CGE modelling: introduction and experience at the Centre of Policy Studies since 1975

Presented by

Peter B. Dixon

at the Workshop on
Capturing the potential for greenhouse gas offsets in Indian agriculture
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Claridges Hotel, New Delhi
Models built by the Centre of Policy Studies (CoPS) are used in Australia, U.S., China and other countries to study the effects on macro, industry, regional, labor-market, distributional and environmental variables of changes in taxes, public consumption, social-security payments, environmental policies, technologies, international commodity prices, interest rates, wage setting arrangements and union behavior, immigration, infrastructure and major-project expenditures, and known levels and exploitability of mineral deposits (the Dutch disease).
CoPS’ U.S. Model USAGE is applied by

USITC on import restraints, free trade agreements, baseline forecasting & validation
U.S. Treasury on Waxman-Markey greenhouse bill
Dept. of Commerce on illegal immigration, stimulus, national export initiative, biofuel policy, environmental regulation
Dept. of Agriculture on illegal immigration, biofuels
Dept. of Homeland Security on terrorist events and counterterrorism policies, H1N1 epidemic, illegal immigration
Dept. of Energy on greenhouse policies, biofuel policies
Canadian Government on US jobs from trade with Canada, North American integration
Cato Institute on low-skilled immigration
Mitre Corporation on airport infrastructure (NextGen)
Dept. of Transport on costs/benefits of road infrastructure
Plan of presentation

1. CGE history and relationship to I-O modelling
2. Building a CGE model
3. Ingredients in a successful long-term CGE project
4. Concluding remarks
Wassily Leontief (1936 & 1941) made two great contributions:
(a) The input-output table, and
(b) The input-output model that uses I-O table

CGE modelling is another form of modelling that uses the I-O table
- Started with the work of Leif Johansen (1960) in Norway
Distinguishing features of CGE relative to I-O modelling

(1) CGE emphasizes behaviour by individual agents

(2) CGE introduces resource constraints

(3) CGE emphasizes substitution possibilities and price sensitive behaviour
Similarities between Johansen’s CGE and Leontief’s I-O models

Leontief: \[ X = (I - A)^{-1}Y \]

Johansen: \[ v_1 = T v_2 \]

Leontief was fascinated with his \((I - A)^{-1}\) matrix the typical element of which shows the effect on the output of good \(i\) of a unit increase in exogenous demand for good \(j\).

Johansen was fascinated with his \(T\) matrix part of which shows the effect on the output of good \(i\) of a unit increase in exogenous demand for good \(j\).
Leontief versus Johansen: the effect on the output of $i$ of a unit increase in exogenous demand for $j$

Leontief (I-O)

$$(I - A)^{-1} = \begin{bmatrix}
all \geq 0 \\
mainly > 0 \\
\end{bmatrix}
$$

In Leontief’s world (the 1930s) there is high unemployment
⇒ no upward pressure on prices of primary factors from extra demand

Johansen (CGE)

$$T_{x,y} = \begin{bmatrix}
mainly < 0 \\
all \geq 0 \text{ but mainly } < 1 \\
mainly < 0 \\
\end{bmatrix}
$$

In Johansen’s world (the 1950s) there is full employment
⇒ upward pressure on prices of primary factors from extra demand
# Building a CGE model: the input-output database

The Absorption Matrix is a fundamental component of a CGE model, depicting the basic flows within an economy. The matrix illustrates the interdependencies among Producers, Investors, Households, Exports, and Government.

<table>
<thead>
<tr>
<th>Basic Flows</th>
<th>Margins</th>
<th>Sales Taxes</th>
<th>Labour</th>
<th>Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td><strong>I</strong></td>
<td><strong>I</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td><strong>↑</strong></td>
<td><strong>I</strong></td>
<td><strong>↑</strong></td>
<td><strong>↓</strong></td>
<td><strong>↓</strong></td>
</tr>
<tr>
<td><strong>C×S</strong></td>
<td><strong>↑</strong></td>
<td><strong>↑</strong></td>
<td><strong>↓</strong></td>
<td><strong>↓</strong></td>
</tr>
<tr>
<td><strong>BAS1</strong></td>
<td><strong>MAR1</strong></td>
<td><strong>TAX1</strong></td>
<td><strong>LAB0CCIND</strong></td>
<td><strong>CAPITAL</strong></td>
</tr>
<tr>
<td><strong>BAS2</strong></td>
<td><strong>MAR2</strong></td>
<td><strong>TAX2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BAS3</strong></td>
<td><strong>MAR3</strong></td>
<td><strong>TAX3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BAS4</strong></td>
<td><strong>MAR4</strong></td>
<td><strong>TAX4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BAS5</strong></td>
<td><strong>MAR5</strong></td>
<td><strong>TAX5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Joint Production Matrix:
- **Size** → **I**
- **↑**
- **C**
- **MAKE**

