# Introduction to Computable General Equilibrium Model (CGE)

Dhazn Gillig
&
Bruce A. McCarl

Department of Agricultural Economics
Texas A&M University

# 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 $\Rightarrow$ 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)
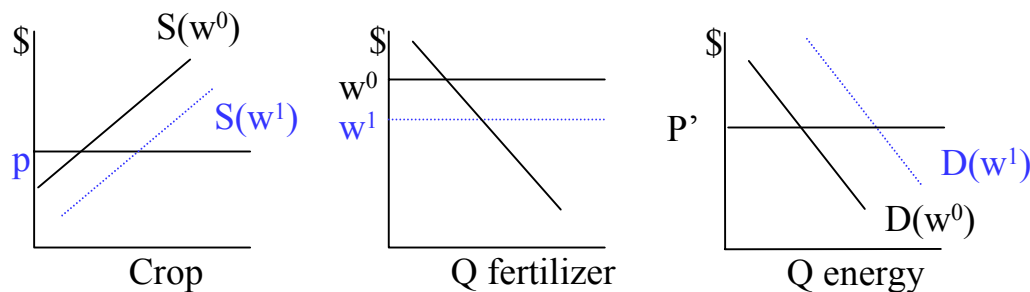
| Econometrics Modeling | CGE Modeling |
|---|---|
| • Regression estimations | • Benchmark data |
| • Simultaneous equations | • Deviation from benchmark equilibrium |
| • Relies on data size | • Explicit specifications |
