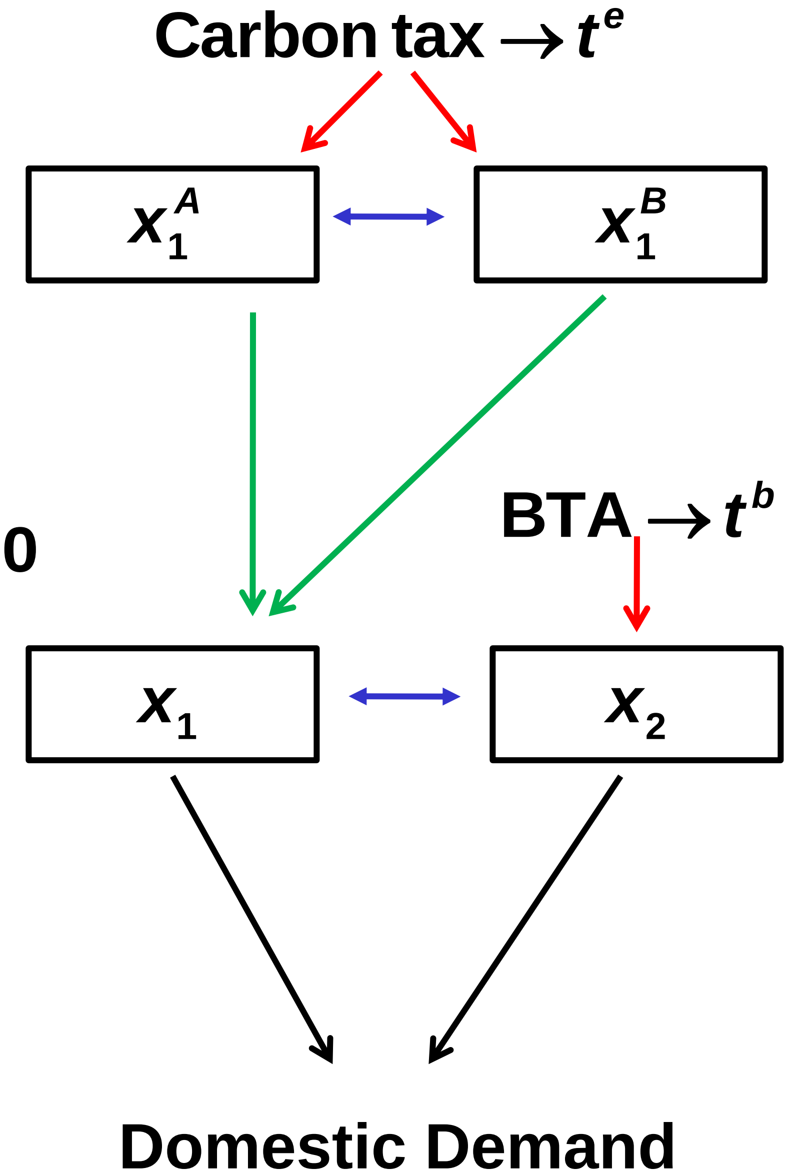
Vertical Market Structure

<u>**Stage**</u>

Domestic Upstream:

Technology:
$$\begin{cases} x_1 = \phi x_1^u \\ x_1^u = x_1^A + x_1^B \\ e_1 = g(x_1^u), g'(x_1^u) > 0 \end{cases}$$

Domestic Downstream:



Successive Oligopoly Model

- **Three-stage game:**

  (1) Domestic government commits to t^e and t^b

  (2)/(3) Nash equilibria upstream and downstream

- **Downstream revenue functions:**

$$R_1(x_1, x_2) \qquad (1)$$

$$R_2(x_1, x_2) \qquad (2)$$

- **Downstream profit functions:**

$$\pi_1 = R_1(x_1, x_2) - c_1 x_1 \qquad (3)$$

$$\pi_2 = R_2(x_1, x_2) - c_2 x_2 \qquad (4)$$

Downstream Equilibrium

- **First-order conditions are:**

$$R_{1,1} = c_1 \quad (5)$$

$$R_{2,2} = c_2 \quad (6)$$

- **Nash equilibrium downstream:**

$$\begin{bmatrix} R_{1,11} & R_{1,12} \\ R_{2,21} & R_{2,22} \end{bmatrix} \begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix} \quad (7)$$

- **Slopes of reaction functions:**

$$dx_1 / dx_2 = r_1 = -(R_{1,12} / R_{1,11}) \quad (8)$$

$$dx_2 / dx_1 = r_2 = -(R_{2,21} / R_{2,22}) \quad (9)$$

where for *strategic substitutes* (*complements*)

