Lecture 3.2

1 2 Sim?
Easy CGE Modeling

David Roland-Holst, Sam Heft-Neal, and Anaspree Chaiwan
UC Berkeley and Chiang Mai University

Training Workshop
Economywide Assessment of High Impact Animal Disease
14-18 January 2013
InterContinental Hotel, Phnom Penh, Cambodia
1-2-3 CGE Model

- 1 country, 2 activities, 3 commodities
- 2 activities, producing D and E.  
  - E not consumed domestically.
- Additional commodity, M, consumed domestically but not produced.
Structural Assumptions

- Aggregate GDP (X) is fixed.
  - Full employment model.
- Trade balance set exogenously.
- World prices of M and E are fixed.
- Total absorption (Q) is endogenous.
Analytical 1-2-3 Model

Flows

1. $\bar{X} = G(E, D^S; \Omega)$
2. $Q^S = F(M, D^D; \sigma)$
3. $Q^D = \frac{Y}{P^q}$
4. $\frac{E}{D^S} = g_2(P^e, P^d)$
5. $\frac{M}{D^D} = f_2(P^m, P^d)$
6. $Y = P^x \cdot \bar{X} + R \cdot B$

Prices

7. $P^m = R \cdot pw^m$
8. $P^e = R \cdot pw^e$
9. $P^x = g_1(P^e, P^d)$
10. $P^q = f_1(P^m, P^d)$
11. $R \equiv 1$

Equilibrium Conditions

12. $D^D - D^S = 0$
13. $Q^D - Q^S = 0$
14. $pw^m \cdot M - pw^e \cdot E = B$
Identities

15. \( P^x \cdot X \equiv P^e \cdot E + P^d \cdot D^S \)

16. \( P^q \cdot Q^S \equiv P^m \cdot M + P^d \cdot D^D \)

17. \( Y \equiv P^q \cdot Q^D \)
Definitions for the 1-2-3 CGE Model

Endogenous Variables
E: Export good
M: Import good
D$: Supply of domestic good
D$: Demand for domestic good
Q$: Supply of composite good
Q$: Demand for composite good
Y: Total income
Pe$: Domestic price of export good
Pm$: Domestic price of import good
Pd$: Domestic price of domestic good
Px$: Price of aggregate output
Pq$: Price of composite good
R: Exchange rate

Exogenous Variables
pw$: world price of export good
pw$: world price of import good
B: Balance of trade
σ: Import substitution elasticity
Ω: Export transformation elasticity
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<td><strong>Total</strong></td>
<td>$P^d \cdot D^S + P^e \cdot E$</td>
<td>$P^q \cdot Q^S$</td>
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Trade Schematically

CET

slope = -PD/PE

slope = E/D = k \left( \frac{P_E}{P_D} \right)^\sigma

Indifference Curve

slope = M/D = k \left( \frac{P_D}{P_M} \right)^\sigma

Domestic Goods/Services

Exports

Imports

Domestic Goods/Services

PPF
Maximize $Q = F(M, D; \sigma)$

with respect to: $M, E, D^D, D^S$

subject to:

1. $G(E, D^S; \Omega) \leq \bar{X}$ technology

2. $pw^m \cdot M \leq pw^e \cdot E + \bar{B}$ balance of trade

3. $D^D \leq D^S$ domestic market

Shadow Prices

$\lambda^x = P^x / P^q$

$\lambda^b = R / P^q$

$\lambda^d = P^d / P^q$
Assumptions

- A CET transformation technology between a domestic good D and an export Good E
- CES preferences in final demand over D and imports M
- A fixed balance of trade
- Fixed government demand and investment (example of “macroeconomic closure”)
- Fixed terms-of-trade (small country assumption)
- Macro identities hold (income constraints, balance of trade, etc.)
1-2-3 Model Descriptively
Foreign Capital Inflow

Q = F(M,D)

Balance of Trade

X = G(E,D)

Domestic Market
Terms of Trade Deterioration

\[ Q = F(M,D) \]

\[ \frac{P_E}{P_M} \downarrow \]

Balance of Trade

Domestic Market

\[ X = G(E,D) \]
## The 123 model in Excel

19 endogenous variables and equations
- variables are “scaled” as a share of GDP
- Basic inputs are macroeconomic accounts data

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<tr>
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<th>B</th>
<th>C</th>
<th>D</th>
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<td>Exogenous Variables</td>
<td>Base Year</td>
<td>Current</td>
<td>Endogenous Variables</td>
<td>Base Year</td>
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### Parameters

