“Climate Policy and Border Measures: The Case of the US Aluminum Industry”

Background

- **Failure to reach international agreement on reduction of carbon emissions – increased focus on unilateral climate policy**
- **Carbon taxes were applied in Australia, tradable permits adopted in EU and recently Québec**
- **Unilateral policies often include some type of border measure targeted at energy-intensive imports (Frankel, 2007)**
- **Logic of border measures: *carbon leakage* and loss of *competitiveness* (WTO/UNEP, 2009)**

Why Border Measures?

- **Focus in literature on how trade policy instruments might be used to prevent carbon leakage**
- **Hoel (1996) shows coalition setting carbon taxes should set import tariffs (export subsidies) against free-riding countries**
- **If treated as border tax adjustments (BTAs), their use in presence of domestic excise taxes well-understood in literature on *origin* vs. *destination-based* taxation systems (Lockwood *et al*., 1994)**
- **Basic principle captured in WTO rules, as long as BTA is *neutral* in terms of its effects on trade (WTO, 1997)**

Level of Analysis

- **20 of 25 studies of BTAs analyzed recently by Quirion and Branger (2014) based on CGE analysis**
- **Mattoo and Subramanian (2012) – analysis of BTAs applied to all imports and exports**
- **CGE modeling may be based on inappropriate sector-level aggregation – especially if focus is industry-specific effects of BTAs**
- **Karp (2010) suggests partial equilibrium analysis useful as prelude to construction of CGE models**

Motivation

- **Energy-intensive industries such as steel, aluminum, chemicals, paper and cement most likely to be affected by unilateral climate policy (Houser et al., 2008)**
- **If imperfect competition matters in these sectors, issues of carbon leakage and competitiveness best analyzed in tradition of, *inter alia*, Conrad (1993) and Barrett (1994)**
- **Use simple model to trace out potential effects of US and Québec climate policies in US aluminum industry where border measures (BTAs) are assumed WTO-legal**

Aluminum Production

- Primary aluminum produced in vertical process initially requiring bauxite and alumina
- Aluminum extracted from alumina by electrolytic reduction method using carbon anodes
- Production process energy-intensive, energy accounting for 25% of production costs (USITC, 2010)
- Two key sources of GHG emissions (Carbon Trust, 2011):

  - production process (2-3 tCO_2/t of aluminum)

  - upstream electricity generation (3-20 tCO2/t aluminum)

Aluminum Industry: Market Structure

Table 1: Market Structure of North American Aluminum Industry

US Producers	Market Share (%)	Canadian Producers	Market Share (%)
Alcoa	50.8	Rio Tinto Alcan	51
Century Aluminum	21.2	Alcoa	31
Rio Tinto Alcan	5.3	Alouette	18
Columbia Falls Aluminum	5.0		
Other	17.7		
1/H	2.94		2.57

North American Aluminum Industry

- **Reasonable to treat US and Canada as segmented markets where Canadian producers compete in US**
- **50% of US consumption via imports predominantly from Canada, and US is most important export market for Canada**
- **Key difference between US and Canadian aluminum production is that latter exclusively sources hydro-electric power**
- **Estimated GHG emissions: 2.5 tCO_2/t of aluminum in Canada (CIEEDAC, 2013) compared to 7.4 tCO2/t of aluminum in US (Carbon Trust, 2011)**

Model

- **Specific version of Sheldon and McCorriston (2012): model with linear demand that can easily be calibrated to industry and used for policy simulation**
- **Inverse derived demand functions:**

$$p_1 = a_1 - b_1 Q_1 - kQ_2 \quad (1)$$

$$p_2 = a_2 - b_2 Q_2 - kQ_1 \quad (2)$$

where a_i, b_i and $k > 0$, and $b_1 b_2 - k_2 \geq 0$

Model

- **Profit functions of symmetric US and Canadian firms:**

$$\pi_1 = (p_1 - c_1)q_1 \quad (3)$$

$$\pi_2 = (p_2 - c_2)q_2 \quad (4)$$

- **First-order conditions are:**

$$p_1 - c_1 + q_1\left[\frac{\delta p_1}{\delta Q_1}\frac{\delta Q_1}{\delta q_1} + \frac{\delta p_1}{\delta Q_2}\frac{\delta Q_2}{\delta q_1}\right] = 0 \quad (5)$$

$$p_2 - c_2 + q_2\left[\frac{\delta p_2}{\delta Q_2}\frac{\delta Q_2}{\delta q_2} + \frac{\delta p_2}{\delta Q_1}\frac{\delta Q_1}{\delta q_2}\right] = 0 \quad (6)$$

