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

Articles:

Klaus Conrad: "Taxes and Subsidies for Pollution-Intensive Industries as Trade Policy", ***Journal of Environmental Economics and Management*****, 1993: 121-135**

Steve McCorriston and Ian Sheldon: "Market Access and WTO Border Tax Adjustments for Environmental Taxes under Imperfect Competition", ***Journal of Public Economic Theory*****, 2005: 579-592**

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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:**

$$q(t) = q_0 + ca.a.e + t(1-a)e \qquad (1)$$

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:**

$$\pi(x,X,t)=r(x,X)-c(x,q(t)) \qquad (2)$$

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

- **Profit for foreign firm is:**

$$\Pi(x,X,T)=R(x,X)-C(X,Q(T)) \qquad (3)$$

where foreign firm's cost function is:

$$Q(\mathrm{T})=Q_0+CA.A.e+T(1-A)e \qquad (4)$$

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:

$$r_X < 0; \quad r_{xX} < 0; \quad R_x < 0; \quad R_{Xx} < 0 \tag{5}$$

- First-order conditions are:

$$\pi_x = r_x(x, X) - c_x(x, q(t)) = 0 \tag{6}$$

$$\Pi_X = R_X(x, X) - C_X(X, Q(T)) = 0 \tag{7}$$

with second-order conditions:

$$\pi_{xx} < 0; \quad \Pi_{XX} < 0 \tag{8}$$

Also assume:

$$\Omega = \pi_{xx}\Pi_{XX} - \pi_{xX}\Pi_{Xx} > 0 \tag{9}$$

Stage 2

- **Solutions to (6) and (7) depend on domestic and foreign emissions taxes, *t* and *T*:**

$$x = f(t, T); \quad X = F(t, T) \qquad (10)$$

- **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:**

$$q_a = ca_a . a + ca - t = 0 \qquad (11)$$

Similarly for foreign firm:

$$Q_A = CA_A . A + CA - T = 0 \qquad (12)$$

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:

$$dx/dt = f_t = v_x(1-a).e.\frac{\Pi_{XX}}{\Omega} < 0$$

$$dx/dT = f_T = -V_X(1-A).e.\frac{r_{xX}}{\Omega} > 0 \qquad (13)$$

$$dX/dT = F_T = V_X(1-A).e.\frac{\pi_{xx}}{\Omega} < 0$$

$$dX/dt = F_t = -v_X(1-a).e.\frac{R_{Xx}}{\Omega} > 0$$

- 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:**

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

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

- **First-order condition from (14) is:**

$$r_X F_t + ((1-a)e.v_x f_t)(t - md) = 0 \qquad (16)$$

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*:**

$$\hat{t}_g = md + \frac{R_{Xx}}{(1-a)e.v_x.\Pi_{XX}}[r_X - md.(1-A)e.V_X] \qquad (17)$$

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

  - second term in (17) is negative (see (5) and (8)), and v_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:

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

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

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

$$\hat{T} = md + MD - \frac{r_x}{(1-A)e.V_X} \quad (19)$$

Cooperative Behavior: Taxes

- **Comparing (17) with (19), tax higher with cooperation:**

  - reflects marginal damage in both countries, md(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*:

$$q(s,t) = q_0 + (ca - s).a.e + t(1 - a)e \qquad (20)$$

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

$$dx / ds = f_s = -v_x.a.e.\frac{\Pi_{xx}}{\Omega} > 0$$

$$dx / dS = f_S = V_X.A.e.\frac{r_{xX}}{\Omega} < 0 \qquad (21)$$

$$dX / dS = F_S = -V_X.A.e.\frac{\pi_{xx}}{\Omega} > 0$$

$$dX / ds = F_s = v_X.a.e.\frac{R_{Xx}}{\Omega} < 0$$

Non-Cooperative Behavior: Taxes and Subsidies

- Domestic government maximizes:

$$\max_{s,t} w = r(x,X) - c(x,q(s,t)) + t.(1-a).e.v - s.a.e.v - d(P) \quad (22)$$