- **Elasticity for CET (st)**: 0.60
- **Elasticity for CES/Q (sq)**: 0.60
- **Scale for CET (at)**: 2.22
- **Scale for CES/Q (aq)**: 1.97
- **Rho for CET (rt)**: 2.67
- **Rho for CES/Q (rq)**: 0.67
- **Share for CET (bt)**: 0.77
- **Share for CES/Q (bq)**: 0.38

### Exogenous Variables

- **World Price of Imports (wm)**: 0.89
- **World Price of Exports (we)**: 1.01
- **Import Tariffs (tm)**: 0.13
- **Import Duties (te)**: 0.01
- **Indirect Taxes (ts)**: 0.03
- **Foreign Grants (ft)**: 0.02
- **Net Priv. Remittances (re)**: 0.01
- **Output (X)**: 1.00

### Endogenous Variables

- **Export Good (E)**: 0.33
- **Import Good (M)**: 0.50
- **Supplies of Domestic Good (Ds)**: 0.67
- **Demand of Domestic Good (Dd)**: 0.33
- **Demand of Composite Good (Qs)**: 0.08
- **Demand of Domestic Good Good (Qd)**: 1.18
- **Aggregate Savings (S)**: 0.27
- **Consumption (C)**: 0.83
- **Investment (Z)**: 1.00
- **Government Savings (Sg)**: 0.01
- **Walras Law (Z-S)**: 0.00

### Equilibrium Conditions

- **Exchange Rate (Er)**: 1.00
- **Price of Supply (Ps)**: 0.00
- **Price of Demand (Pd)**: 0.00

### Equilibrium Flows

- **CET Transformation (CETEQ)**: 1.00
- **Supply of Goods (ARMG)**: 1.18
- **Domestic Demand (DEM)**: 1.00
- **E/D Ratio (EDRAT)**: 0.49
- **M/D Ratio (MDRAT)**: 0.75

### Real Flows

- **CET Transformation (CETEQ)**: 1.00
- **Supply of Goods (ARMG)**: 1.18
- **Domestic Demand (DEM)**: 1.00
- **E/D Ratio (EDRAT)**: 0.49
- **M/D Ratio (MDRAT)**: 0.75

### Nominal Flows

- **Revenue Equation (TAXEQ)**: 0.20
- **Total Income Equation (INC)**: 1.13
- **Savings Equation (SAV)**: 0.27
- **Consumption Function (CONS)**: 0.83

### Prices

- **Import Price Equation (PMEQ)**: 1.00
- **Export Price Equation (PEEQ)**: 1.00
- **Sales Price Equation (PTEQ)**: 1.00
- **Output Price Equation (PXEQ)**: 1.00
- **_numeraire (REQ)**: 1.00

### Equilibrium Conditions

- **Domestic Good Market (DEQ)**: 0.00
- **Composite Good Market (QEQ)**: 0.00
- **Current Account Balance (CABAL)**: 0.08
- **Government Budget (GBUD)**: -0.01

16 January 2013
The 123 model in Excel

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- 19 endogenous variables and equations
- variables are “scaled” as a share of GDP
- Basic inputs are macroeconomic accounts data

16 January 2013
Variables are identified to the solver by name.
• Must run the solver any time parameters or baseline data are changed.

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<td>Scale for CET (at)</td>
<td>= X0/(bt*E0^(rt)+(1-bt)*Ds0^(rt))^(1/rt)</td>
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<td>Share for CET (bt)</td>
<td>= 1/(1+(Pd0/Pe0)*(E0/Ds0)^(rt-1))</td>
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<td>Rho for CET (rt)</td>
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<td>Scale for CES/Q (aq)</td>
<td>= Qs0/(bq*M0^(-rq)+(1-bq)*Dd0^(-rq))^(1/rq)</td>
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<td>Share for CES/Q (bq)</td>
<td>= (Pm0/Pd0)<em>(M0/Dd0)^(1+rq)/(1+(Pm0/Pd0)</em>(M0/Dd0)^(1+rq))</td>
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To run a counterfactual experiment

- Change the Current values of Exogenous Variables (column F of the 1-2-3 Model Sheet)
- Run the Solver
- Examine Results Summary and Endogenous Variables
- NB: Be sure to re-calibrate after each experiment
A Model with Consumption, Government, and Investment

Real Flows
(1) \( X = G(E,D^S;\omega) \)
(2) \( Q^S = F(M,D^D;\sigma) \)
(3) \( Q^D = C + Z + G \)
(4) \( E/D^S = g_2(Pe,Pd) \)
(5) \( M/D^D = f_2(Pm, Pt) \)