| • Time-Series method | • Handling large movements in relative prices |
| • Identification problem | • Welfare analysis |
| • Not appropriate for welfare analysis | • Inter-industry analysis |

**Reference:** Adam, C. "CGE Models: Specification, calibration and macroeconomic application" Department of Economics, University of Oxford, Oxford, UK

# 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**

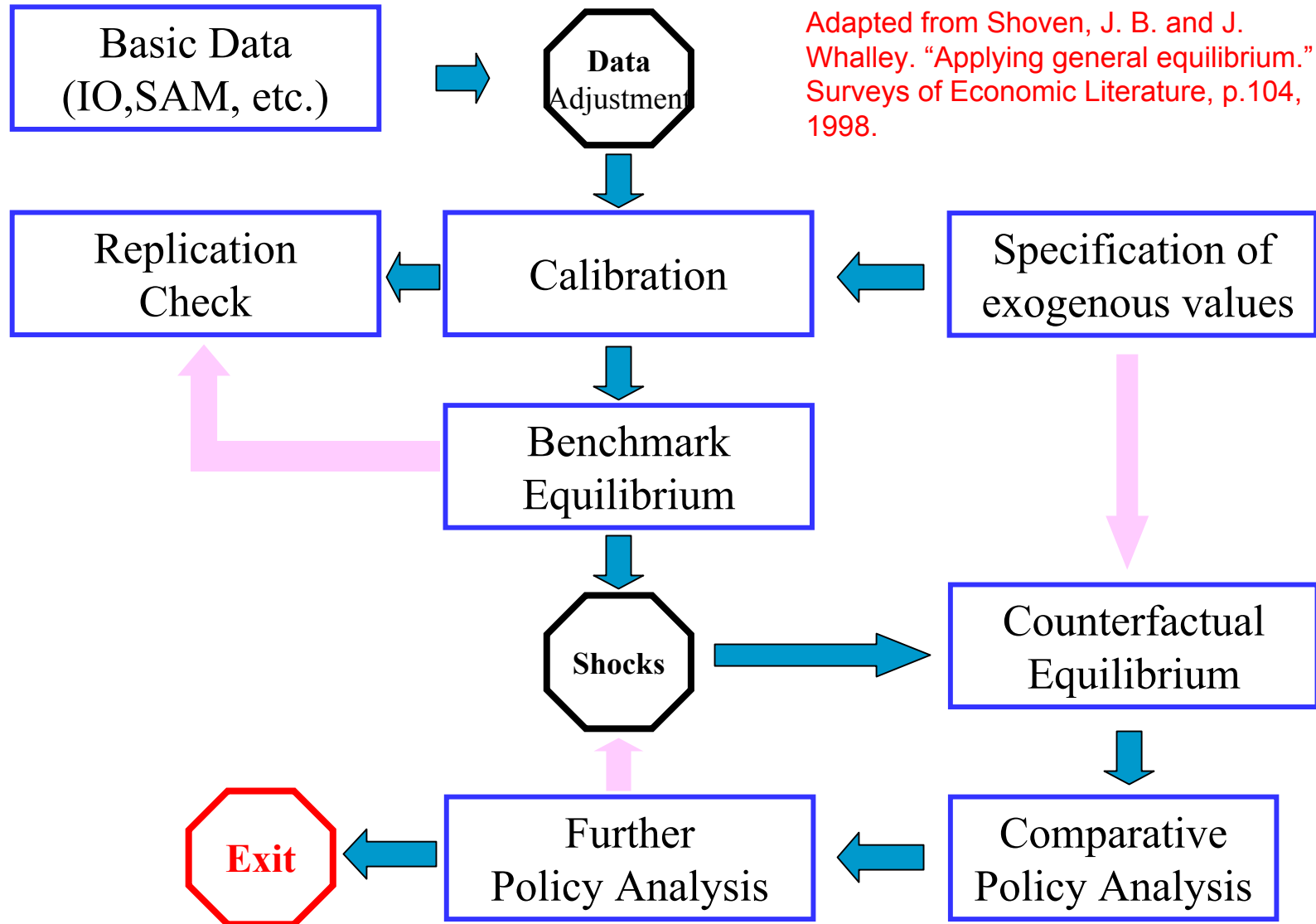- e.g.climate change issues : $CO_2$ emission using SGM, MERGE, EPPA models

