Introduction to Computable General Equilibrium Model (CGE)

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Course Outline

- Overview of CGE
- An Introduction to the Structure of CGE
- An Introduction to GAMS
- Casting CGE models into GAMS
- Data for CGE Models & Calibration
- Incorporating a trade & a basic CGE application
- Evaluating impacts of policy changes and casting nested functions & a trade in GAMS
- Mixed Complementary Problems (MCP)
This Week’s Road Map

- What is (C)GE? and Why CGE?
- How does CGE fit into Ag-Econ or Econ
- Contrast with Partial Equilibrium & Econometrics
- Benefits and Drawbacks of CGE
- Overview of a CGE Model
- Theory Behind CGE
What is (C)GE Analysis?

- An analytical approach looking at the economy as a complete system of interdependent components (industries, households, investors, government, importers, exporters)

- Recognize economic shocks on one component creating ripple effects throughout the system

- Representative of producer and consumer behaviors

- “Computable” => a system providing quantitative analysis by solving the GE numerically.
Why use GE Analysis?

- **Economy wide impact analysis**
  - global, multi-regional, multi-sectoral economies
  - backward/forward impacts on other sectors from “shocks”

- **Tracing distributional impacts of consumer income changes**
  - factor and commodity markets

- **Broad scope**
  - institutions, production sectors, households

- **Flexible to handle broad range of policy issues**
  - tax, trade, pollution, ghg emission, etc
How does CGE fit in the AgEcon?

■ Moving away from
  • individual analysis at a farm or firm or industry level ⇒ to a multi-industry level

■ Analysis of policy changes that cut across both Ag and non-Ag sectors
Why not use Partial Equilibrium?

- PE assumes that a “shock” produces direct price changes that do not have meaningful income effect and thus other prices are constant.
- Welfare measures are for direct price changes.
- Not consider resource endowments (subsidy pulls resources away from other sectors)
- Not capture income effects endogenously (no link between factor incomes and expenditures)
When is PE appropriate?

- When only interested in sectoral policies
- Small income shares
- “Shocks” produce direct price changes that do not cause any other prices to change. This assumption is satisfied only when other markets are dominated by price-fixing (perfect price elasticity of supply and demand functions)
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Benefits from Using CGE? (1)

- **Accounting and theoretical consistency:**
  - Accounting consistency: expenditures cannot exceed incomes
  - Consistent factor allocation making sure that factor markets clear.
  - Conceptual and computational consistency
    - **Walras’ Law:** hh are on their budget constraints
      - zero profit conditions for firms
      - supply = demand
  - Tracking consequences of policy choices
    (e.g. taxes)
Benefits from Using CGE? (2)

- Inter-industry or multi-sector backward/forward linkage:
  - Agriculture to Non-agriculture and vice versa

- Welfare analysis:
  - A policy analysis focuses on changes in real income resulting from changes in prices (X% of GDP), not on CS or PS.
  - e.g. farmers are consumers in input sectors (ie. fertilizer or energy markets) but are also producers in output sectors (ie. cotton market).
Benefits from Using CGE? (3)

- Extension to include environmental indicators
  - e.g. climate change issues: CO2 emission using SGM, MERGE, EPPA models

Hertel, T. W. “Applied general equilibrium analysis of agricultural and resource policies. Staff Paper 99-2, Department of Agricultural Economics, Purdue University, March 1999.
Drawbacks of CGE?

- **Difficulties of model selection, parameter specification, and functional forms (CES vs. Cobb)**
  - Benchmark equilibrium \(\Rightarrow\) functional forms \(\Rightarrow\) choice of elasticities and other parameter values are based on empirical work
- **Data consistency – calibration problem**
- **Not a statistical test of the model specification**
  - deterministic calibration
- **Not good for monetary or fiscal policies**
  - focuses on the relationship between relative price changes and the flow of goods and services, **not** levels of prices
- **Complexity and require skill to maintain the model**
CGE Overview -- Steps in CGE Modeling


Basic Data (IO, SAM, etc.) → Data Adjustment → Calibration → Benchmark Equilibrium → Shocks → Counterfactual Equilibrium

Replication Check → Specification of exogenous values

Further Policy Analysis → Exit

Comparative Policy Analysis
CGE Overview -- Economy Representation

Adapted from Krauss, M. B. and H. G. Johnson. “General Equilibrium Analysis: A Micro-Economic Tex.” Figure 1.2, page 27, 1974
CGE Overview -- Commodity Flow

