The Use of Discrete Choice Research in Hybrid Energy-economy Models

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Goal for energy-economy models:

To be useful to policy-makers, an energy-economy model should be able to simulate real policies in a realistic manner.
Traditional Energy-economy Models

Traditional top-down models
- Not able to explore policies that directly influence technologies (e.g. equipment standards)
- Not suitable for detailed modeling of technological change

Traditional bottom-up models
- Treat similar technologies as perfect substitutes (incandescent vs. compact fluorescent lightbulbs)
- Ignore risk, option value
- Ignore heterogeneity in the market
CIMS Model – a Hybrid

- Technologically explicit
  - Tracks technology purchases, retirements, retrofits
- Behaviourally realistic
  - Simulates the way in which people choose between technologies based on empirical studies
- Macroeconomic feedbacks
  - Realistic representation of import substitution, elasticities
Technology in CIMS

**Demand**

**Industry**
- Chemicals
- Industrial minerals
- Iron and Steel
- Metal smelting
- Mining
- Other Manufacturing
- Pulp and Paper

**Transportation**
- Commercial
- Residential

**Supply**

**Upstream**
- Coal Mining
- Natural Gas Extraction
- Petroleum Crude

**Downstream**
- Electricity Generation
- Petroleum Refining
## Technology in CIMS

<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost</th>
<th>Fuel Type</th>
<th>Fuel Cost</th>
<th>Direct CO2 Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>$25,511</td>
<td>85/15 Eth/Gas</td>
<td>$1,490/yr</td>
<td>0.049 kg/km</td>
</tr>
<tr>
<td>Methanol</td>
<td>$26,300</td>
<td>85/15 Meth/Gas</td>
<td>$1,975/yr</td>
<td>0.195 kg/km</td>
</tr>
<tr>
<td>Hybrid</td>
<td>$29,000</td>
<td>Gasoline</td>
<td>$496/yr</td>
<td>0.109 kg/km</td>
</tr>
<tr>
<td>Battery Electric</td>
<td>$48,500</td>
<td>Electricity</td>
<td>$262/yr</td>
<td>0 kg/km</td>
</tr>
<tr>
<td>Fuel Cell (H2)</td>
<td>$140,000</td>
<td>Hydrogen</td>
<td>$2,085/yr</td>
<td>0 kg/km</td>
</tr>
</tbody>
</table>

Behaviour in CIMS

• There is no “law” governing human decision-making:
  – People do not “optimize” – i.e., pick lowest financial cost technologies
  – Similar technologies are not perfect substitutes (compact fluorescent lights)
  – People are different from one another

• We must use real-world data to predict how people make choices and react to policies
  – Discrete choice modeling
Vehicle Choice Experiment

If these were the only four vehicles available to you, which would you choose?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Price</td>
<td>$21,000</td>
<td>$26,000</td>
<td>$29,000</td>
<td>$45,000</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$25/week</td>
<td>$22/week</td>
<td>$16/week</td>
<td>$36/week</td>
</tr>
<tr>
<td>Stations with Proper Fuel</td>
<td>100%</td>
<td>25%</td>
<td>100%</td>
<td>5%</td>
</tr>
<tr>
<td>Express Lane Access</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>Emissions Compared to Current Vehicle</td>
<td>Equal</td>
<td>25% Less</td>
<td>40% Less</td>
<td>100% Less</td>
</tr>
<tr>
<td>Power Compared to Current Vehicle</td>
<td>Equal</td>
<td>Equal</td>
<td>25% Less</td>
<td>10% Less</td>
</tr>
</tbody>
</table>

- Varied attribute levels
- Received over 3,000 responses
Results of Vehicle Choice Experiment

<table>
<thead>
<tr>
<th>Attribute</th>
<th>$\beta$ - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>-9.01E-05</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>-4.60E-03</td>
</tr>
<tr>
<td>Fuel Availability</td>
<td>1.16</td>
</tr>
<tr>
<td>Express Lane Access</td>
<td>-0.16</td>
</tr>
<tr>
<td>Power</td>
<td>-0.22</td>
</tr>
<tr>
<td>ASC – Gasoline</td>
<td>-1.70</td>
</tr>
<tr>
<td>ASC – Alternative Fuel</td>
<td>-2.01</td>
</tr>
<tr>
<td>ASC – Hybrid Electric</td>
<td>-0.36</td>
</tr>
</tbody>
</table>

Utility_s = $\beta_{CC} \times (\text{Capital Cost}_i) + \beta_{FC} \times (\text{Fuel Cost}_i) + \beta_{FA} \times (\text{Fuel Availability}_i) + \beta_{EL} \times (\text{Express Lane}_i) + \beta_{P} \times (\text{Power}_i) + \beta_{ASC}$

$$MS_i = \frac{e^{U_i}}{\sum_{j} e^{U_j}}$$
Simple Interpretation of Vehicle Choice Experiment

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Change Equal to $1000 Increase in Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cost</td>
<td>$-19.59 / month</td>
</tr>
<tr>
<td>Fuel Availability</td>
<td>+ 8%</td>
</tr>
<tr>
<td>Express Lane Access</td>
<td>+ 56%</td>
</tr>
<tr>
<td>Power*</td>
<td>+ 4%</td>
</tr>
</tbody>
</table>
Other Choice Experiments at EMRG

- Home energy retrofit choice (Canada)
  - Weather stripping, insulation, double/triple paned windows
- Home heating system choice (Canada)
  - Heat pump, electric baseboard, oil, etc.
- Industrial heating system choice (Canada)
  - Boiler, cogeneration system, boiler retrofits
- Mode choice and road and parking charges (Vancouver)
  - Carpooling, transit, single occupancy
- Mode choice (Canada)
  - Single occupancy, transit, walk/cycle, park & ride
- Vehicle choice (Canada)
  - Hybrid, fuel cell, gasoline
Integrate Behaviour into CIMS

• Incorporate results of discrete choice models into CIMS
  – Account for feedbacks throughout the economy
• Realistic representation of behaviour
  – How people choose between technologies
  – How they change their choices in response to a policy
Some Sample Results
(Transportation Policy)

New vehicle emissions in Ontario:

$50/t CO2 tax

Incentives for vehicle switching
- Increase other fuel availability
- Surcharge on gasoline vehicles
- Express lane access for hybrid and fuel cell

Incentives for mode switching
- Improving transit (reducing commuting time, waiting time, number of transfers)
- Reduce cost of transit 30%
- Increase cycling lane access
Sample National Results

- Integrate DCM results into a whole-economy model
- Simulate technology oriented or financial oriented policies
Conclusions

• Hybrid models have:
  – Explicit representation of technologies
  – Realistic representation of behaviour
  – Macroeconomic feedbacks
• Allows simulation of real policies with realistic results