“Climate Policy and Border Tax Adjustments: The Case of the North American Aluminum Industry”

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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 oligopolistic rent-shifting matters in these sectors, issues of carbon leakage and competitiveness best analyzed in tradition of, *inter alia*, Conrad (1993) and Barrett (1994)**
- **Use simple linear oligopoly model to trace out potential effects of US carbon tax in North American 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 well-defined North American market 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 McCorriston and Sheldon (2005): conjectural variations with linear demand that can easily be calibrated to industry and used for policy simulation**
- **Inverse derived demand functions:**

$$p_1 = a_1 - b_1Q_1 - kQ_2 \qquad (1)$$

$$p_2 = a_2 - b_2Q_2 - kQ_1 \qquad (2)$$

where a_i, b_i and $k > 0$, and $b_1b_2\text{-}k_2 \geq 0$

Model

- **Aggregate first-order conditions:**

$$p_1 - c_1 - Q_1 V_1 = 0 \qquad (3)$$

$$p_2 - c_2 - Q_2 V_2 = 0 \qquad (4)$$

where V_i are aggregate conjectural variations parameters

- **Using (1)-(4), comparative statics can be derived from:**

$$\begin{bmatrix} dQ_1 \\ dQ_2 \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} (b_2 + V_2) & -k \\ -k & (b_1 + V_1) \end{bmatrix} \begin{bmatrix} -dc_1 \\ -dc_2 \end{bmatrix} \qquad (5)$$

Leakage

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

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{dQ_2}{-dQ_1} \right] \equiv \left[\frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{\Delta^{-1} k dc_1}{-\{\Delta^{-1}(b_2 + V_2) dc_1\}} \right] \qquad (6)$$

- **Given $\Delta^{-1} k dc_1 > 0$, and $\{\Delta^{-1}(b_2 + V_2) dc_1\} < 0$, direction of 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**

BTAs and Neutrality

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

(i) Import-volume -

$$t^b = \frac{(dQ_2 / dc_1)\, g^e}{-(dQ_2 / dc_2)} = \frac{\Delta^{-1}(k) g^e}{\Delta^{-1}(b_1 + V_1)} \qquad (7)$$

(ii) Import-share -

$$t^b = \frac{[(dQ_2 / dc_1) + (dQ_1 / \mathrm{dc}_1)] g^e}{[(dQ_1 / dc_2) + (dQ_2 / dc_2)]} = \frac{[\Delta^{-1}\{k + (b_2 + V_2)\}] g^e}{[\Delta^{-1}\{k + (b_1 + V_1)\}]} \qquad (8)$$

Policy Simulation

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

$$W = \pi_1 + \Gamma + g^e\{f'(Q_1)\}Q_1 + t^b Q_2 - d(e_1 + e_2) \qquad (9)$$

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

Simulation Results

Table 2: Welfare Effects of US Carbon Policies ($ billion)				
Variable	Pre-policy	US carbon tax	Volume BTA	Share BTA
Producer profits	2.29	1.93	1.99	2.13
User surplus	11.72	11.09	10.87	10.39
Tax revenue	0.00	0.45	0.73	1.28
Social cost	0.52	0.49	0.49	0.49
Social welfare	13.49	12.98	13.10	13.31
Net deadweight loss	-	-0.14	-0.09	-0.03
Effective carbon price ($/t$CO_2$)	-	282	282	282
BTA ($/t)	-	-	138	441
Market share (%)	57	54	55	58
Emissions (CO_2t - millions)	24.67	23.27	23.36	23.56
Leakage	-	0.13	0.00	-0.69

Conclusion

- Once oligopoly is allowed for in aluminum production, competitiveness can be defined in terms of rent-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 oligopolistic firms respond to changes in costs
- Net deadweight losses due to second-best structure of problem