
AED 7210, Applied Microeconomics
Motivation

- Despite logic for multilateral approach to dealing with climate change, countries pursuing national efforts

- Carbon taxes already applied in several countries, e.g., Australia; while others have chosen system of tradable emissions permits, e.g., EU

- Expectation that energy-intensive industries downstream from electricity generation will face increased costs of production

- Consequently, proposed climate legislation often includes some type of border measure (Frankel, 2009)
Trade and Climate Policy

- With no international carbon price, unilateral climate policy may affect *competitiveness* of domestic firms
- Also, non-universal application of climate policies creates potential for *carbon leakage*
- Related concerns have basis in economics of *pollution havens*, i.e., increased concentration of pollution-intensive activity in countries with weaker climate policy (Perroni and Rutherford, 1993)
- Focus in literature has been on whether trade policy instruments might be used to prevent leakage (Hoel, 1996; Maestad, 1998)
Trade and Climate Policy

- Hoel (1996) shows cooperating countries could set common carbon taxes as well as use import tariffs (export subsidies) on energy-intensive goods to shift terms of trade against free-riders.

- Concern border policies will not be WTO consistent.

- However, if treated as border tax adjustments (BTAs), use in presence of domestic excise tax well-founded in literature on destination-based tax systems (Lockwood and Whalley, 2010).

- Essentially this is basis for EU’s VAT tax which is applied to imports and rebated on exports.
BTAs and WTO Rules

- GATT Article II:2(a) allows members to place on imports of any good, a BTA equivalent to an internal tax on like good.

- However, under GATT Article III:2, BTA cannot be applied in excess of that applied to domestic good.

- Idea is that BTA has to be neutral in terms of impact on trade, i.e., objective is to preserve competitive equality between domestic and imported goods.

- GATT also allows export rebates of a domestic tax as long as rebate does not exceed level of domestic tax, i.e., does not violate GATT Subsidies Code.
Even after much debate about legal permissibility of BTAs, two key aspects remain unresolved with respect to climate policy:

- Will BTAs for carbon taxes be allowed on imports/exports of energy-intensive goods? There is precedent in case of CFCs.

- Will BTAs be allowed for cap-and-trade policies?

Even assuming BTAs are WTO-legal, there is still crucial issue of how to analyze policy that may affect several stages of a vertical production system.
Competitiveness

- Carbon leakage and competitiveness often linked in policy debate, but latter 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; Kennedy, 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; Messerlin, 2012)

- 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

Stage

Domestic Upstream:

Technology:

\[
\begin{align*}
    x_1 &= \phi x_1^u \\
    x_1^u &= x_1^A + x_1^B \\
    e_1 &= g(x_1^u), \quad g'(x_1^u) > 0
\end{align*}
\]

Domestic Downstream:

Carbon tax $\rightarrow t^e$

BTA $\rightarrow t^b$

Domestic Demand
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:

  \[ R_1(x_1, x_2) \] (1)

  \[ R_2(x_1, x_2) \] (2)

- Downstream profit functions:

  \[ \pi_1 = R_1(x_1, x_2) - c_1 x_1 \] (3)

  \[ \pi_2 = R_2(x_1, x_2) - c_2 x_2 \] (4)
Downstream Equilibrium

- First-order conditions are:
  \[ R_{1,1} = c_1 \] \hspace{1cm} (5)
  \[ R_{2,2} = c_2 \] \hspace{1cm} (6)

- Nash equilibrium downstream:
  \[
  \begin{bmatrix}
  R_{1,11} & R_{1,12} \\
  R_{2,21} & R_{2,22}
  \end{bmatrix}
  \begin{bmatrix}
  dx_1 \\
  dx_2
  \end{bmatrix}
  =
  \begin{bmatrix}
  dc_1 \\
  dc_2
  \end{bmatrix}
  \] \hspace{1cm} (7)

