Who Will Pay What?  
Modeling the Distribution of Costs of Climate Change Policies

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Tax Analysis Division

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Revenue Estimating & Tax Research Conference  
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Disclaimer

Analysis and conclusions presented here are my own and should not be interpreted as those of the Congressional Budget Office.
Overview

- Climate Change Modeling
- Linking Demographic, Tax, and Expenditures Data
- IO Model
- Results

Climate Change Modeling

- Cross-divisional work at CBO
  - Microsimulation of distributional effects small part
  - Estimating allowance price trajectory
  - Budgeting effects
  - International trade effects
  - International & Domestic offsets
  - Transportation & Electricity sector
Basic Problem

CO₂

And some other gases, too

Basic Solution

- Put a price on carbon
- Can be achieved directly with a tax, or indirectly with a “cap-and-trade” program
  Tax = price certain, quantity uncertain
  Cap = quantity certain, price uncertain
Why Microsimulation?

Distributional Analysis
- Analyze Regressivity/Progressivity of Policies
- Rank by income?
- Rank by expenditures? (permanent income hypothesis)
- Regional analysis

Database Preparations
- Standard CBO database for tax distribution analyses links the Census Bureau’s Current Population Survey with the Internal Revenue Service’s Statistics of Income data
- Need to match expenditures data to this database
  - 2006 Consumer Expenditures Survey data
Consumer Expenditure Survey

- Collects detailed expenditures information on households over 12 month period
- Designed to calculate basket weights in CPI calculation
- Two separate surveys: Interview & Diary
- Released as quarterly cross-sections, but we convert to annual panel files
Consumer Expenditure Survey

Average Annual Household Utility and Gasoline Expenditures by Income Quintile, 2007

<table>
<thead>
<tr>
<th>Dollars</th>
<th>All Households</th>
<th>Lowest</th>
<th>Second</th>
<th>Middle</th>
<th>Fourth</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>1,303</td>
<td>848</td>
<td>1,104</td>
<td>1,285</td>
<td>1,446</td>
<td>1,831</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>480</td>
<td>273</td>
<td>369</td>
<td>428</td>
<td>559</td>
<td>773</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>151</td>
<td>82</td>
<td>123</td>
<td>127</td>
<td>177</td>
<td>243</td>
</tr>
<tr>
<td>Total Utilities</td>
<td>1,934</td>
<td>1,203</td>
<td>1,596</td>
<td>1,840</td>
<td>2,181</td>
<td>2,847</td>
</tr>
<tr>
<td>Gasoline &amp; Motor Oil</td>
<td>2,384</td>
<td>1,046</td>
<td>1,768</td>
<td>2,418</td>
<td>2,988</td>
<td>3,696</td>
</tr>
<tr>
<td>Total Energy-Intensive Expenditures</td>
<td>4,318</td>
<td>2,249</td>
<td>3,364</td>
<td>4,258</td>
<td>5,169</td>
<td>6,543</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percent of Income</th>
<th>All Households</th>
<th>Lowest</th>
<th>Second</th>
<th>Middle</th>
<th>Fourth</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>2.1</td>
<td>8.1</td>
<td>4.0</td>
<td>2.8</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.8</td>
<td>2.6</td>
<td>1.3</td>
<td>0.9</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>0.2</td>
<td>0.8</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Total Utilities</td>
<td>3.1</td>
<td>11.4</td>
<td>5.8</td>
<td>4.0</td>
<td>3.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Gasoline &amp; Motor Oil</td>
<td>3.8</td>
<td>9.9</td>
<td>6.4</td>
<td>5.2</td>
<td>4.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Total Energy-Intensive Expenditures</td>
<td>6.8</td>
<td>21.4</td>
<td>12.2</td>
<td>9.2</td>
<td>7.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>


CE Adjustments: Renters

Missing Critical Information for 6% of the Sample
CE Adjustments: Diary Data

### Multiplicative Adjustment Factors

<table>
<thead>
<tr>
<th>Category</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Away</td>
<td>* 1.617609</td>
</tr>
<tr>
<td>Food at Home</td>
<td>* 0.823904</td>
</tr>
<tr>
<td>Alcohol Away</td>
<td>* 1.217858</td>
</tr>
<tr>
<td>Alcohol at Home</td>
<td>* 1.634421</td>
</tr>
<tr>
<td>Clothing and Shoes</td>
<td>* 1.603027</td>
</tr>
<tr>
<td>Furniture</td>
<td>* 1.321044</td>
</tr>
</tbody>
</table>

### Additive Adjustment Amounts

<table>
<thead>
<tr>
<th>Category</th>
<th>Adjustment Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toiletries</td>
<td>+ $317.00</td>
</tr>
<tr>
<td>Nondurables</td>
<td>+ $594.47</td>
</tr>
<tr>
<td>Prescription Drugs</td>
<td>+ $130.88</td>
</tr>
<tr>
<td>Business Services</td>
<td>+ $36.79</td>
</tr>
<tr>
<td>Tolls</td>
<td>+ $14.60</td>
</tr>
<tr>
<td>Other Education</td>
<td>+ $70.55</td>
</tr>
</tbody>
</table>