Prices
(10) \( Pm = (1 + tm) \cdot R \cdot pwm \)
(11) \( Pe = (1 + te) \cdot R \cdot pwe \)
(12) \( Pt = (1 + ts) \cdot Pq \)
(13) \( Px = g_1(Pe,Pd) \)
(14) \( Pq = f_1(Pm, Pt) \)
(15) \( R = 1 \)

Nominal Flows
(6) \( T = tm \cdot R \cdot pwm \cdot M \)
\[ + ts \cdot Pq \cdot Q^D \]
\[ + ty \cdot Y - te \cdot R \cdot pwe \cdot E \]
(7) \( Y = Px \cdot X + tr \cdot Pq + re \cdot R \)
(8) \( S = s \cdot Y + R \cdot B + Sg \)
(9) \( C \cdot Pt = (1 - s - ty) \cdot Y \)

Equilibrium Conditions
(16) \( D^D - D^S = 0 \)
(17) \( Q^D - Q^S = 0 \)
(18) \( pwm \cdot M - pwe \cdot E - ft - re = B \)
(19) \( Pt \cdot Z - S = 0 \)
(20) \( T - Pq \cdot G - tr \cdot Pq - ft \cdot R - Sg = 0 \)

Accounting Identities
(i) \( Px \cdot X = Pe \cdot E + Pd \cdot D^S \)
(ii) \( Pq \cdot Q^S = Pm \cdot M + Pt \cdot D^D \)
### Definitions

#### Endogenous Variables

- E: Export good
- M: Import good
- DS: Supply of domestic good
- DD: Demand for domestic good
- QS: Supply of composite good
- QD: Demand for composite good
- Pe: Domestic price of export good
- Pm: Domestic price of import good
- Pd: Producer price of domestic good
- Pt: Sales price of composite good
- Px: Price of aggregate output
- Pq: Price of composite good
- R: Exchange rate
- T: Tax revenue
- Sg: Government savings
- Y: Total income
- C: Aggregate consumption
- S: Aggregate savings
- Z: Aggregate real investment

#### Exogenous Variables

- pwm: World price of import good
- pwe: World price of export good
- tm: Tariff rate
- te: Export subsidy rate
- ts: sales/excise/value-added tax rate
- ty: direct tax rate
- tr: government transfers
- ft: foreign transfers to government
- re: foreign remittances to private sector
- s: Average savings rate
- X: Aggregate output
- G: Real government demand
- B: Balance of trade
- rhot: Export transformation elasticity
- rhoc: Import substitution elasticity
<table>
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<td>Z</td>
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<tr>
<td>Hshld</td>
<td>Y</td>
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<tr>
<td>Govt</td>
<td>$T_X$</td>
<td>$T_H$</td>
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<tr>
<td>Cap</td>
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<td>$S_H$</td>
<td>$S_G$</td>
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<tr>
<td>Wrld</td>
<td>M</td>
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</tbody>
</table>
Diagrammatic 1-2-3 model

\[ \text{Slope} = \frac{P_D}{P_M} \]

\[ Q = F(M,D) \]

\[ D^D = D^S \]

Domestic Market

\[ X = G(E,D) \]

Balance of Trade

\[ P_M M = P_E E + B \]

\[ \text{Slope} = \frac{P_E}{P_M} \]

\[ \text{Slope} = \frac{P_D}{P_E} \]
Foreign Capital Inflow

Q = F(M,D)
Slope = pd/pm

E = G(E,D)
Slope = pd/pe

Real Appreciation

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Adverse Terms of Trade Movement

\[ Q = F(M, D) \]

\[ \text{Slope} = \frac{pd}{pm} \]

\[ X = G(E, D) \]

\[ \text{Real Depreciation} \]
Download the Excel spreadsheet Cambodia_Mini_CGE.xls
This is a heuristic, 2 sector CGE model in six spreadsheets:
1. AggMat – A matrix of zeros and ones to aggregate a standard GTAP SAM to fit the two sector framework
2. BaseSAM – The initial input SAM, taken from GTAP 5.
3. SAM – The aggregated initial SAM and a counterfactual SAM for comparative static assessment
4. Model – The primary data and equation spreadsheet
5. Parameters – A registry of structural parameter values
6. Dictionary – complete definitions of variables and parameters
This is the primary functional component of the Mini_CGE, containing all
1. Endogenous variables, 87 (suffixes _a and _o for agriculture and other)
2. Equations 86 (one is redundant because of Walras Law)
3. Exogenous variables, 27 and
4. A few examples of counterfactual experiments.
Parameters: Supply and Demand

Production

\( \sigma^p \) \( \text{sigmap} \) - Substitution elasticity between total intermediate demand, \( ND \), and value added, \( VA \).