**Reference:** Hertel, T. W. "General equilibrium analysis of U.S. Agriculture: What does it contribute? *J. of Agr. Econ. Res.*42(1990):3-9.

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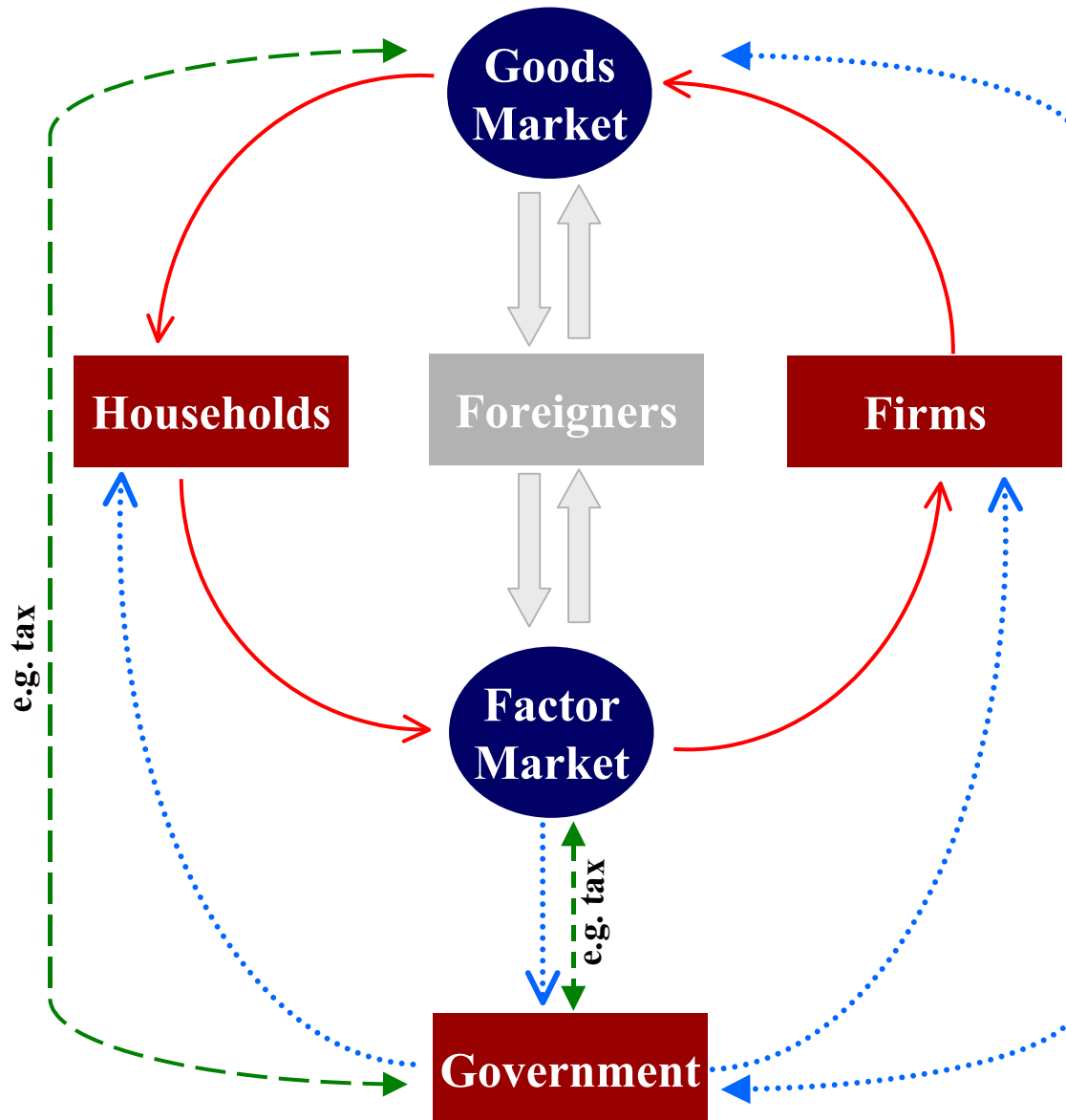
# Drawbacks of CGE?

