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

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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 tCO₂/t of aluminum)
  - upstream electricity generation (3-20 tCO₂/t aluminum)
## Aluminum Industry: Market Structure

### Table 1: Market Structure of North American Aluminum Industry

<table>
<thead>
<tr>
<th>US Producers</th>
<th>Market Share (%)</th>
<th>Canadian Producers</th>
<th>Market Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoa</td>
<td>50.8</td>
<td>Rio Tinto Alcan</td>
<td>51</td>
</tr>
<tr>
<td>Century Aluminum</td>
<td>21.2</td>
<td>Alcoa</td>
<td>31</td>
</tr>
<tr>
<td>Rio Tinto Alcan</td>
<td>5.3</td>
<td>Alouette</td>
<td>18</td>
</tr>
<tr>
<td>Columbia Falls Aluminum</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>17.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/H</td>
<td>2.94</td>
<td></td>
<td>2.57</td>
</tr>
</tbody>
</table>
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 tCO₂/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:

  \[ p_1 = a_1 - b_1 Q_1 - kQ_2 \]  \hspace{1cm} (1)

  \[ p_2 = a_2 - b_2 Q_2 - kQ_1 \]  \hspace{1cm} (2)

where \( a_i, b_i \) and \( k > 0 \), and \( b_1b_2-k_2 \geq 0 \)
Model

- Profit functions of symmetric US and Canadian firms:
  \[ \pi_1 = (p_1 - c_1)q_1 \]  \hspace{1cm} (3)
  \[ \pi_2 = (p_2 - c_2)q_2 \]  \hspace{1cm} (4)

- First-order conditions are:
  \[ p_1 - c_1 + q_1 \left[ \frac{\delta p_1}{\delta Q_1} \frac{\delta Q_1}{\delta q_1} + \frac{\delta p_1}{\delta Q_2} \frac{\delta Q_2}{\delta q_1} \right] = 0 \]  \hspace{1cm} (5)
  \[ p_2 - c_2 + q_2 \left[ \frac{\delta p_2}{\delta Q_1} \frac{\delta Q_1}{\delta q_2} + \frac{\delta p_2}{\delta Q_2} \frac{\delta Q_1}{\delta q_2} \right] = 0 \]  \hspace{1cm} (6)
Model

- Aggregating (5) and (6):

\[ p_1 - c_1 - Q_1 \lambda_1 = 0 \]  \hspace{1cm} (7)

\[ p_2 - c_2 - Q_2 \lambda_2 = 0 \]  \hspace{1cm} (8)

where \( \lambda_i \) capture mark-up of price over marginal cost

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

\[
\begin{align*}
\begin{bmatrix}
    dQ_1 \\
    dQ_2
\end{bmatrix}
= & \frac{1}{\Delta} \begin{bmatrix}
    (b_2 + \lambda_2) & -k \\
    -k & (b_1 + \lambda_1)
\end{bmatrix}
\begin{bmatrix}
    -dc_1 \\
    -dc_2
\end{bmatrix}
\end{align*}
\]  \hspace{1cm} (9)
Leakage

- Leakage $l$ defined as:

\[
I = \frac{dQ_2}{dQ_1} = \left[ \frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{dQ_2}{dQ_1} \right] = \left[ \frac{f'(Q_2)}{f'(Q_1)} \cdot \frac{\Delta^{-1}kdc_1}{\Delta^{-1}(b_2 + \lambda_2)dC_1} \right]
\]

- Given $\Delta^{-1}kdc_1 > 0$, 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) **Import-volume** -

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

(ii) **Import-share** -

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

\[
W = \pi_1 + \Gamma + g^e \{f'(Q_1)\}Q_1 + t^bQ_2 - d(e_1 + e_2) \tag{13}
\]

- 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 \( t^e \)
Calibration

- 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)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-policy</th>
<th>US carbon tax</th>
<th>Volume BTA</th>
<th>Share BTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producer profits</td>
<td>2.29</td>
<td>1.96</td>
<td>2.03</td>
<td>2.18</td>
</tr>
<tr>
<td>User surplus</td>
<td>11.72</td>
<td>11.15</td>
<td>10.92</td>
<td>10.40</td>
</tr>
<tr>
<td>Tax revenue</td>
<td>0.00</td>
<td>0.46</td>
<td>0.74</td>
<td>1.30</td>
</tr>
<tr>
<td>Social cost</td>
<td>0.52</td>
<td>0.49</td>
<td>0.49</td>
<td>0.50</td>
</tr>
<tr>
<td>Social welfare</td>
<td>13.49</td>
<td>13.08</td>
<td>13.20</td>
<td>13.40</td>
</tr>
<tr>
<td>Deadweight loss</td>
<td>-</td>
<td>-0.11</td>
<td>-0.06</td>
<td>-0.02</td>
</tr>
<tr>
<td>Effective carbon price ($/tCO₂)</td>
<td>-</td>
<td>282, 84</td>
<td>282, 84</td>
<td>282, 84</td>
</tr>
<tr>
<td>BTA ($/t)</td>
<td>-</td>
<td>-</td>
<td>141</td>
<td>469</td>
</tr>
<tr>
<td>Market share (%)</td>
<td>57</td>
<td>55</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>Emissions (CO₂ t - millions)</td>
<td>24.67</td>
<td>23.31</td>
<td>23.41</td>
<td>23.64</td>
</tr>
<tr>
<td>Leakage</td>
<td>-</td>
<td>0.12</td>
<td>0.00</td>
<td>-0.78</td>
</tr>
</tbody>
</table>
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.