- Slopes of reaction functions:
  \[ dx_1 / dx_2 = r_1 = -(R_{1,12} / R_{1,11}) \] \hspace{1cm} (8)
  \[ dx_2 / dx_1 = r_2 = -(R_{2,21} / R_{2,22}) \] \hspace{1cm} (9)

where for strategic substitutes (complements) \[ R_{i,ij} < 0(> 0), \ r_i < 0(> 0) \] (Bulow et al., 1985)
Downstream Equilibrium

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

\[
\begin{bmatrix}
dx_1 \\
dx_2
\end{bmatrix} = \Delta^{-1} \begin{bmatrix}
a_2 & -b_1 \\
-b_2 & a_1
\end{bmatrix} \begin{bmatrix}
dc_1 \\
dc_2
\end{bmatrix}
\]  

where: \( a_1 = R_{1,11} \) \( a_2 = R_{2,22} \)
\( b_1 = R_{1,12} \) \( b_2 = R_{2,21} \),

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

From (8) and (9), substitute \( r_i = -\frac{(b_i)}{a_i} \) into (10):

\[
\begin{bmatrix}
dx_1 \\
dx_2
\end{bmatrix} = \Delta^{-1} \begin{bmatrix}
a_2 & a_1 r_1 \\
a_2 r_2 & a_1
\end{bmatrix} \begin{bmatrix}
dc_1 \\
dc_2
\end{bmatrix}
\]  

(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:

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

(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:

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

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

\[
I = \frac{de_2}{-de_1} = \left[ \frac{g'(x_2^U)}{g'(x_1^U)} \cdot \frac{\Delta^{-1} a_2 r_2 dc_1}{-(\Delta^{-1} a_2 dc_1)} \right]
\]  
(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 \( I > 0 \) \( (I < 0) \) if \( r_2 < 0 \) \( (r_2 > 0) \)
BTAs and Trade Neutrality

- Assume $t^b$, can be targeted at imports – affects $dc_2$ which feeds back into foreign electricity production, and, hence carbon leakage by (13):

$$dx_2^U / dc_2 = d(x_2^A + x_2^B) / dc_2$$

- 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:

\[ t^b = \frac{(dx_2 / dc_1) \ t^e}{-(dx_2 / dc_2)} \]  \quad (15)

Already know \( dx_2/dc_1 \) depends on sign of \( r_2 \)

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

\[ dx_2 = \Delta^{-1} a_1 \ dc_2 \]  \quad (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, i.e., *pass-through* of \( t^e \) matters
Trade Neutrality – Import Volume

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

\[
t^b = -r_2 \{ p_{1,1}^U D \} t^e = -r_2 d c_1 \tag{17}
\]

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
Trade Neutrality – Import Volume

(ii) Appropriate BTA defined as:

\[
t^b = \frac{t^e \left[ \frac{dx_2}{dc_1} + \frac{dx_1}{dc_1} \right]}{\left[ \frac{dx_1}{dc_2} + \frac{dx_2}{dc_2} \right]}
\]  

(18)

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

\[
t^b = \frac{(r_2 + 1) t^e}{(r_1 + 1)} = \frac{(r_2 + 1) dc_1}{(r_1 + 1)}
\]  

(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
Competitiveness – Import Volume

- Under rule that $dx_2 = 0$, change in domestic downstream output is derived from (12), and assuming $a = a_1 \approx a_2$:

$$dx_1 = \Delta^{-1} a(dc_1 + r_1 dc_2) \quad (20)$$

Given $\Delta^{-1} > 0, a < 0, dc_1 > dc_2$, and $|r_1| < 1$, then $dx_1 < 0$

i.e., domestic downstream firm still reduces output

- In terms of profits totally differentiate (3):

$$d\pi_1 = R_{1,1} dx_1 + R_{1,2} dx_2 - c_1 dx_1 + \pi_{1,c_1} dc_1 \quad (21)$$