Production

CD, CES, Fixed function

Factors & Intermediate inputs

CET function

Exports

Domestic

Imports

Consumption

Household

Government

Investment

Intermediate use

Trade Balance

Imperfect substitutability
Armington function

Theory Behind CGE (1)

Consumption Case

\[ P_1 Q_{1A} + P_2 Q_{2A} = P_1 \overline{Q}_{1A} + P_2 \overline{Q}_{2A} \]
\[ P_1 Q_{1B} + P_2 Q_{2B} = P_1 \overline{Q}_{1B} + P_2 \overline{Q}_{2B} \]
\[ P_1 (Q_{1A} - \overline{Q}_{1A}) + P_2 (Q_{2A} - \overline{Q}_{2A}) = 0 \]
\[ P_1 Z_{1A} + P_2 Z_{2A} = 0 \Rightarrow \text{Walras’ Law} \]
\[ P_1 Z_{1B} + P_2 Z_{2B} = 0 \]
\[ P_1 (Z_{1A} + Z_{1B}) + P_2 (Z_{2A} + Z_{2B}) = 0 \]

Implication

- \( \text{MRS}_A q_1 q_2 = \text{MRS}_B q_1 q_2 \)

price adjustment process
Implication

- $\text{MRS}_A^{q_1q_2} = \text{MRS}_B^{q_1q_2}$
- Homo degree “0” in price

$\implies$ doubling in prices doubles incomes and therefore quantities demanded are unchanged

$\implies$ If $p^* = (p^*_1, p^*_2)$ is a Walrasian equilibrium price vector then so is $ap^* = (a p^*_1, ap^*_2)$ for $a > 0$

$\implies$ relative price $p^*_1 / p^*_2$ is a focus
Theory Behind CGE (3)

**Production Case**

- tracing contract curves (CC) or efficiency production locus
- MRTS measures a rate at which one input can be substituted for another while maintaining the same level of output
- \( MRTS_{q_1}^{LK} = MRTS_{q_2}^{LK} = \text{factor price ratio (w/r)} \)
Walrasian Equilibrium (1)

Consumption:

- The value of market demands equals the value of the economy’s endowment.

\[ \sum_{i=1}^{N} p_i X_i(p) = \sum_{i=1}^{N} p_i w_i \]

- The value of market excess demands equals zero at all prices.

\[ \sum_{i=1}^{N} p_i [X_i(p) - w_i] = 0 \]

- A general equilibrium in this system is a set of prices \( p_i^* \) such that \( X_i(p^*) - w_i \leq 0 \).

- If \( p_i^* > 0 \) then \( X_i(p^*) - w_i = 0 \); otherwise, \( X_i(p^*) - w_i < 0 \).

\( w_i \) is an endowment of goods i.
Walrasian Equilibrium (2)

Production:

A general equilibrium in this system is a set of prices $p_j^*$ and activity $Q_j^*$ such that:

1. Demand is less than or equal to the supply.
   
   \[ X_j + \sum_i a_{ji}Q_i - Q_j \leq 0 \quad \forall j \]

   If $p_j^* > 0$ then
   \[ X_j + \sum_i a_{ji}Q_i - Q_j = 0 \quad \forall j \]

2. No production activity makes positive profits.
   
   \[ P_jQ_j - \sum_i P_i a_{ij}Q_j - rW_j \leq 0 \quad \forall j \]

   If $Q_j^* > 0$ then
   \[ P_jQ_j - \sum_i P_i a_{ij}Q_j - rW_j = 0 \quad \forall j \]

$W_j$ is a factor usage in sector $j$ and $r$ is a factor price, $a_{ij} = \text{use of goods } i \text{ in activity } j$. 
Examples of CGE?

- Welfare effects of tax reform
- Trade policy
  - single country
  - global trade (GTAP: Hertel T.)
- Energy and environment
  - Whalley and Wigle (1990)
  - GHG emission (MERGE: Manne A., SGM: Sands R., EPPA: MIT)
- Labor markets
- Public finance
Wrap Up

- What and Why CGE
- Benefits and Drawbacks
- Overview of CGE Modeling
- Theory Behind CGE

Next:
- Structure of CGE
  - fundamental relationship
  - interpretation of results
  - incorporating shocks
  - comparative analysis
References

Hertel, T. W. “Applied general equilibrium analysis of agricultural and resource policies. Staff Paper 99-2, Department of Agricultural Economics, Purdue University, March 1999.