$R_{i,ij} < 0 (> 0)$, $r_i < 0 (> 0)$

Downstream Equilibrium

- **Solution found by re-arranging and inverting (7), and simplifying notation:**

$$\begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \Delta^{-1} \begin{bmatrix} a_2 & -b_1 \\ -b_2 & a_1 \end{bmatrix} \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix} \qquad (10)$$

where: $a_1 = R_{1,11} \quad a_2 = R_{2,22}$

$b_1 = R_{1,12} \quad b_2 = R_{2,21}$,

and for stability, $a_i < 0$, **and** $\Delta = (a_1 a_2 - b_1 b_2) > 0$

- **From (8) and (9), substitute** $r_i = -(b_i) / a_i$ **into (10):**

$$\begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \Delta^{-1} \begin{bmatrix} a_2 & a_1 r_1 \\ a_2 r_2 & a_1 \end{bmatrix} \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix} \qquad (11)$$

Upstream Equilibrium

- In each country, two upstream firms *A* and *B* whose combined output is $x_j^A + x_j^B = x_j^U$

- Upstream equilibrium derived in similar fashion to that downstream:

$$\begin{bmatrix} dx_j^A \\ dx_j^B \end{bmatrix} = (\Delta_j^U)^{-1} \begin{bmatrix} a_j^B & a_j^A r_j^A \\ a_j^B r_j^B & a_j^A \end{bmatrix} \begin{bmatrix} dc_j^A \\ dc_j^B \end{bmatrix} \qquad (12)$$

where $a_j^A, a_j^B < 0$, and $(\Delta_j^U) > 0$

- t^e raises domestic upstream costs c_1^A and c_1^B, raising price of electricity, $dc_1 = dp_1^U = p_{1,1}^U(dx_1^A + dx_1^B)$, and thereby affecting imports of final good, dx_2 / dc_1

Carbon Leakage

- **Following Karp (2010), carbon leakage defined as:**

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{g'(x_2^U)}{g'(x_1^U)} \cdot \frac{dx_2^U}{-dx_1^U} \right] \quad (13)$$

- **Given technology and (11), (13) re-written as:**

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{g'(x_2^U)}{g'(x_1^U)} \cdot \frac{\Delta^{-1} a_2 r_2 dc_1}{-(\Delta^{-1} a_2 dc_1)} \right] \quad (14)$$

Using (11), $\Delta^{-1} a_2 dc_1 < 0$, *direction* of carbon leakage determined by r_2, e.g., suppose $g'(x_2^U) = g'(x_1^U)$, then $l > 0$ ($l < 0$) if $r_2 < 0$ ($r_2 > 0$)

Neutral BTAs

- Assume t^b, can be targeted at imports – affects dc_2 which feeds back into foreign electricity production, $dx_2^U / dc_2 = d(x_2^A + x_2^B) / dc_2$

  and hence carbon leakage by (13)

- WTO/GATT rules not specific on neutrality of BTAs - consider two cases:

  (i) Change in c_2 that keeps *volume of imports* constant given t^e

  (ii) Change in c_2 that keeps *market share of imports* constant given t^e

- **(i) Appropriate BTA defined as:**

$$t^b = \frac{(dx_2 / dc_1)\ t^e}{-(dx_2 / dc_2)} \qquad (15)$$

Already know dx_2/dc_1 depends on sign of r_2

Using (11), effect of t^b is:

$$dx_2 = \Delta^{-1} a_1 dc_2 \qquad (16)$$

Since $\Delta^{-1} > 0$ and $a_1 < 0$, then $dx_2 / dc_2 < 0$

Under imperfect competition, if $t^b = t^e$, there will be non-neutral outcome, *pass-through* of t^e matters