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

$$ca_a.a + ca = s + t \quad (23)$$

- Optimal tax and subsidy rates are:

$$\hat{\hat{t}} = md + \frac{R_{Xx}}{e.v_x.\Pi_{XX}}[r_X - md.(1-A)e.V_X] \quad (24)$$

$$\hat{\hat{s}} = -\frac{R_{Xx}}{e.v_X \Pi_{XX}}[r_X - md.(1-A)e.V_X] > 0 \quad (25)$$

Non-Cooperative Behavior: Taxes and Subsidies

- Comparing (24) and (17), $\hat{t}_G < \hat{\hat{t}}$, 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 $\hat{\hat{t}} + \hat{\hat{s}} = md$, given (23), firm equates marginal abatement cost to marginal damage, determining $\hat{\hat{a}}$, and with $\hat{t} + \hat{\hat{s}} > \hat{t}_G$, then $\hat{\hat{a}} > \hat{a}$
- 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:

$$\max_{t,T,s,S} \mathrm{TW} = r(x,X) - c(x,q(s,t)) + R(x,X) - C(X,Q(S,T)) + (t.(1-a) - s.a).e.v + (T.(1-A) - S.A).e.V - d(P) - D(P) \quad (26)$$

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

$$\tilde{t} = md + MD - \frac{R_x}{e.v_x}, \quad \tilde{s} = \frac{R_x}{e.v_x} < 0$$
$$\tilde{T} = md + MD - \frac{r_x}{e.V_X}, \quad \tilde{S} = \frac{r_x}{e.V_X} < 0 \quad (27)$$

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*:

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

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

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

$$dx/dZ = f_Z = -V_X . Q_0 . \frac{r_{xX}}{\Omega} > 0$$

$$dX/dZ = F_Z = V_X . Q_0 . \frac{\pi_{xx}}{\Omega} < 0 \qquad (29)$$

$$dX/dz = F_z = -v_X . q_0 \frac{R_{Xx}}{\Omega} > 0$$

Non-Cooperative Behavior: Taxes/Input Subsidies

- **Domestic government maximizes:**

$$\max_{z,t} w = r(x,X) - c(x,q(z,t)) + t.(1-a).e.v + z.q_0.v - d(P) \tag{31}$$

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:**

$$t^* = md \tag{32}$$

$$z^* = \frac{R_{Xx}}{q_0.v_x \Pi_{xx}}[r_X - md.(1-A)e.V_X] < 0$$

- **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:

$$\max_{t,T,z,Z} \text{TW} = r(x,X) - c(x,q(z,t)) + R(x,X) - C(X,Q(Z,T)) + t.(1-a).e.v + z_0.q.v + T.(1-A).e.V + Z_0.Q.V - d(P) - D(P) \quad (33)$$