- **Difficulties of model selection, parameter specification, and functional forms (CES vs. Cobb)**
  - Benchmark equilibrium **=>** functional forms **=>** 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**
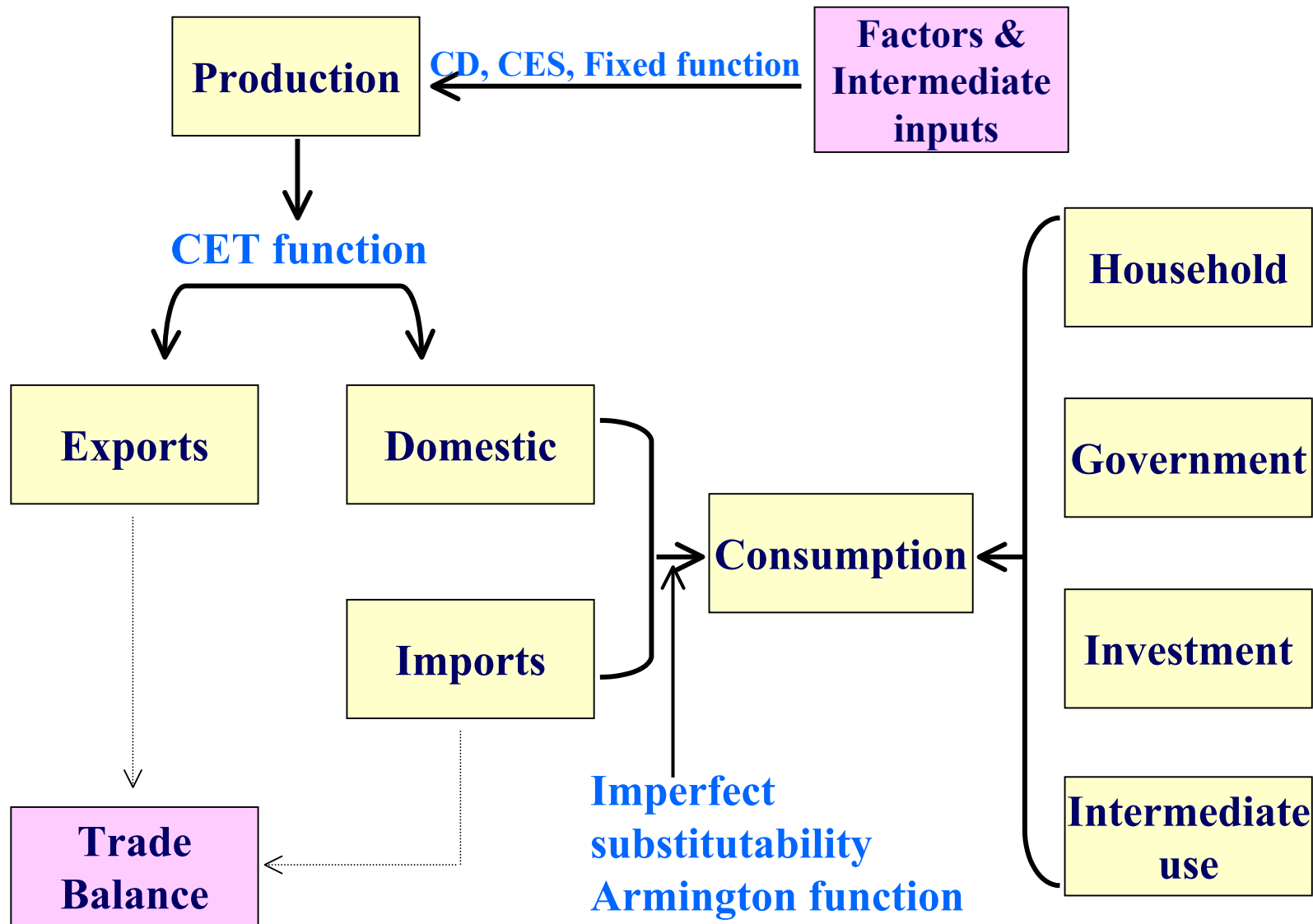
# CGE Overview -- Steps in CGE Modeling



Adapted from Shoven, J. B. and J. Whalley. "Applying general equilibrium." Surveys of Economic Literature, p.104, 1998.

Basic Data (IO,SAM, etc.) → Data Adjustment → Calibration ← Specification of exogenous values