- **Using (11) and (15), and after some manipulation:**

$$t^b = -r_2\{p_{1,1}^U D\}t^e = -r_2 dc_1 \qquad (17)$$

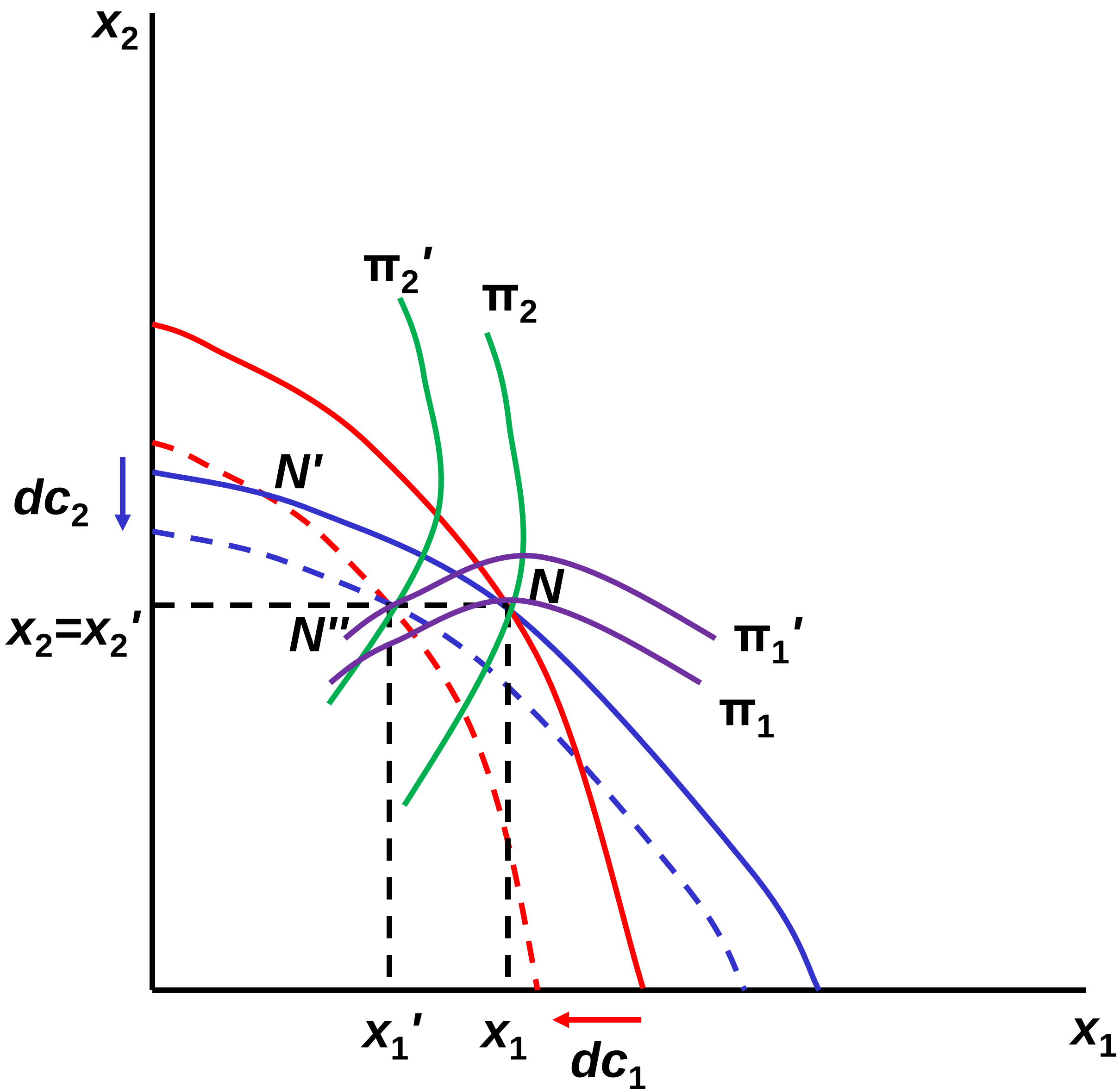
where $p_{1,1}^U < 0$, $D = (\Delta^U)^{-1}[a_1^B(1+r_1^B) + a_1^A(1+r_1^A)] < 0$, and for reasonable characterizations of demand, $\{.\} < 1$

Form and size of t^b depend on r_2 and extent of pass-through of t^e respectively:

- **t^b is an import tax (subsidy) if $r_2 < 0$ ($r_2 > 0$)**

- **$t^b < t^e$ due to *under-shifting* of carbon tax by domestic electricity producers**

