Professor Ian Sheldon: Trade Seminar
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Topic 3: Imperfect Competition, Trade, and Environmental Policy

Articles:
Motivation (Conrad, 1993)

- Rules on tariffs and export subsidies have resulted in governments seeking other instruments to *shift rents*

- To maintain *competitiveness* and reduce *leakage*, environmental policy instruments may be substitutes for both industrial and trade policy

- In an oligopolistic setting, Conrad (1993) models a dirty industry in two countries competing in a third-country market

- If government taxes SO$_2$ or CO$_2$ emissions, affects its firm’(s) competitiveness – as a consequence, may adopt abatement and input subsidies

- Essentially an application of *strategic trade theory* as originally applied by Brander and Spencer (1985)
Model

- Motivation for government policy: seek to target negative externalities without reducing share of export market captured by domestic firm

- Two-stage game, played by two competing firms, located in two different countries, with two rent-seeking governments:
  
  (1) governments pre-commit to environmental policies
  
  (2) firms determine level of abatement, and choose output to maximize profits

- Equilibrium in (2) is Nash given policy choices in (1)

- Nash game between countries determined by Nash game between firms, resulting in sub-game perfect equilibrium of two-stage game
Stage 2

Production and Abatement Costs:

- Domestic firm produces $x$ at cost $c(x,q(t))$, where $q(t)$ is price of polluting input, other input prices being constant, and thereby omitted from cost function.

- Price of polluting input is:

\[ q(t) = q_0 + ca_a e + t(1-a)e \]  

(1)

where $q_0$ is basic input price, $ca=ca(a)$ is unit abatement cost, which depends on level of abatement $a$ ($0<a<1$), $e$ is emissions coefficient (CO$_2$ per ton of input), and $t$ is emissions tax;

- $ca_a>0$, and $ca_{aa}>0$, i.e, unit abatement costs are increasing and convex in degree of abated emissions.
Stage 2

Firm Behavior:

- **Profit for a domestic firm is:**

\[ \pi(x, X, t) = r(x, X) - c(x, q(t)) \quad (2) \]

where \( r \) is revenue, and \( \pi \) is profit of domestic firm, (upper-case letters refer to foreign firm)

- **Profit for foreign firm is:**

\[ \Pi(x, X, T) = R(x, X) - C(X, Q(T)) \quad (3) \]

where foreign firm’s cost function is:

\[ Q(T) = Q_0 + CA.A.e + T(1 - A)e \quad (4) \]

e being assumed to be the same in both countries
Stage 2

- $x$ and $X$ are substitutes, and marginal revenue of firms declining in output of other firm:
  \[ r_x < 0; \quad r_{xx} < 0; \quad R_x < 0; \quad R_{xx} < 0 \]  
  (5)

- First-order conditions are:
  \[ \pi_x = r_x(x, X) - c_x(x, q(t)) = 0 \]  
  (6)

  \[ \Pi_x = R_x(x, X) - C_x(X, Q(T)) = 0 \]  
  (7)

  with second-order conditions:
  \[ \pi_{xx} < 0; \quad \Pi_{xx} < 0 \]  
  (8)

Also assume:

\[ \Omega = \pi_{xx} \Pi_{xx} - \pi_{xx} \Pi_{xx} > 0 \]  
(9)
Stage 2

- Solutions to (6) and (7) depend on domestic and foreign emissions taxes, $t$ and $T$:
  \[ x = f(t, T); \quad X = F(t, T) \quad \text{(10)} \]

- Degree of abatement $a(A)$ is function of $t(T)$, level of $a(A)$ being chosen prior to production; firm acts to minimize unit cost of $q(Q)$, such that:
  \[ q_a = ca_a . a + ca . t = 0 \quad \text{(11)} \]

Similarly for foreign firm:
\[ Q_A = CA_A . A + CA . T = 0 \quad \text{(12)} \]
i.e., marginal abatement costs equal tax rate

- $a$ and $A$ then treated as exogenous in output game
Stage 2

- Totally differentiating (6) and (7) with respect to \( x, X, t \) and \( T \), using (5), (8) and (9), and also Shepard’s lemma, \( v=c_q(x,q) \) and \( V=C_Q(X,Q) \), \( v(V) \) being input quantity:

\[
\frac{dx}{dt} = f_t = v_x (1-a) e \frac{\Pi_{xx}}{\Omega} < 0
\]
\[
\frac{dx}{dT} = f_T = -V_X (1-A) e \frac{r_{xx}}{\Omega} > 0
\]
\[
\frac{dX}{dT} = F_T = V_X (1-A) e \frac{\Pi_{xx}}{\Omega} < 0 \quad (13)
\]
\[
\frac{dX}{dt} = F_t = -v_X (1-a) e \frac{R_{xx}}{\Omega} > 0
\]