Model

- **Aggregating (5) and (6):**

$$p_1 - c_1 - Q_1\lambda_1 = 0 \qquad (7)$$

$$p_2 - c_2 - Q_2\lambda_2 = 0 \qquad (8)$$

where λ_i capture mark-up of price over marginal cost

- **Using (1),(2), (7) and (8), comparative statics can be derived from:**

$$\begin{bmatrix} dQ_1 \\ dQ_2 \end{bmatrix} = \frac{1}{\Delta}\begin{bmatrix} (b_2 + \lambda_2) & -k \\ -k & (b_1 + \lambda_1) \end{bmatrix}\begin{bmatrix} -dc_1 \\ -dc_2 \end{bmatrix} \qquad (9)$$

Leakage

- **Leakage *l* defined as:**

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{dQ_2}{-dQ_1} \right] \equiv \left[\frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{\Delta^{-1} k dc_1}{-\{\Delta^{-1}(b_2 + \lambda_2) dc_1\}} \right] \qquad (10)$$

- **Given $\Delta^{-1} k dc_1 > 0$, and $\{\Delta^{-1}(b_2 + \lambda_2) dc_1\} < 0$, leakage is determined by GHG emissions rates in US and Canada and extent of output change in both countries in response to US carbon tax, given cap-and-trade policy already implemented in Quebec**

BTAs and Neutrality

- **Under WTO rules, BTAs have to be *neutral* in their effect on trade, two potential definitions satisfying criterion:**

(i) <u>Import-volume</u> -

$$t^b = \frac{(dQ_2 / dc_1)\, g^e}{-(dQ_2 / dc_2)} = \frac{\Delta^{-1}(k) g^e}{\Delta^{-1}(b_1 + \lambda_1)} \qquad (11)$$

(ii) <u>Import-share</u> -

$$t^b = \frac{[(dQ_2 / dc_1) + (dQ_1 / \mathrm{dc}_1)] g^e}{[(dQ_1 / dc_2) + (dQ_2 / dc_2)]} = \frac{[\Delta^{-1}\{k + (b_2 + \lambda_2)\}] g^e}{[\Delta^{-1}\{k + (b_1 + \lambda_1)\}]} \qquad (12)$$

Figure 1: Import Volume Neutrality (Cournot)