Figure 1: Import Volume Neutrality



- **(ii) Appropriate BTA defined as:**

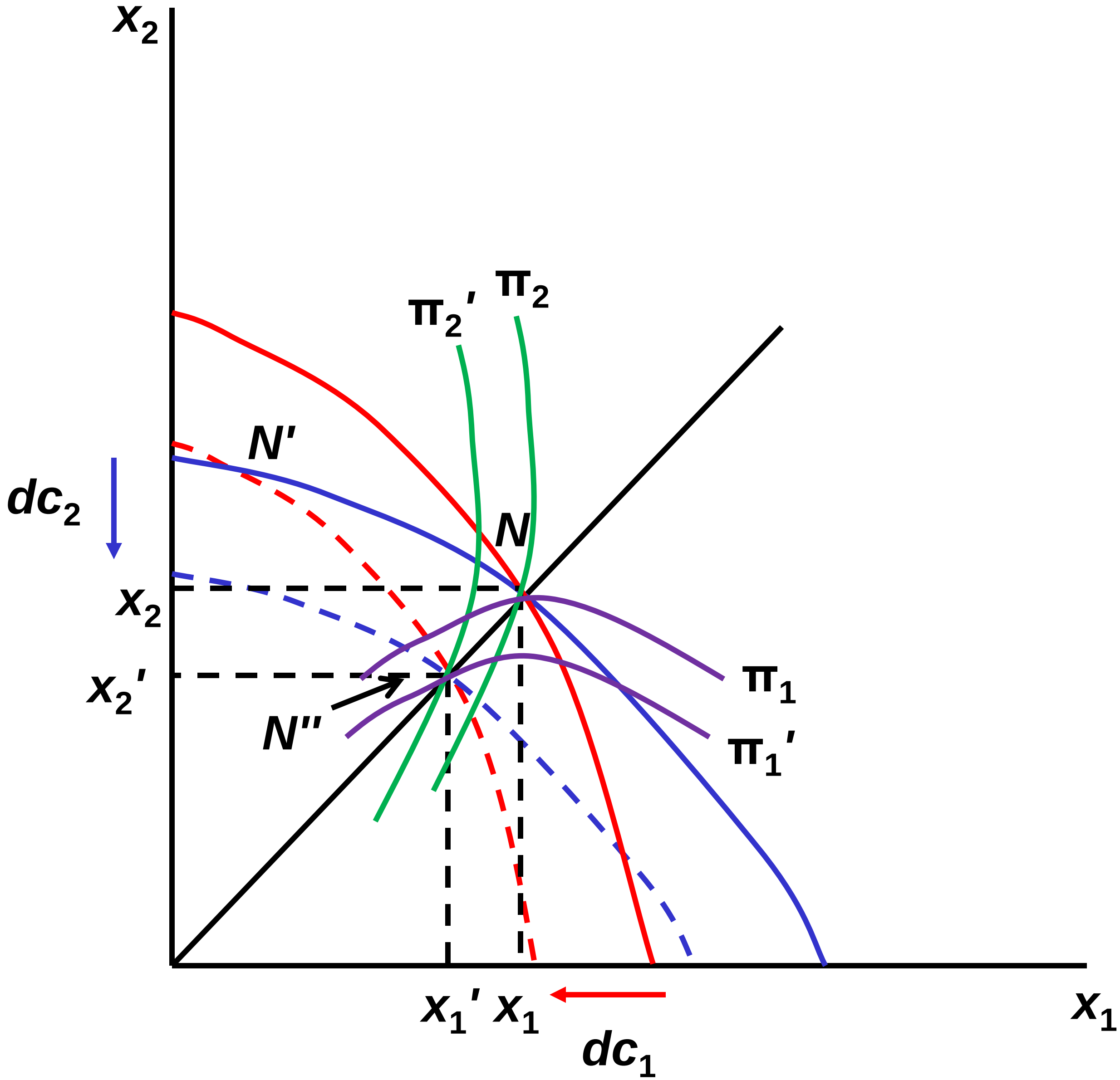
$$t^b = \frac{t^e\,[\,(dx_2 / dc_1) + (\,dx_1 / dc_1)\,]}{[\,(dx_1 / dc_2) + (dx_2 / dc_2)\,]} \qquad (18)$$

Substituting in from (11), neutral t^b is:

$$t^b = \frac{(r_2 + 1)\,t^e}{(r_1 + 1)} = \frac{(r_2 + 1)\,dc_1}{(r_1 + 1)} \qquad (19)$$

- **with $r_i < 0$, and given, $|r_1| > |r_2|$, neutral t^b is an import tax, and t^b for import-share neutrality > t^b for import-volume neutrality**

Figure 2: Import Share Neutrality



Conclusions

Analysis of BTAs more complex when vertically-related markets can be characterized as successive oligopoly

Carbon leakage can be prevented through use of BTAs, but competitiveness concerns not necessarily resolved

Deadweight losses to domestic consumers an issue in presence of carbon tax and BTA

Classic second-best problem: three market failures and only two policy instruments