Given $dx_2 = 0$, and $\pi_{1,c_1} dc_1 = -c_1 dx_1$ from (3), $d\pi_1 < 0$

i.e., domestic downstream firm’s profits decline
Competitiveness – Import Volume

- Totally differentiating (4):

\[ d\pi_2 = R_{2,2} dx_2 + R_{2,1} dx_1 - c_2 dx_2 + \pi_{2,c_2} dc_2 \]  

(22)

and assuming \( a = a_1 \approx a_2 \), (22) can be re-written:

\[ d\pi_2 = R_{2,1} dx_1 + \pi_{2,c_2} dc_2 \]  

(23)

\[ = x_2[\Delta^{-1} p_{2,1} a (dc_1 + r_1 dc_2) - dc_2] \]

\( \Delta^{-1} > 0, p_{2,1} < 0, a < 0 \), and \( r_1 < 0 \), as long as \([.]>0\), then \( d\pi_2 > 0 \)

- Foreign downstream firm’s profits increase – due to BTA being set appropriately, and less than carbon tax
Figure 1: Import Volume Neutrality

$$\pi_1' \quad \pi_2'$$

$$d\pi_2$$

$$x_2 = x_2'$$

$$N'$$

$$N''$$

$$x_1' \quad x_1$$

$$d\pi_1$$
Competition – Import Share

- Derive \( dx_1 \) and \( dx_2 \), assuming \( a = a_1 \approx a_2 \), and using

\[ \text{(19) to substitute in for } dc_2 : \]

\[
dx_1 = \Delta^{-1} \left[ a dc_1 \left( 1 + r_1 \left\{ \frac{(r_2 + 1)}{(r_1 + 1)} \right\} \right) \right] \tag{24}
\]

\[
dx_2 = \Delta^{-1} \left[ a dc_1 \left( r_1 + \left\{ \frac{(r_2 + 1)}{(r_1 + 1)} \right\} \right) \right] \tag{25}
\]

As \( \Delta^{-1} > 0, a < 0, \) and \( r_1 < 0, \) then \( dx_1 < 0, \) and \( dx_1 < 0 \)

- In terms of profits, substitute (24) and (25) into (21) and (22) respectively:
Competitiveness – Import Share

\[ d\pi_1 = x_1 dc_1 \left\{ p_{1,2} \Delta^{-1} a \left[ r_2 + \left( \frac{r_2 + 1}{r_1 + 1} \right) \right] - 1 \right\} \]  \hspace{1cm} (26)

\[ d\pi_2 = x_2 dc_2 \left\{ p_{2,1} \Delta^{-1} a \left[ 1 + (1 + r_1) \left( \frac{r_2 + 1}{r_1 + 1} \right) \right] - 1 \right\} \]  \hspace{1cm} (25)

In (26) and (25), \( \Delta^{-1} > 0, p_{i,j} < 0, a < 0, r_i < 0, \) and \([.] > 0; \) therefore as long as \( p_{1,2} \Delta^{-1} a[.] > 1 \) in (24), and \( p_{2,1} \Delta^{-1} a[.] > 1 \) in (25), then \( d\pi_1 > 0 \) and \( d\pi_2 > 0 \)

- Domestic and foreign downstream firms’ profits increase, collusion being “facilitated”
Figure 2: Import Share Neutrality

\[
\begin{align*}
\pi_2, & \quad \pi_2' \\
\pi_1, & \quad \pi_1' \\
N', & \quad N'' \\
N & \quad \text{Point of Intersection}
\end{align*}
\]
Political Economy of BTAs

- Domestic downstream firm will lobby for trade-neutrality to be defined in terms of market share – moves it into Pareto-superior profit set
- Foreign downstream firm will lobby for trade-neutrality to be defined in terms of import volume
- In either case, even with trade neutrality and no carbon leakage ensured, deadweight loss to consumers
- Minimizing latter distortion requires third policy instrument
Conclusions

- Analysis of BTAs more complex with vertically-related markets and 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