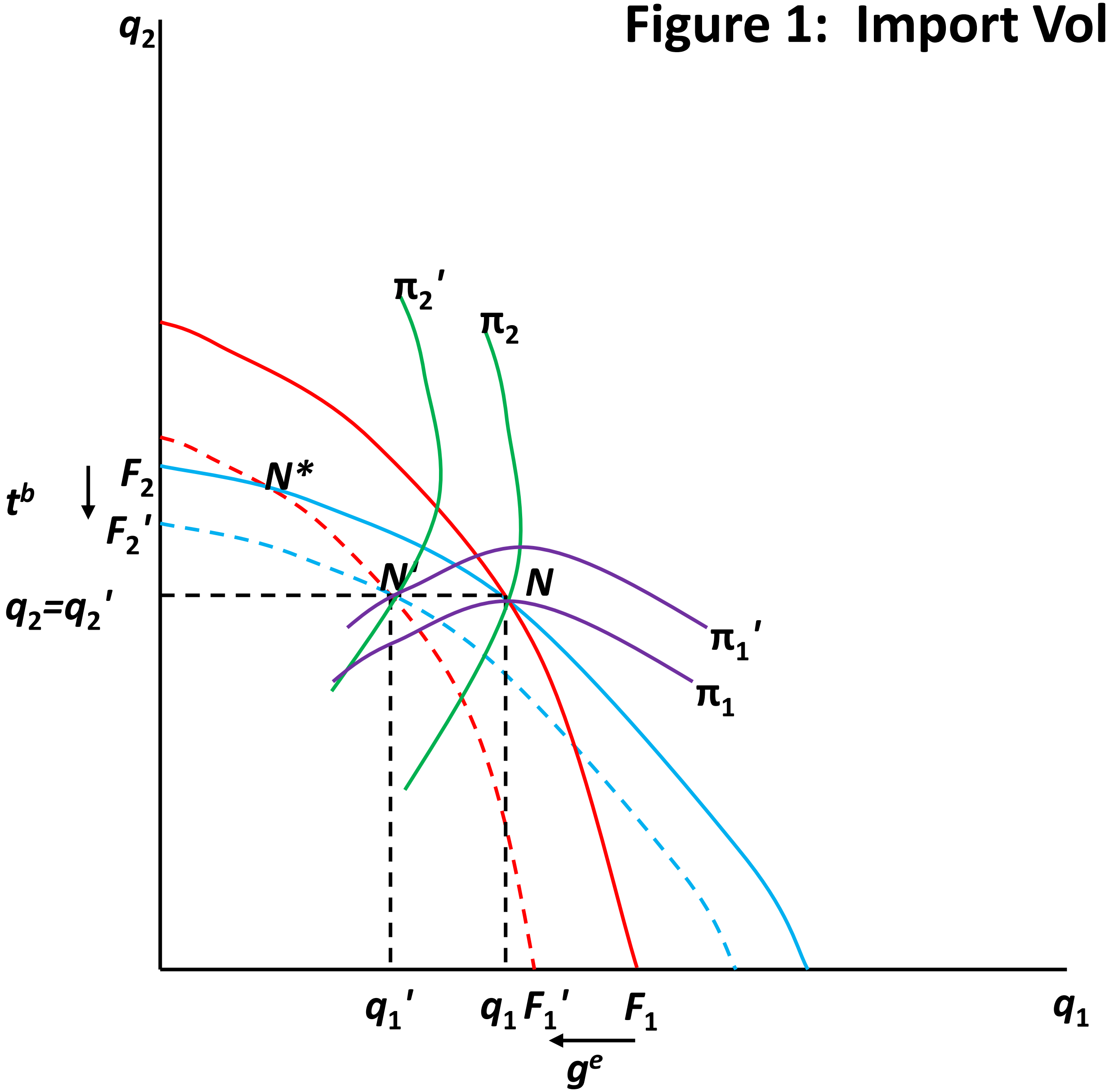
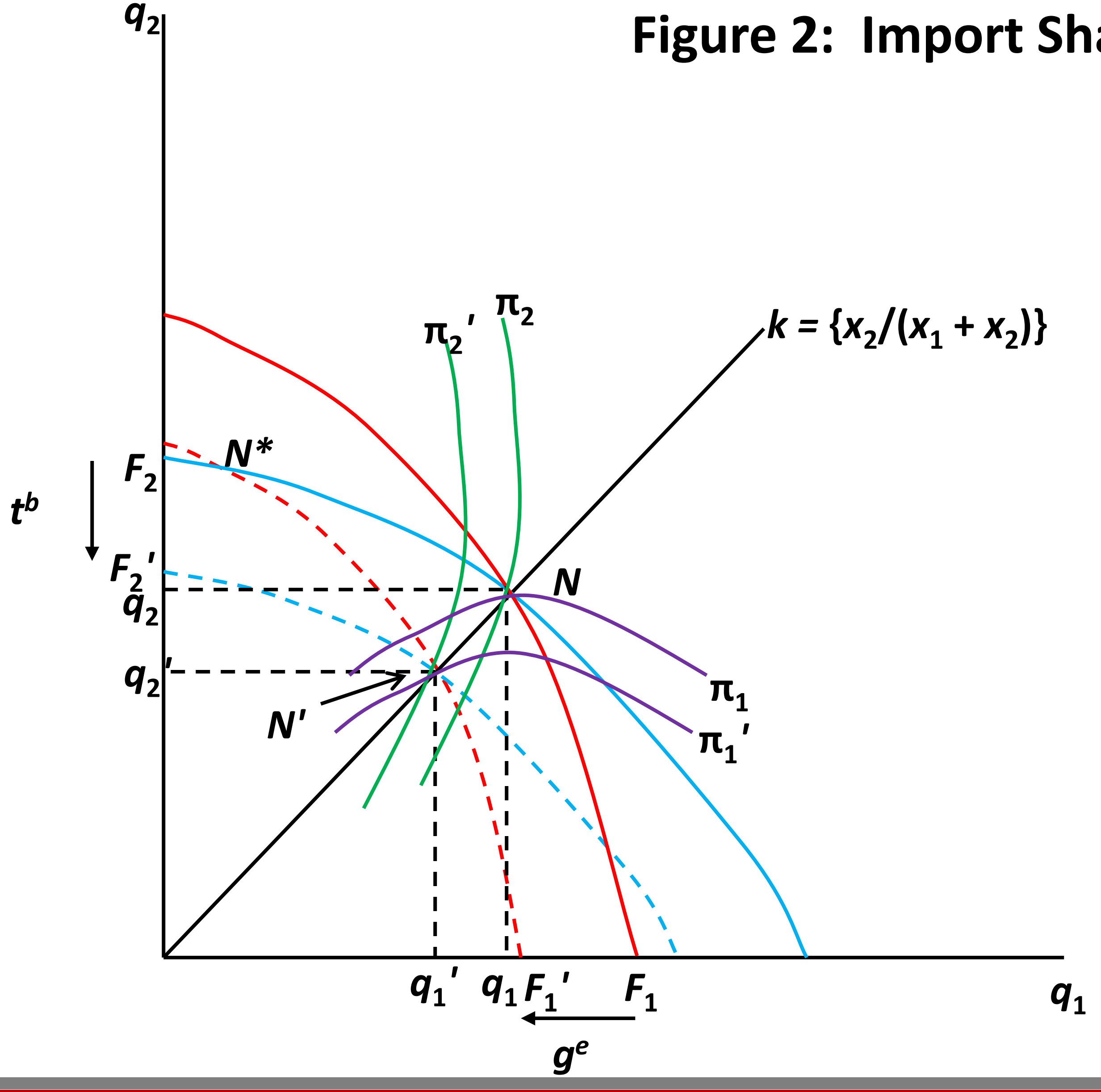