\( \sigma^v \) \( \text{sigmav} \) - Substitution elasticity between labor, and the capital-sector specific factor bundle, \( KF \).

\( \sigma^k \) \( \text{sigmak} \) - Substitution elasticity between capital and the sector specific factor.

Final demand

\( \eta \) \( \text{eta} \) - Income elasticity

\( \sigma^g \) \( \text{sigmag} \) - Government expenditure substitution elasticity

\( \sigma^i \) \( \text{sigmai} \) - Investment expenditure substitution elasticity
Parameters – Trade and Factors

Trade elasticities

\( \sigma^m \) \( \textbf{sigmam} \) - Armington import elasticity
\( \sigma^x \) \( \textbf{sigmax} \) - CET transformation elasticity (between domestic and export supply).
\( \varepsilon \) \( \textbf{epse} \) - Export demand elasticity.

Supply elasticities

\( \omega^l \) \( \textbf{omegal} \) - Aggregate labor supply elasticity
\( \omega^k \) \( \textbf{omegak} \) - Capital mobility elasticity. 0 emulates sector-specific capital. Use a high value to approximate perfectly mobile capital.
\( \omega^f \) \( \textbf{sigmak} \) - Sector-specific supply elasticities.
Install or Initialize the Solver

Look under Tools/Solver or the Office Button/Excel Options

The **Solver** solution algorithm is invoked by clicking on the **Solve** button.

The status bar at the bottom of the Excel screen displays (minimal) information on each iteration, including iteration count and value of the objective function.

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If successful, the solver will display the following dialog box:

![Solver Results Dialog Box](image)

To have the *Solver* overwrite the values of the endogenous variables, simply click on the OK button. Users can experiment with the other options.
If solution convergence was achieved, the model should have reproduced the base data set (within the limits of the convergence tolerance). All equations should evaluate to 0. The expression of Walras’ Law should evaluate to 0. All deviations from initial values should evaluate to 0. A final test is to check the consistency of the resulting SAM.

The SAM spreadsheet, contains the solution SAM. The solution SAM is expressed in terms of the model solution. For example, the labor remuneration cell (in agriculture) contains the formula:

\[ =\text{wage}*\text{ld}_a/\text{scale} \]

If the SAM is not consistent, either the solution is inconsistent, the model has been mis-specified, or the formulas in the SAM have been mis-specified. The formula is adjusted by the scale variable to make the solution SAM comparable with the initial SAM.
If this is a new model, it is recommended to check model homogeneity. This involves a perturbation of the model numéraire. If the model is homogeneous in prices, perturbation of the model numéraire should leave all volumes constant, and adjust all prices and value variables by the same percentage amount as the percentage change in the numéraire (i.e. all relative prices remain constant). To check homogeneity, multiply the initial value of the numéraire by some constant, e.g. in cell L23, for the exchange rate substitute

=er0*1.1

Initially, the only equations which will be affected by this change are the domestic investment equation, the domestic trade prices, and the tariff revenue equation because these are the only equations where the numéraire (the exchange rate) appears. Invoke Solver to find a new solution to the model. If the homogeneity test fails (other than due to the lack of convergence), at least one of the equations has been mis-specified, or there could be a built-in nominal rigidity, such as a fixed nominal wage. If both tests succeed, the model should be re-initialized, and the next step is to run one or more shocks to the model.
1. Tariff Abolition
2. Full Trade Reform
3. Agricultural Export Tax
4. Agricultural Export Price Changes
5. Other Export Price Changes
Moving to GAMS

- The Excel version of 1-2-3 is easily accessible, but must be highly simplified to be tractable.
- Using a higher level programming language enables us to include more economic structure and behavior.
- The Generalized Algebraic Modeling System (GAMS) is the language of choice for this kind of work.
• The homepage of the GAMS corporation ([www.gams.com](http://www.gams.com)) contains a lot of useful information.

• From the homepage, a full user guide can be downloaded at [www.gams.com/docs/document.htm](http://www.gams.com/docs/document.htm); the user guide contains the syntax for all GAMS commands and very helpful as a reference when writing GAMS models. Note that the user guide is also available via the Help function in GAMS-IDE.

• All readers are advised to study the introductory chapter of this manual when starting to learn the GAMS software.
Questions?