Replication Check ← Calibration

Calibration → Benchmark Equilibrium

Benchmark Equilibrium → Shocks → Counterfactual Equilibrium

Counterfactual Equilibrium → Comparative Policy Analysis → Further Policy Analysis → Exit
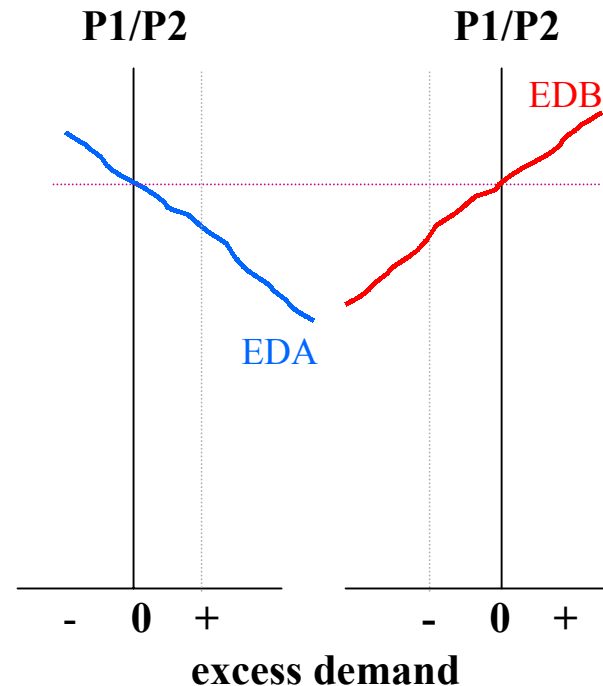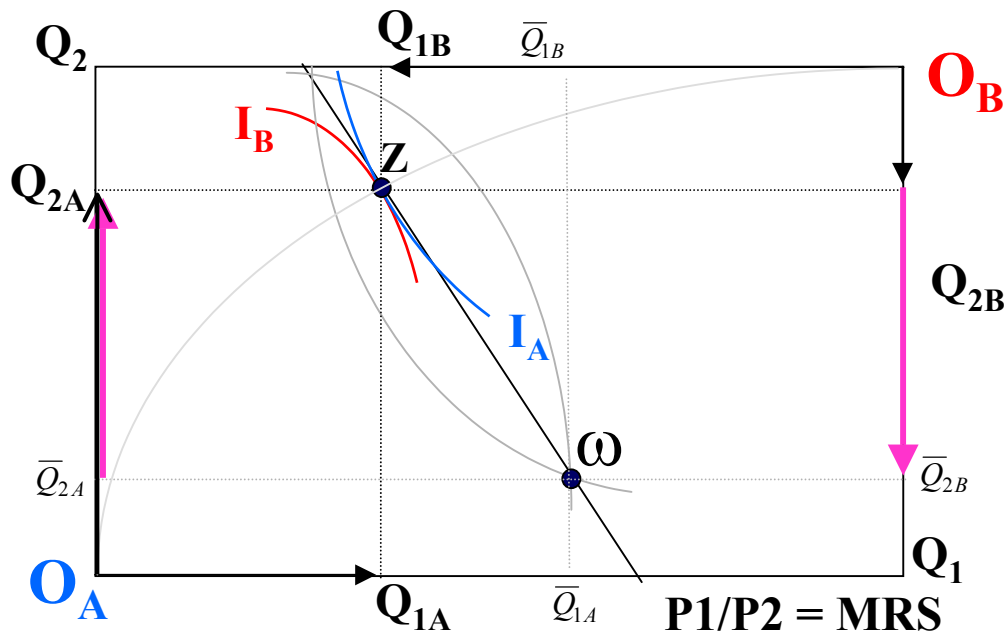
Adapted from Krauss, M. B. and H. G. Johnson. "General Equilibrium Analysis: A Micro-Economic Tex." Figure 1.2, page 27, 1974

# CGE Overview -- Commodity Flow



**Reference:** Lofgren, H., R. L. Harris, S. Robinson, M. Thomas, and M. El-Said. "A Standard computable general equilibrium (CGE) model in GAMS, IFPRI, Washington, D.C.