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

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

$$T^{**} = md + MD; \quad Z^{**} = \frac{-r_x}{Q_0.V_X} > 0 \quad (34)$$

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

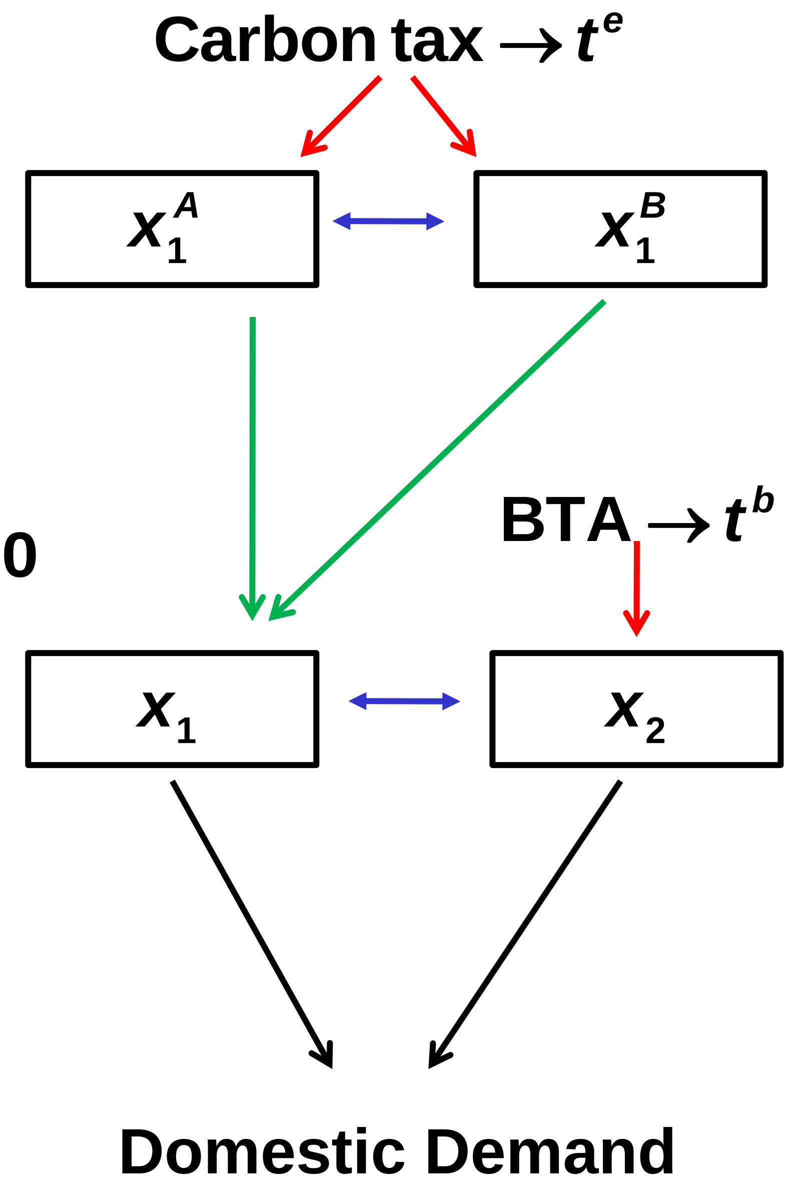
<u>**Stage**</u>

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:**

$$R_1(x_1, x_2) \tag{1}$$

$$R_2(x_1, x_2) \tag{2}$$

- **Downstream profit functions:**

$$\pi_1 = R_1(x_1, x_2) - c_1 x_1 \tag{3}$$

$$\pi_2 = R_2(x_1, x_2) - c_2 x_2 \tag{4}$$

Downstream Equilibrium

- **First-order conditions are:**

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

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

- **Nash equilibrium downstream:**

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

- **Slopes of reaction functions:**

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

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

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:

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

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):

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

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:**

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

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

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

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 $r_2 < 0$ ($r_2 > 0$)

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

Trade Neutrality – Import Volume

- **(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, i.e., *pass-through* of t^e matters

Trade Neutrality – Import Volume

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

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

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

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

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

Competiveness – Import Volume

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

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

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

i.e., domestic downstream firm still reduces output

- **In terms of profits totally differentiate (3):**

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

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

i.e., domestic downstream firm's profits decline

Competiveness – Import Volume

- Totally differentiating (4):