- Domestic (foreign) firm’s output decreasing in domestic (foreign) tax and increasing in foreign (domestic) tax.
Non-Cooperative Behavior: Taxes

- Pollutant is global public bad, i.e., $d(P)$ is a convex domestic damage function, $P = (1- a)e.v + (1- A)e.V$

- Governments maximize relevant objective functions:

$$\max_t w = r(x, X) - c(x, q(t)) + t.(1- a).e.v - d(P) \quad (14)$$

$$\max_T W = R(x, X) - C(X, Q(T)) + T.(1- A).e.V - D(P) \quad (15)$$

- First-order condition from (14) is:

$$r_x F_t + ((1- a)e.v x f_t)(t - md) = 0 \quad (16)$$

where $md$ is marginal damage in domestic country
Non-Cooperative Behavior: Taxes

- Re-writing (16) gives optimal domestic tax $\hat{t}_G$, given foreign tax $T$:

$$\hat{t}_G = md + \frac{R_{xx}}{(1-a)e.\nu_x.\Pi_{xx}} [r_x - md.(1-A)e.V_x]$$  \hspace{1cm} (17)

- Optimal tax set lower than Pigouvian tax of $\hat{t}_G = md$

  - second term in (17) is negative (see (5) and (8)), and $\nu_x > 0$, i.e., prevents loss of market share by domestic firm

  - need to account for increased marginal damage from emissions leakage, $md.(1-A)e.V_x$

- Optimal environmental policy incorporates both industrial and trade policy
Cooperative Behavior: Taxes

- If governments cooperate over environmental taxes \( t \) and \( T \), maximize objective function:

\[
\max_{t,T} \ TW = r(x, X) - c(x, q(t)) + R(x, X) - C(X, Q(T)) + t(1-a).e.v + T(1-A).e.V - d(P) - D(P) \tag{18}
\]

where \( D(P) \) is foreign damage function; solving \( \delta TW/\delta t = 0 \) and \( \delta TW/\delta T = 0 \) simultaneously for \( t \) and \( T \):

\[
\hat{t} = md + MD - \frac{R_x}{(1-a)e.v_x}
\]

\[
\hat{T} = md + MD - \frac{r_x}{(1-A)e.V_x}
\]
Cooperative Behavior: Taxes

- Comparing (17) with (19), tax higher with cooperation:
  - reflects marginal damage in both countries, \( \text{md}(\text{MD}) \)
  - taxes also exceed marginal damage, \( R_x < 0 \) and \( r_x < 0 \), i.e., neither country has to worry about loss of competitiveness/leakage
  - each country takes into account negative effects of their contribution to global public bad, so there is cooperation over tax rates
  - importing country’s damage function is ignored though, plus their consumers face potential deadweight loss
Non-Cooperative Behavior: Abatement Subsidies

- (1) can be modified to include an abatement subsidy $s$:

\[
q(s,t) = q_0 + (ca - s) a e + t(1 - a) e
\]  
\[\tag{20}\]

- Totally differentiating (6) and (7) with respect to $x$, $X$, $t$, $s$, $T$ and $S$:

\[
\frac{dx}{ds} = f_s = -v_x a e \frac{\Pi_{xx}}{\Omega} > 0
\]

\[
\frac{dx}{dS} = f_S = V_x A e \frac{r_{xx}}{\Omega} < 0
\]  
\[\tag{21}\]

\[
\frac{dX}{dS} = F_s = -V_x A e \frac{\Pi_{xx}}{\Omega} > 0
\]

\[
\frac{dx}{ds} = F_s = v_x a e \frac{R_{xx}}{\Omega} < 0
\]
Non-Cooperative Behavior: Taxes and Subsidies

- Domestic government maximizes:

\[
\max_{s,t} w = r(x, X) - c(x, q(s, t)) + t(1 - a) e v - s a e v - d(P)
\]

where \( x = f(t, T, s, S) \); \( X = F(t, T, s, S) \), and the new cost minimizing condition for domestic firm is:

\[
ca_a a + ca = s + t
\]

- Optimal tax and subsidy rates are:

\[
\hat{t} = \hat{m} d + \frac{R_{xx}}{e v_x \Pi_{xx}} [r_x - \hat{m} d (1 - A) e V_x]
\]

\[
\hat{s} = - \frac{R_{xx}}{e v_x \Pi_{xx}} [r_x - \hat{m} d (1 - A) e V_x] > 0
\]
Non-Cooperative Behavior: Taxes and Subsidies

- Comparing (24) and (17), \( \hat{t}_G < \hat{t} \), due to \((1-a) < 1\) not being in denominator of (24), i.e., abatement plays no role in tax, abatement being directly rewarded through \(s\).