Import Duty Matrix:
- **Size** → **I**
- **↑**
- **C**
- **TARIFF**

**Notes:**
- **C** = Number of commodities
- **I** = Number of industries
- **S** = 2; domestic and imported
- **M** = Number of occupations
- **N** = Number of commodities used as margins
Value of inputs equals value of output

\[
\text{Sum}(\text{BAS1}) + \text{Sum}(\text{MAR1}) + \text{Sum}(\text{TAX1}) + \\
\text{Sum}(\text{LABOCCIND}) + \text{Sum}(\text{CAPITAL})
\]

\[
= \text{Sum}(\text{BAS1}) + \text{Sum}(\text{BAS2}) + \text{Sum}(\text{BAS3}) + \text{Sum}(\text{BAS4}) + \text{Sum}(\text{BAS5})
\]

\[
+ \text{Sum}(\text{MAR1}) + \text{Sum}(\text{MAR2}) + \text{Sum}(\text{MAR3}) + \text{Sum}(\text{MAR4}) + \text{Sum}(\text{MAR5})
\]

\[
- \left[ \text{Sum}(\text{BAS1(imp)}) + \text{Sum}(\text{BAS2(imp)})
\right.
\]

\[
\left. + \text{Sum}(\text{BAS3(imp)}) + \text{Sum}(\text{BAS5(imp)}) \right]
\]

\[
\text{Sum}(\text{BAS1}) + \text{Sum}(\text{MAR1}) + \text{Sum}(\text{TAX1}) + \\
\text{Sum}(\text{LABOCCIND}) + \text{Sum}(\text{CAPITAL})
\]

\[
= \text{Sum}(\text{BAS1}) + \text{Sum}(\text{BAS2}) + \text{Sum}(\text{BAS3}) + \text{Sum}(\text{BAS4}) + \text{Sum}(\text{BAS5})
\]

\[
+ \text{Sum}(\text{MAR1}) + \text{Sum}(\text{MAR2}) + \text{Sum}(\text{MAR3}) + \text{Sum}(\text{MAR4}) + \text{Sum}(\text{MAR5})
\]

\[
- \left[ \text{Sum}(\text{BAS1(imp)}) + \text{Sum}(\text{BAS2(imp)})
\right.
\]

\[
\left. + \text{Sum}(\text{BAS3(imp)}) + \text{Sum}(\text{BAS5(imp)}) \right]
\]
Income and expenditure measures of GDP

\[ \text{Sum(LABOCCIND)} + \text{Sum(CAPITAL)} + \text{Sum(TAX1)} \]

\[ + \sum_{\phi=2}^{5} \text{Sum(TAX}\phi) \]

\[ = \text{Sum(BAS2)} + \text{Sum(MAR2)} + \text{Sum(TAX2)} \]

\[ + \text{Sum(BAS3)} + \text{Sum(MAR3)} + \text{Sum(TAX3)} \]

\[ + \text{Sum(BAS4)} + \text{Sum(MAR4)} + \text{Sum(TAX4)} \]

\[ + \text{Sum(BAS5)} + \text{Sum(MAR5)} + \text{Sum(TAX5)} \]

\[ - \left[ \sum_{\phi=1}^{3.5} \text{Sum(BAS}\phi(\text{imp})) \right] - \text{Sum(TARIFF)} \]
A sequence of solutions using required solution for t-1 as initial solution for t

Initial solution $\bar{V}(0)$ $\Rightarrow$ $\bar{V}(1)$ $\Rightarrow$ $\bar{V}(2)$

Johansen/Euler computation

Required solution

move exogenous variables from year-0 to year-1 values

move exogenous variables from year-1 to year-2 values
Ingredients in a successful long-term CGE project

Success and longevity of CoPS attributed to

- sharp policy focus, initially tariffs
- the leadership of the foundation director Alan Powell who set the standards of openness and collegiality
- adaptability of CoPS’ models reflecting extensions of Johansen techniques
- willingness to respond to clients needs
(1) up-to-date data

Historical simulations:
Tell the model about movements in observed variables since the last input-output table.