Imputing Expenditures

**Two Methods Used:**

- Hot deck imputation
  - Single households <$150,000 income
  - Married households <$300,000 income

- Regression imputation for high income households
Statistical Match SOI/CPS & CE

- Hot deck routine with both rigid and flexible matching criteria
  - Fixed: Region
  - Flexible: Age (+/- 1 year increments)
    Income (+/- 2% increments)
    Family Type (+/- 1 child only)
- Use CPS Income as bridge to SOI income
- Carry over expenditure ratios

High Income Regressions

- Both income and expenditure amounts are top coded
- Impute expenditure amounts based on regression models for high-income households
- Separate models for electricity, gasoline, fuel oil, natural gas, and total expenditures
High Income Regressions

- Estimate electricity, gasoline, fuel oil, natural gas expenditures
- Estimate total expenditures
- Distribute non-carbon intensive expenditures based on observed distribution in high income CE households
High Income Regressions

In(Consumption) by ln(Pre-tax-Income), CEX 2004

High Income Regressions

Ln(Consumption) = Ln(Pre-tax-Income)
Now What?

**IO Model**

- Need to simulate the effects a carbon cap-and-trade policy will have on consumer prices
- Leontief (1941)
- Fullerton (1995); Metcalf (1998, etc.)
### IO Model: Make & Use Tables

<table>
<thead>
<tr>
<th>Industries 1, 2, ...</th>
<th>Commodities</th>
<th>Total Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Make Table</td>
<td>g</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Input</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

V: Make matrix, industry-by-commodity (I x c)
g: Total commodity output, column vector (c x 1)
g: Total industry output, row column vector (I x 1)

<table>
<thead>
<tr>
<th>Industries 1, 2, ...</th>
<th>Commodities 1, 2, ...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use Table U</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Value Added</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Commodity Output</td>
<td>g'</td>
</tr>
</tbody>
</table>

U: Intermediate use matrix, commodity-by-industry (c x I)
g: Total commodity output, column vector (c x 1)
g: Total industry output, row column vector (I x 1)
E: Final Demand (c x k)
W: Value Added (I x I)

### IO Model: Basic

\[
a_{i1}p_1 + a_{i2}p_2 + \cdots + a_{im}p_m + v_i = p_i, \\
a_{11}p_1 + a_{12}p_2 + \cdots + a_{1m}p_m + v_1 = p_1, \\
\vdots \quad \vdots \quad \cdots \quad \vdots \quad \vdots \\
a_{m1}p_1 + a_{m2}p_2 + \cdots + a_{mm}p_m + v_m = p_m.
\]
IO Model: Basic

\[ a_1 p_1 + a_2 p_2 + \cdots + a_n p_n + v_i = p_i, \]
\[ a_1 p_1 + a_2 p_2 + \cdots + a_n p_n + v_i = p_i, \]
\[ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \]
\[ a_1 p_1 + a_2 p_2 + \cdots + a_n p_n + v_i = p_i, \]

\[ A'P + V = P \]
\[ P = (I - A')^{-1}V \]

And then we add a Tax Matrix

\[ P = (I - A')^{-1}(V + (AT)'l) \]
IO Model
Imports & Non-Combustive Uses

\[ a_1^t p_1^t + a_2^t p_2^t + a_3^t p_3^t + \cdots + a_n^t p_n^t + \cdots + a_1^n p_1^n + a_2^n p_2^n + \cdots + a_n^n p_n^n + v_i = P_i^t, \]

\[ \vdots = \vdots \]

\[ a_1^t p_1^t + a_2^t p_2^t + a_3^t p_3^t + \cdots + a_n^t p_n^t + a_1^n p_1^n + a_2^n p_2^n + \cdots + a_n^n p_n^n + v_i = P_i^t, \]

\[ P^d = (I - A_d)^i (V + (A_d T) I + \{A_d P^m}) \]

Additional adjustments are made for non-combustive uses of fossil fuels
(but I won’t bore you further with the equations)

IO Model Results

- Policy Simulation based on 2006 economy
- Allowance price of $19 per metric ton of CO₂
  (including imported petroleum products)
- Total allowance revenues of about 0.7% of GDP
IO Model: Price Change Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>0.5%</td>
</tr>
<tr>
<td>Clothing</td>
<td>0.2%</td>
</tr>
<tr>
<td>Nondurables</td>
<td>0.4%</td>
</tr>
<tr>
<td>Electricity</td>
<td>8.8%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>11.4%</td>
</tr>
<tr>
<td>Gasoline</td>
<td>4.2%</td>
</tr>
<tr>
<td>All Expenditures</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

Waxman-Markey Distribution
(2020 policy in 2010 $s)

Based on CBO letter to Senator Camp, June 19, 2009
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