- Also, as \(\hat{t} + \hat{s} = md\), given (23), firm equates marginal abatement cost to marginal damage, determining \(\hat{a}\), and with \(\hat{t} + \hat{s} > \hat{t}_G\), then \(\hat{a} > \hat{a}\).

- Size of \(s\) depends on impact of gain in foreign firm’s market share and resulting emissions leakage.

- Higher welfare compared to tax-only case highlights importance of using two policy instruments to target two externalities - pollution and imperfect competition.
Cooperative Behavior: Taxes and Subsidies

- If governments cooperate over taxes and subsidies $t$, $T$, $s$ and $S$, they maximize objective function:

$$
\text{max}_{t,T,s,S} TW = r(x, X) - c(x, q(s, t))
+ R(x, X) - C(X, Q(S, T))
+ (t.(1-a) - s.a).e.v
+ (T.(1-A) - S.A).e.V - d(P) - D(P)
$$

(26)

- Solving simultaneously for $t$, $T$, $s$ and $S$:

$$
\tilde{t} = md + MD - \frac{R_x}{e.V_x}, \quad \tilde{s} = \frac{R_x}{e.V_x} < 0
$$

(27)

$$
\tilde{T} = md + MD - \frac{r_x}{e.V_x}, \quad \tilde{S} = \frac{r_x}{e.V_x} < 0
$$
Cooperative Behavior: Taxes and Subsidies

- Compared to (19), tax rate on emissions is still greater than total marginal damage, \((md+MD)\), but taxes no longer dependent on abatement

- Effects of environmental damage and abatement efforts are disentangled

- Differences in abatement associated with differences in abatement cost function, taxing abatement offsets a country’s advantage at abatement efforts

- Marginal abatement costs equal to \(\tilde{t} + \tilde{s}; \tilde{T} + \tilde{S}\), and also know from (27) that \(\tilde{t} + \tilde{s} = md + MD; \tilde{T} + \tilde{S} = md + MD\), i.e., marginal abatement costs equalized across countries
Non-Cooperative Behavior: Input Subsidies

- (1) can also be modified to include an input subsidy $z$:

$$ q(z, t) = q_0 (1 + z) + c a . a . e + t (1 - a) e $$  (28)

- Totally differentiating (6) and (7) with respect to $x, X, t, z, T$ and $Z$:

$$ \frac{dx}{dz} = f_z = v_x q_0 \frac{\Pi_{xx}}{\Omega} < 0 $$

$$ \frac{dx}{dZ} = f_z = -V_x Q_0 \frac{r_{xx}}{\Omega} > 0 $$  (29)

$$ \frac{dX}{dZ} = F_z = V_x Q_0 \frac{\Pi_{xx}}{\Omega} < 0 $$

$$ \frac{dX}{dz} = F_z = -v_x q_0 \frac{R_{xx}}{\Omega} > 0 $$
Non-Cooperative Behavior: Taxes/Input Subsidies

- Domestic government maximizes:

\[
\max_{z,t} w = r(x, X) - c(x, q(z, t)) + t(1 - a)e_v \\
+ zq_0v - d(P)
\]

(31)

\(z\) does not affect degree of abatement, marginal abatement costs being equal to tax rate as in (11)

- Optimal tax and input subsidy rates are:

\[t^* = md\] (32)

\[z^* = \frac{R_{xx}}{q_0v_x \Pi_{xx}} [r_x - md.(1 - A)e.V_x] < 0\]

- Tax is targeted at externality, while input subsidy is targeted at raising domestic firm’s exports
Cooperative Behavior: Taxes/Input Subsidies

- If governments cooperate over taxes and input subsidies $t$, $T$, $z$ and $Z$, they maximize:

$$\max_{t,T,z,Z} TW = r(x, X) - c(x, q(z, t))$$

$$+ R(x, X) - C(X, Q(Z, T))$$

$$+ t(1-a)e.v + z_0.q.v$$

$$+ T(1-A)e.V + Z_0.Q.V - d(P) - D(P)$$

- Solving simultaneously for $t$, $T$, $z$ and $Z$:

$$t** = md + MD; \quad z** = \frac{-R_x}{q_0 \cdot v_x} > 0$$

$$T** = md + MD; \quad Z** = \frac{-r_x}{Q_0 \cdot V_x} > 0$$
Cooperative Behavior: Taxes/Input Subsidies

- Globally uniform emissions tax takes care of global public bad efficiently – marginal abatement costs same across countries

- Tax on polluting input internalizes effect of own exports on other firm’s market share