Historical simulations produce up-to-date input-output data that can’t be contradicted by available statistics.

Historical simulations produce valuable estimates of trends in technologies, consumer preferences and other unobservables.
What do clients want: (2) detail in the focus area

Clients interested in biofuel policy required extension of a 500 commodity model to

- include as separate commodities: Corn; Switch grass; Crop residue; Cellulosic materials; Organic by-products; Corn ethanol; Dried distillers grains with solubles; Cellulosic ethanol; Advanced ethanol; Gasoline; Diesel; and Other fuels
- explicit complementarity conditions specifying the operation of tariff rate quotas on imports of Sugar and other agricultural products
- 72 types of agricultural land
What do clients want:
(3) disaggregated results

CGE results for the U.S.: income changes from an Iron & steel safeguard tariff

<table>
<thead>
<tr>
<th>Income changes:</th>
<th>Million dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tariff revenue</td>
<td>649.9</td>
</tr>
<tr>
<td>Labor income</td>
<td>-386.0</td>
</tr>
<tr>
<td>Capital income</td>
<td>-294.3</td>
</tr>
<tr>
<td>Iron and steel industry</td>
<td>239.5</td>
</tr>
<tr>
<td>Input suppliers to Iron and steel</td>
<td>67.4</td>
</tr>
<tr>
<td>Other industries (including steel users)</td>
<td>-601.2</td>
</tr>
<tr>
<td>GDP</td>
<td>-30.4</td>
</tr>
</tbody>
</table>
What do clients want: (4) baseline forecasts

% output changes 2005-13: baseline and liberalization

-60 -50 -40 -30 -20 -10 0 10 20 30
Liberalization baseline GDP growth

- Broadwoven fabric
- Narrow fabrics
- Nonwoven fabrics
- Knit fabrics
- Yarn and textile finishing n.e.c.
- Thread
- Carpets and rugs
- Coated fabrics not rubberized
- Tire cord
- Cordage and twine
- Textile goods n.e.c.
- Curtains and draperies
- House furnishings n.e.c.
- Textile bags
- Canvas and related products
- Pleating and stitching
- Automotive & apparel trimming
- Embroideries
- Fabricated textile products n.e.c.
- Women's hosiery, except socks
- Hosiery n.e.c.
- Apparel from purchased materials

Legend:
- × Liberalization
- ○ baseline
- GDP growth
What do clients want: (5) historical decomposition

<table>
<thead>
<tr>
<th>Driving factor</th>
<th>Percentage effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shifts in foreign demands and import supply curves</td>
<td>-4.8</td>
</tr>
<tr>
<td>2. Changes in protection</td>
<td>-5.6</td>
</tr>
<tr>
<td>3. Technical change</td>
<td>24.4</td>
</tr>
<tr>
<td>4. Growth in aggregate employment</td>
<td>16.7</td>
</tr>
<tr>
<td>5. Changes in import/domestic preferences</td>
<td>-4.0</td>
</tr>
<tr>
<td>6. Changes in required rates of return</td>
<td>-7.0</td>
</tr>
<tr>
<td>7. Other factors</td>
<td>-5.2</td>
</tr>
<tr>
<td>Total</td>
<td>14.5</td>
</tr>
</tbody>
</table>
What do clients want: 
(6) validation

(1) Computing validation

(2) Historical validation

(3) Forecasting validation

(4) Explanation validation

Vital for assessing
- what has been taken into account?
- is the relevant data up-to-date and accurate?
- are the mechanisms built into the model adequate?
Explanation validation can take many forms, e.g. a diagram

Welfare effect of carbon tax explained via consumer surplus diagram
Concluding remarks

(1) Disaggregated CGE modelling can produce results that are credible, new, policy-relevant and not available from aggregated models

(2) Johansen (1960) is still worth reading

(3) Derivation from published statistics of a database for a detailed policy-relevant CGE model is highly skilled, painstaking work
Concluding remarks

(4) Primary purpose of CGE modelling is to assist in policy formation. CGE modellers should respect demands of clients for: up-to-date data; sectoral detail; disaggregated results; baselines; decomposition; and validation.

(5) CGE results can be explained convincingly to economists without CGE backgrounds.

(6) CGE modelling benefits from an enduring team environment allowing specialization and accumulation of knowledge across generations.