$$d\pi_2 = R_{2,2}dx_2 + R_{2,1}\,dx_1 - c_2dx_2 + \pi_{2,c_2}dc_2 \qquad (22)$$

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

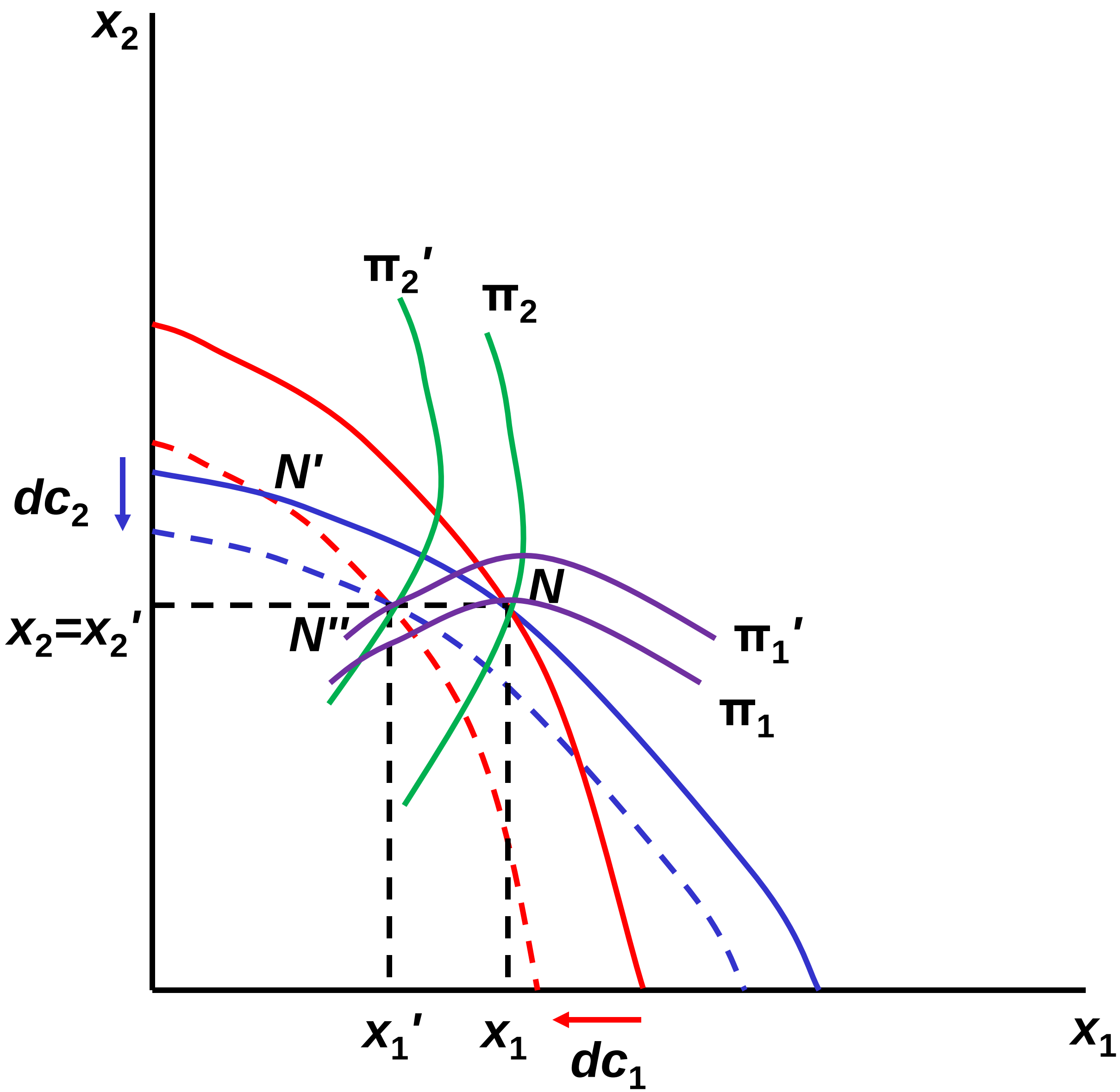
$$d\pi_2 = R_{2,1}\,dx_1 + \pi_{2,c_2}dc_2 \qquad (23)$$

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

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

- Foreign downstream firm’s profits increase – due to BTA being set appropriately, and less than carbon tax

Figure 1: Import Volume Neutrality



Competiveness – Import Share

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

(19) to substitute in for dc_2 :

