

# Computable General Equilibrium (CGE) Models: A Short Course

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## **Session One: THEORY**

# Session 1: Theory

- What are CGE models?
- A brief review: A survey of surveys
- Modeling framework comparison
- Benefits and Drawbacks of CGE
- Structure of a CGE model

# What are CGE models?

- CGE or AGEM
- **Multisectoral**, economy-wide **nonlinear** equilibrium models that are closely related to the Walrasian model of a **competitive economy**

# What are CGE models?...

- Walrasian competitive equilibrium:
  - All economic agents are price takers who maximize profits or utility
  - Prices freely adjust to clear markets
- Also called price-endogenous models
- **General equilibrium** and **autonomous decision making** are two concepts central to the CGE modeling framework

# What are CGE models?...

- The economy as a complete system of interdependent components
- Recognize economic shocks on one component creating ripple effects throughout the system
- Fundamental links among production structure, pattern of demand, and incomes of various institutions
- Simply implies that supply equals demand

# What are CGE models?...

- The idea that a competitive market economy reaches an equilibrium of supply and demand, determined by the demand functions and production functions of consumers and firms
- Representative of producer and consumer behaviors
- “Computable” => a system providing quantitative analysis by solving the GE numerically

# What are CGE models?...

- Applied model in two respects:
  - 1) it is based on observed economic data for a regional/national economy
  - 2) it is designed to simulate the behavior of the modeled economy
- Permit predictions and counterfactuals
- Can simulate the response to shocks and policy interventions

# What are CGE models?...

- CGE models are a standard tool of empirical analysis
- Widely used to analyze the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets, or contain menus of different tax, subsidy, quota or transfer instruments
- The main function of these models is to simulate the effects of economic policies

# A Brief Review

- Robinson, Sherman. 1989. "Multisector Models of Developing Countries: A Survey," in H.B. Chenery and T.N. Srinivasan, eds., *Handbook of Development Economics*. Amsterdam: North Holland. pp. 906-932.
- Shoven, J.B., and J. Whalley. 1984. "Applied General Equilibrium Models of Taxation and International Trade: An Introduction and Survey." *Journal of Economic Literature* 22: 1007-1051.

# A Brief Review...

- Two strands in the literature:
- Adelman & Robinson 1978, LDC applications
- Shoven & Walley 1984, DC applications

# A Brief Review...

- Multisectoral models deal with questions of economic structure
- Changes in economic structure largely define the process of development
- 1950s: the linear input-output models, later extended IOs based on SAM
- 1960s: Linear programming (LP) models, introduced optimization and possibility of introducing prices into analysis

# A Brief Review...

- Problems with LP:
  - *Linearity* assumption leading to extreme behavior especially in dynamic models
  - The problem of *terminal conditions* in dynamic models
  - Problems with interpretation of *shadow prices* generated by the model

# A Brief Review...

- 1970s: Non-linear, multisectoral CGEs simulate the workings of a market economy and solving for prices and quantities simultaneously
- CGEs are natural outgrowth of IO and LP models adding substitutability in production and demand as well as prices and income flows

# Modeling framework comparison

## Partial equilibrium vs general equilibrium:

- PE assumes that a “shock” produces direct price changes that do not have meaningful income effect and thus other prices are constant
- No intersectoral effects of price changes and demand shifts
- 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)

# Modeling framework comparison

## Partial equilibrium vs general equilibrium:

- PE is appropriate when only interested in sectoral policies and small income shares
- “Shocks” produce direct price changes that do not cause any other prices to change

# Modeling framework comparison

## Economy-wide models:

- IO Models
- Linear Programming Models
- Macroeconometric-models

# Modeling framework comparison

- IO & LP methods reflect a pure command economy where a central authority fully controls the resources and has to make optimal decisions only subject to technological and physical constraints
- CGE models a "natural outgrowth" of IO & LP that add neoclassical substitutability in production and demand, as well as explicit system of market prices and a complete specification of the income flows in the economy

# Modeling framework comparison

## Econometric Modeling

- Regression estimations
- Relies on data size
- Time-Series method
- Not appropriate for welfare analysis

## CGE Modeling

- Benchmark data
- Explicit specification
- Interindustry analysis
- Welfare analysis
- Handling large movements in relative prices