- Essentially cooperative policy with taxes/input subsidies resolves externality problem, but also “facilitates” collusion among firms – i.e., deadweight losses imposed on importing country
Motivation (McCorriston and Sheldon, 2005)

- 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
BTAs and WTO Rules

- 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:
  \[
  R_1(x_1, x_2) \quad \text{(1)}
  \]
  \[
  R_2(x_1, x_2) \quad \text{(2)}
  \]

- Downstream profit functions:
  \[
  \pi_1 = R_1(x_1, x_2) - c_1 x_1 \quad \text{(3)}
  \]
  \[
  \pi_2 = R_2(x_1, x_2) - c_2 x_2 \quad \text{(4)}
  \]
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:

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

(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 \( \Delta = (a_1a_2 - b_1b_2) > 0 \)

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

\[
\begin{bmatrix}
  dx_1 \\
  dx_2
\end{bmatrix} = \Delta^{-1} \begin{bmatrix}
  a_2 & a_1r_1 \\
  a_2r_2 & a_1
\end{bmatrix} \begin{bmatrix}
  dc_1 \\
  dc_2
\end{bmatrix}
\]  

(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:

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

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:

\[
I = \left( \frac{de_2}{-de_1} \right) \equiv \left[ \frac{g'(x^U_2)}{g'(x^U_1)} \right] \left( dx^U_2 - dx^U_1 \right) \tag{13}
\]

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

\[
I = \left( \frac{de_2}{-de_1} \right) \equiv \left[ \frac{g'(x^U_2)}{g'(x^U_1)} \right] \left( \Delta^{-1} a_2 r_2 dc_1 \right) \tag{14}
\]

Using (11), \( \Delta^{-1} a_2 dc_1 < 0 \), direction of carbon leakage determined by \( r_2 \), e.g., suppose \( g'(x^U_2) = g'(x^U_1) \), 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):
  \[
  \frac{dx^U_2}{dc_2} = \frac{d(x^A_2 + x^B_2)}{dc_2}
  \]

- 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:

\[ t^b = \frac{(dx_2 / dc_1) t^e}{-(dx_2 / dc_2)} \]  \hspace{1cm} (15)

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

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

\[ dx_2 = \Delta^{-1} a_1 dc_2 \]  \hspace{1cm} (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:

\[
t^b = -r_2 \{p_{1,1}^U D\} t^e = -r_2 dc_1
\]

where \( p_{1,1}^U < 0 \), \( D = (\Delta^U)^{-1}[a^B_1 (1 + r^B_1) + a^A_1 (1 + r^A_1)] < 0 \), 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:

\[ t^b = \frac{t^e \left[ \left( \frac{dx_2}{dc_1} \right) + \left( \frac{dx_1}{dc_1} \right) \right]}{\left[ \left( \frac{dx_1}{dc_2} \right) + \left( \frac{dx_2}{dc_2} \right) \right]} \]  \hspace{1cm} (18)

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

\[ t^b = \frac{(r_2 + 1) t^e}{(r_1 + 1)} = \frac{(r_2 + 1) dc_1}{(r_1 + 1)} \]  \hspace{1cm} (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
Competiveness – Import Volume

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

$$dx_1 = \Delta^{-1} a (dc_1 + r_1 dc_2)$$  \hspace{1cm} (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):

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

\[ d\pi_2 = R_{2,2}dx_2 + R_{2,1}dx_1 - c_2dx_2 + \pi_{2,c_2}dc_2 \]  \hspace{1cm} (22)

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

\[ d\pi_2 = R_{2,1}dx_1 + \pi_{2,c_2}dc_2 \]  \hspace{1cm} (23)

\[ = x_2[\Delta^{-1} p_{2,1} a (dc_1 + r_1dc_2) - dc_2] \]

\( \Delta^{-1} > 0, p_{2,1} < 0, a < 0, \) 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

\[ \pi_1 = \pi_2 \]

\[ x_2 = x_2' \]

\[ d\pi_2 \]

\[ x_1' \]

\[ x_1 \]

\[ d\pi_1 \]
Competitiveness – Import Share

- Derive $dx_1$ and $dx_2$, assuming $a = a_1 \approx a_2$ , and using (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:
Competiveness – Import Share

\[ d\pi_1 = x_1 d c_1 \left\{ p_{1,2} \Delta^{-1} a \left[ r_2 + \left( \frac{r_2 + 1}{r_1 + 1} \right) \right] - 1 \right\} \]  \hspace{0.5cm} (26)

\[ d\pi_2 = x_2 d c_2 \left\{ p_{2,1} \Delta^{-1} a \left[ 1 + (1 + r_1) \left( \frac{r_2 + 1}{r_1 + 1} \right) \right] - 1 \right\} \]  \hspace{0.5cm} (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
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