Figure 2: Import Share Neutrality (Cournot)



Policy Simulation

- **Based on calibration of model with 2008 data for aluminum industry, evaluate \$25/t CO_2 US carbon tax, given Québec carbon price of \$10/t CO_2, and allow for BTAs**
- **Assume US social welfare function:**

$$W = \pi_1 + \Gamma + g^e \{f'(Q_1)\}Q_1 + t^b Q_2 - d(e_1 + e_2) \qquad (13)$$

- **Tradeoff between targeting global public bad, retaining profits of domestic producers, and minimizing deadweight loss to users of aluminum – but only two instruments, g^e and t^b**

Calibration

- Price and quantity data from USITC (2010) and US Geological Survey (2010)
- Production cost data from Carbon Trust (2011), social cost of carbon emissions (EPA, 2010)
- Price elasticity of demand (Yang, 2005), and elasticity of substitution (USITC, 2004)
- Change in electricity prices due to carbon tax draws on Fowlie's (2009) study of California electricity industry

Simulation Results

Table 2: Welfare Effects of US and Québec Carbon Policies ($ billion)				
Variable	Pre-policy	US carbon tax	Volume BTA	Share BTA
Producer profits	2.29	1.96	2.03	2.18
User surplus	11.72	11.15	10.92	10.40
Tax revenue	0.00	0.46	0.74	1.30
Social cost	0.52	0.49	0.49	0.50
Social welfare	13.49	13.08	13.20	13.40
Deadweight loss	-	-0.11	-0.06	-0.02
Effective carbon price ($/t$CO_2$)	-	282, 84	282, 84	282, 84
BTA ($/t)	-	-	141	469
Market share (%)	57	55	56	58
Emissions (CO_2t - millions)	24.67	23.31	23.41	23.64
Leakage	-	0.12	0.00	-0.78

Conclusion

- Once imperfect competition is allowed for in aluminum production, competitiveness can be defined in terms of profit-shifting
- Extent of both leakage and reduction in competitiveness dependent on interaction between US and Canadian producers
- WTO-legal application of BTAs needs to account for way in which imperfectly competitive firms respond to changes in costs
- Deadweight losses due to second-best structure of problem