# Benefits and Drawbacks of CGE

## Drawbacks:

- CGE as “black box”
- Difficulties of model selection, parameter specification, and functional forms (CES vs. Cobb)
- Data consistency-calibration problems: not a statistical test of the model specification
- 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; require skill to maintain the model

# Benefits and Drawbacks of CGE

## Benefits:

- Conceptual consistency:
  - Based on microeconomic theory
  - Walras Law: hh are on their budget constraints; zero profit conditions for firms; supply=demand
- Accounting consistency:
  - Expenditures cannot exceed incomes
  - Consistent factor allocation making sure that factor markets clear

# Benefits and Drawbacks of CGE

## Benefits:

- Inter-industry or multisector 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
  - E.g. farmers are consumers in input sectors (ie. Fertilizer or energy market) but are also producers in output sectors (ie, cotton market)

# Structure of a CGE model

Example of a dynamic CGE model  
applied to exhaustible resources

# Main Components

- Economic actors
- Behavioral rules for these actors
- Signals: prices in a market economy
- “Rules of the game” – The institutional structure of the economy
- Define “equilibrium conditions”

# Economic Actors

- Producers
  - A Two Level Production
  - Short-run Profit Maximizers
- Household
  - Owns Capital in Non-oil Sectors and Labor
  - Fixed Share Consumption
- The Rest of the World
  - Small Economy Assumption
  - Imperfect Substitution
  - Restricted Capital Flows
- The Government
  - perfect Foresight
  - Maximizes Social Welfare Subject to Workings of a Market Economy
- The Capital Market
  - A "Savings Pool"

# Producers

- Producers are industries or sectors of production of the economy
- Three factors: man-made "*capital*", a natural capital or "*resource*", and *labor*
- All sectors employ capital, labor, and intermediate inputs
- The behavior of all firms (sectors) is assumed to obey a profit maximization rule

# Households

- There is a single representative household in the economy which owns capital in non-oil sectors and labor
- Competitive profit-maximizing behavior assures that the nominal wage rate equals the value of the marginal product of labor
- The household can either save or consume its income
- Household spends a fixed portion of its income on the goods of each sector

# The Government

- The government earns its revenues through direct and indirect taxes, tariffs, and revenues from the oil sector
- The government's total expenditures are a fixed proportion of GDP and include purchases of goods and services from producing sectors on a fixed share basis.
- Channels its revenues from the exhaustible natural capital to augment man-made capital in the non-oil sectors of the economy

# The Government...

- One important feature of the present model is its explicit treatment of the dynamic inter-period market equilibrium
- Market forces establish a one-period equilibrium, or more precisely, a sequence of one period equilibria
- Social planners determine the long run dynamic behavior of the economy by maximizing an inter-temporal social welfare function subject to constraints implied by competitive within-period equilibria and the total availability of the exhaustible resource

# The Government...

- intra-temporal level, the representative household offers a fixed amount of labor and capital on the market and government offers its exhaustible resource
- inter-temporal level the behavior of the system is determined by attaining the optimal rates of resource extraction, household savings and sectoral allocation of investment

# The Government...

- Given the market price of oil and a predetermined social rate of discount, the government, as the owner of the oil resource, determines the optimal rate of resource depletion and through its tax policies influences the household's savings decisions.
- Optimal investment allocation requires that the more productive and profitable sectors of the economy receive a larger share of total investment funds.

# The Rest of the World (ROW)

- The rest of the world is linked to the model through exports, imports, and foreign borrowing
- Two extreme assumptions: perfect substitution and perfect complementarity
- intermediate specification: Armington

# Perfect Substitution

- Products are not differentiated by their country of origin
- Therefore: same price whether it is imported or produced domestically
- Far removed from what is observed in the real world
- Overstates the role of trade policy in determining domestic prices

# Perfect Complementarity

- Assumes that foreign goods and domestic goods cannot be substituted for each other at all
- Zero degree of substitutability
- Not realistic either