# Theory Behind CGE (1)

## ■ Consumption Case

$$P_1 Q_{1A} + P_2 Q_{2A} = P_1 \overline{Q}_{1A} + P_2 \overline{Q}_{2A}$$

$$P_1 Q_{1B} + P_2 Q_{2B} = P_1 \overline{Q}_{1B} + P_2 \overline{Q}_{2B}$$

$$P_1(Q_{1A} - \overline{Q}_{1A}) + P_2(Q_{2A} - \overline{Q}_{2A}) = 0$$

$$P_1 Z_{1A} + P_2 Z_{2A} = 0 \;\;=> \textbf{Walras' Law}$$

$$P_1 Z_{1B} + P_2 Z_{2B} = 0$$

$$P_1(Z_{1A} + Z_{1B}) + P_2(Z_{2A} + Z_{2B}) = 0$$
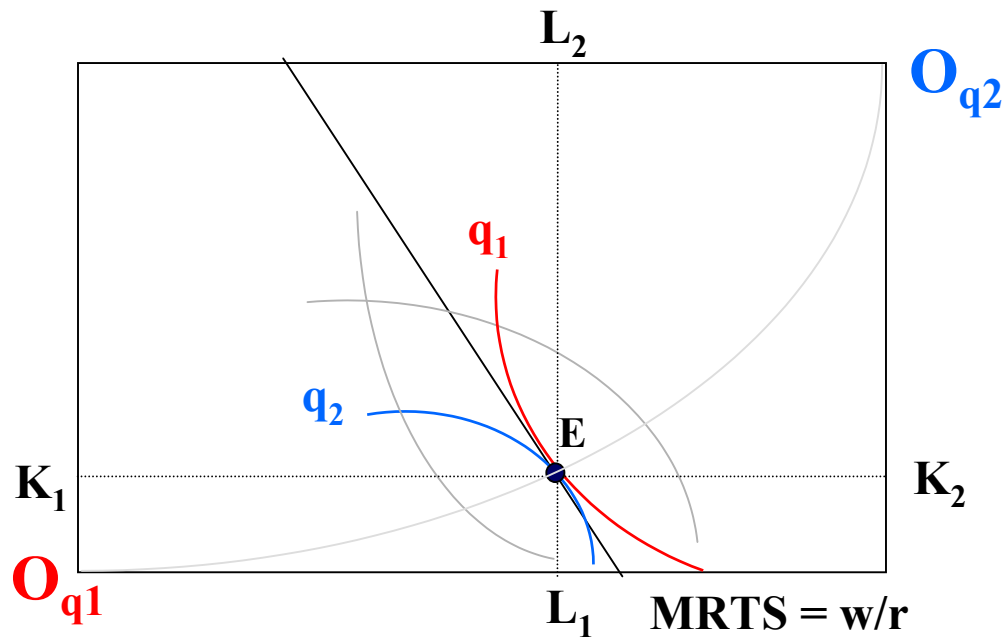
## ■ Implication

• $\mathrm{MRS_A}^{q1q2} = \mathrm{MRS_B}^{q1q2}$

price adjustment process

# Theory Behind CGE (2)

■ **Implication**

- $MRS_A^{q1q2} = MRS_B^{q1q2}$

- Homo degree "0" in price

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

  $\Rightarrow$ If $p^* = (p^*1, p^*2)$ is a Walrasian equilibrium price vector then so is $ap^* = (a\,p^*1, ap^*2)$ for $a > 0$

  $\Rightarrow$ 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
  - $MRTSq_1^{LK} = MRTSq_2^{LK} = $ 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.

$wi$ 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.

    $$X_j + \sum_i a_{ji}Q_i - Q_j \leq 0 \qquad \forall \, j$$

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

    (2) no production activity makes positive profits.

    $$P_jQ_j - \sum_i P_i a_{ij}Q_j - rW_j \leq \mathbf{0} \quad \forall \, j$$

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

$Wj$ is a factor usage in sector j and r is a factor price,
aij = use of goods i 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

Adam, C. "CGE Models: Specification, calibration and macroeconomic application." Department of Economics, University of Oxford, Oxford, UK.

Andreu Mas-Collell, Michael D. Whinston, and Jerry R. Green, <u>Microeconomic Theory</u>. Chapters 15 and 16. Oxford University Press, NY, 1995.

Hertel, T. W. "General equilibrium analysis of U.S. Agriculture: What does it contribute?" *J. of Agr. Econ. Res.*42(1990):3-9.

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

Just, R. E., D. L. Hueth, A. Schmitz. "Applied welfare economics and public policy." Chapter9, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1982.

Lofgren, H., R. L. Harris, S. Robinson, M. Thomas, and M. El-Said. "A standard computable general equilibrium (CGE) model in GAMS, IFPRI, Washington D.C.

McKitrick R. R. "The econometric critique of computable general equilibrium modeling: The role of functional form choice." *Economic Modeling* 15(1998):543-573.

Shoven, J. B. and J. Whalley. "Applying general equilibrium." *Surveys of Economic Literature*, p.104, 1998.

Shoven, J. B. and J. Whalley. "Applying general equilibrium." *Surveys of Economic Literature*, Chapters 2 and 3, 1998.

Whalley, J. "How reliable is Partial Equilibrium analysis?" *The Review of Economics and Statistic 57(3):299-310,* 1975.