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

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

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

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

Competiveness – Import Share

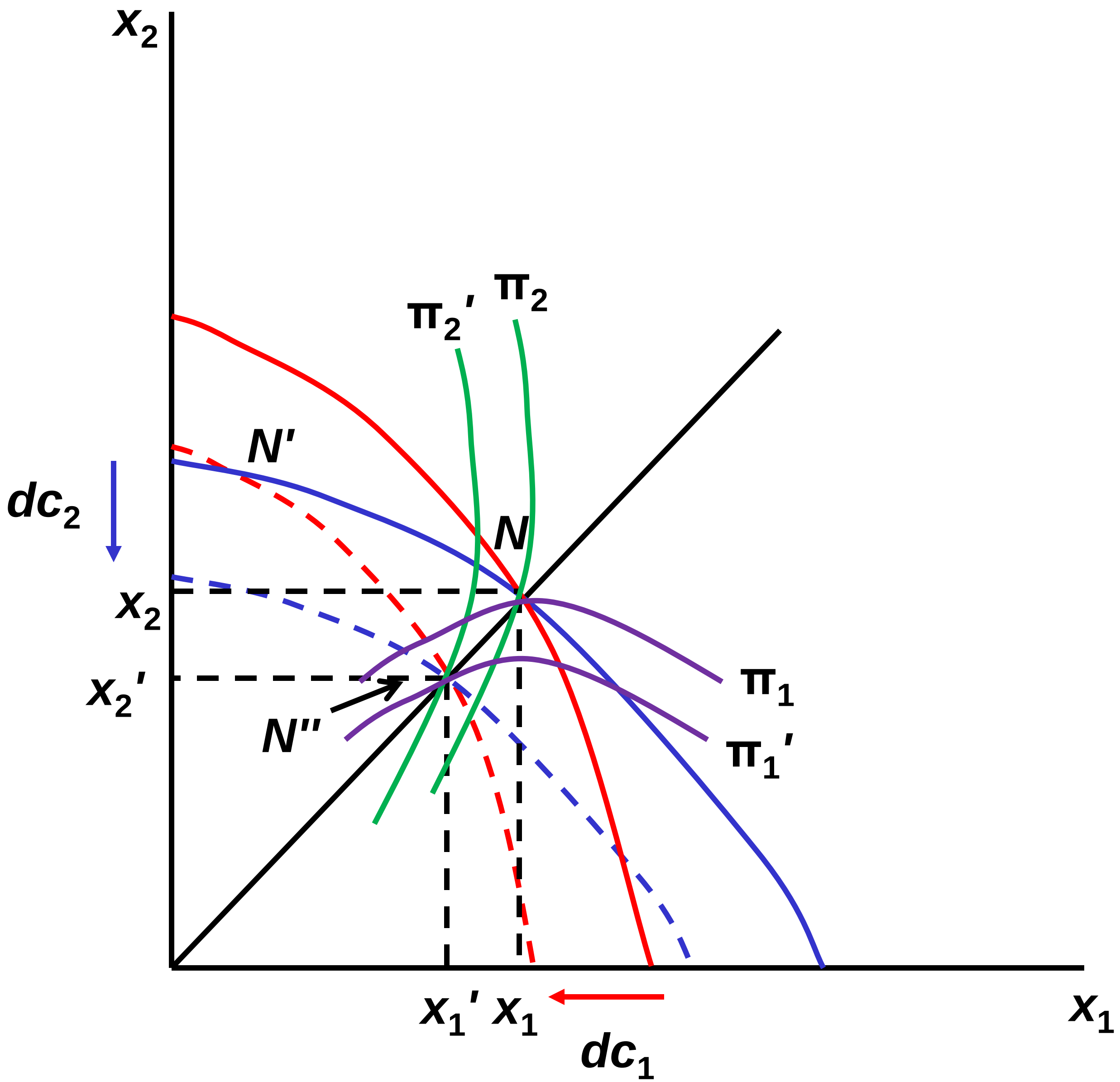
$$d\pi_1 = x_1 dc_1 \left\{ p_{1,2} \Delta^{-1} a \left[r_2 + \left(\frac{r_2 + 1}{r_1 + 1} \right) \right] - 1 \right\} \quad (26)$$

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

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

- 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**