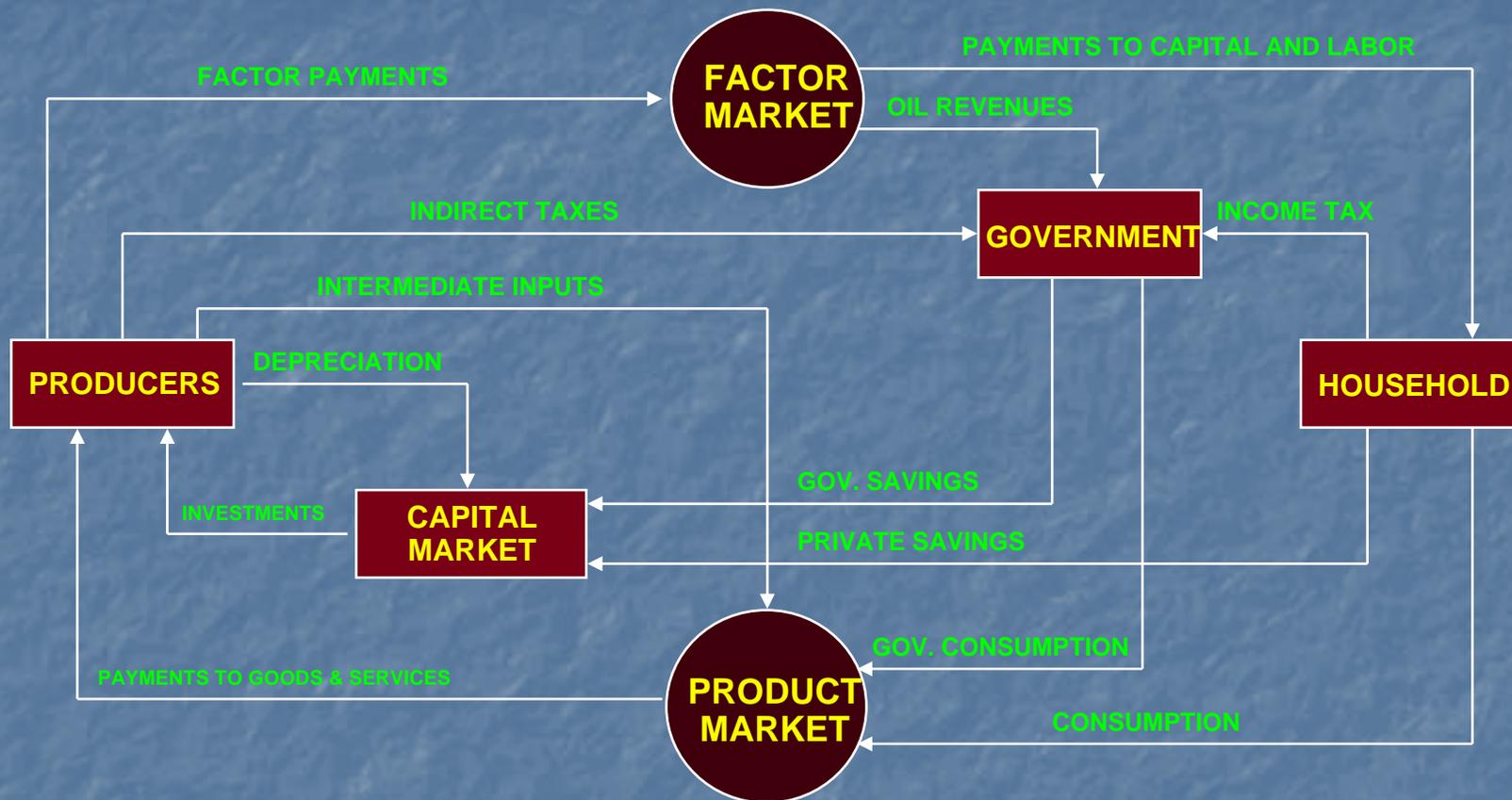
# Armington Specification

- Domestically produced goods and imported goods are imperfect substitutes
- Consumers can choose between imports and domestic goods that are not identical
- This specification allows divergence between domestic price of exports and their world prices

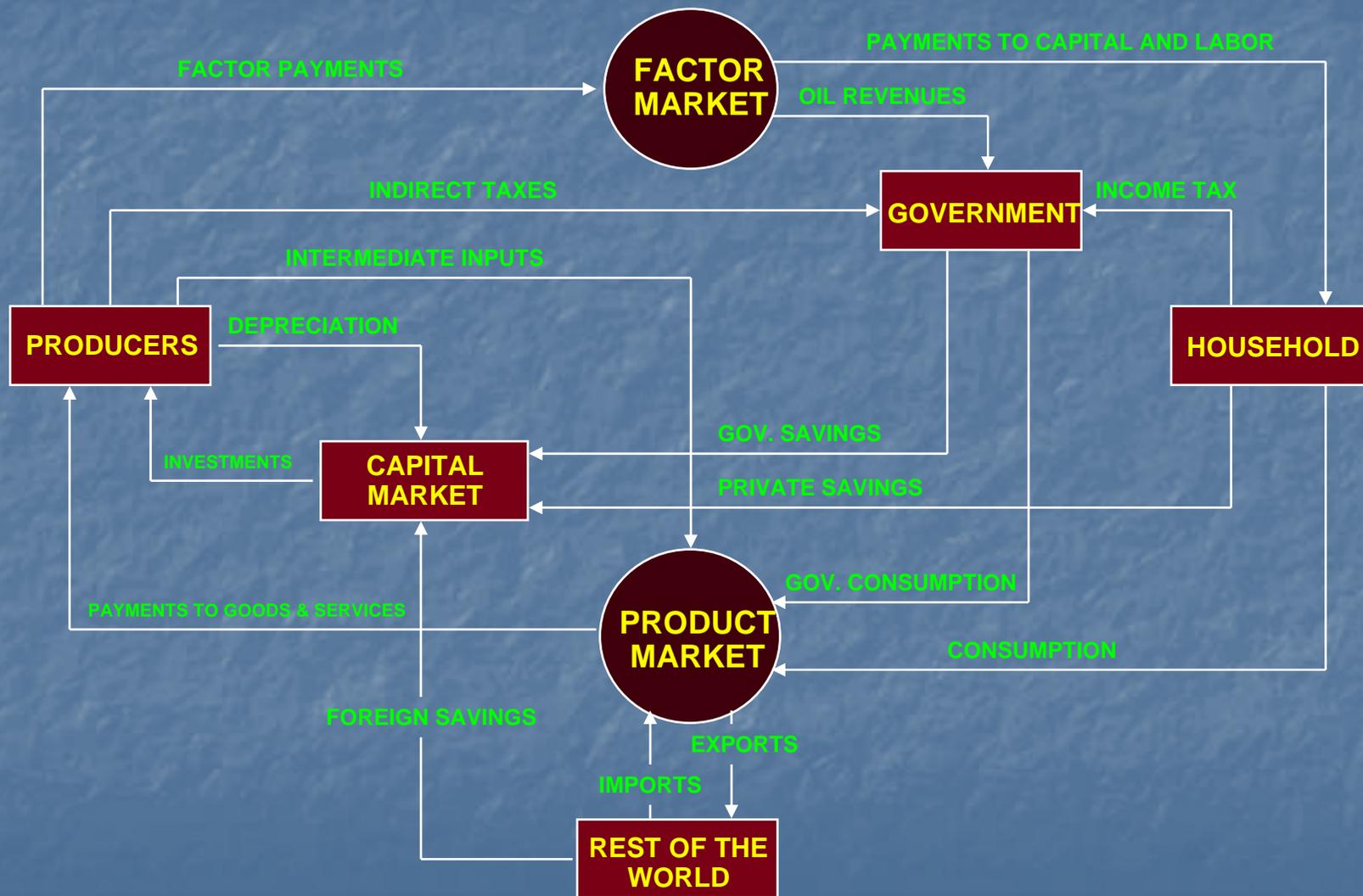
# Circular Flow of Income



# Circular Flow of Income



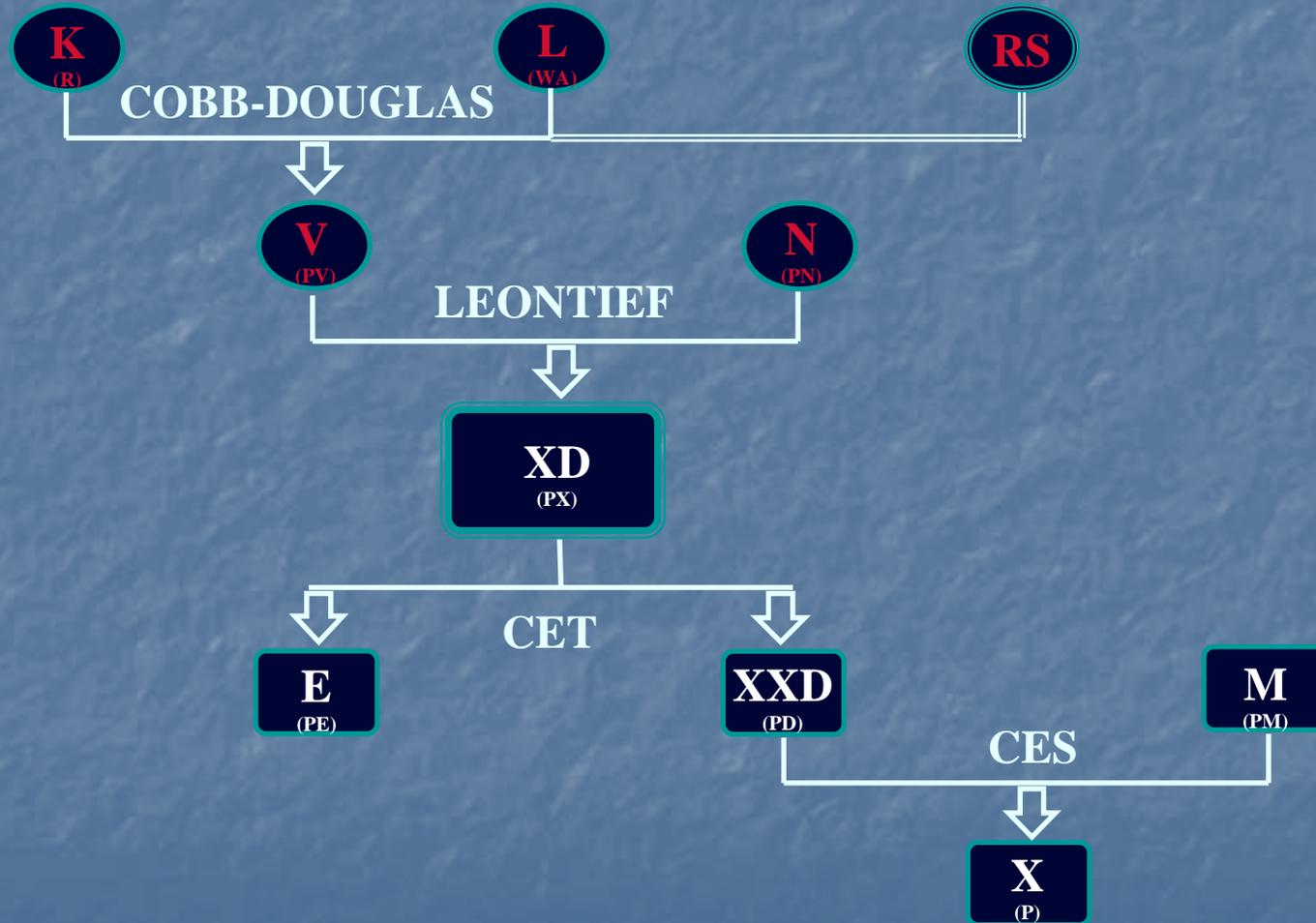
# Circular Flow of Income



# "Rules of the game"

- An economy is assumed to be an equilibrium system in which various quantities affect other through competitive market mechanisms.
- Economic properties are the effect of large numbers of rational consumers and producers interacting through a system of prices.
- The level of income, preferences, and prices jointly determine aggregate demand; while the price of inputs and demand for output determines the profitability (and therefore quantity of output) for each firm and sector.
- The system reaches equilibrium through a process of adjustments by consumers and producers to the current price structure.

# Signals: prices in a market economy



# Define “equilibrium conditions”

- The “equilibrium conditions” or “system constraints” that must be satisfied, but that are not taken into account by any agent in making his decisions.
- The signals represent the equilibrating variables of the model. E.g. a market equilibrium in a competitive model is defined as a set of prices and associated quantities such that **all excess demand are zero**.
- In a market economy, prices are the equilibrating variables that vary to achieve market clearings.