An Introduction to the Emissions Prediction and Policy Analysis (EPPA) model

October 4, 2013

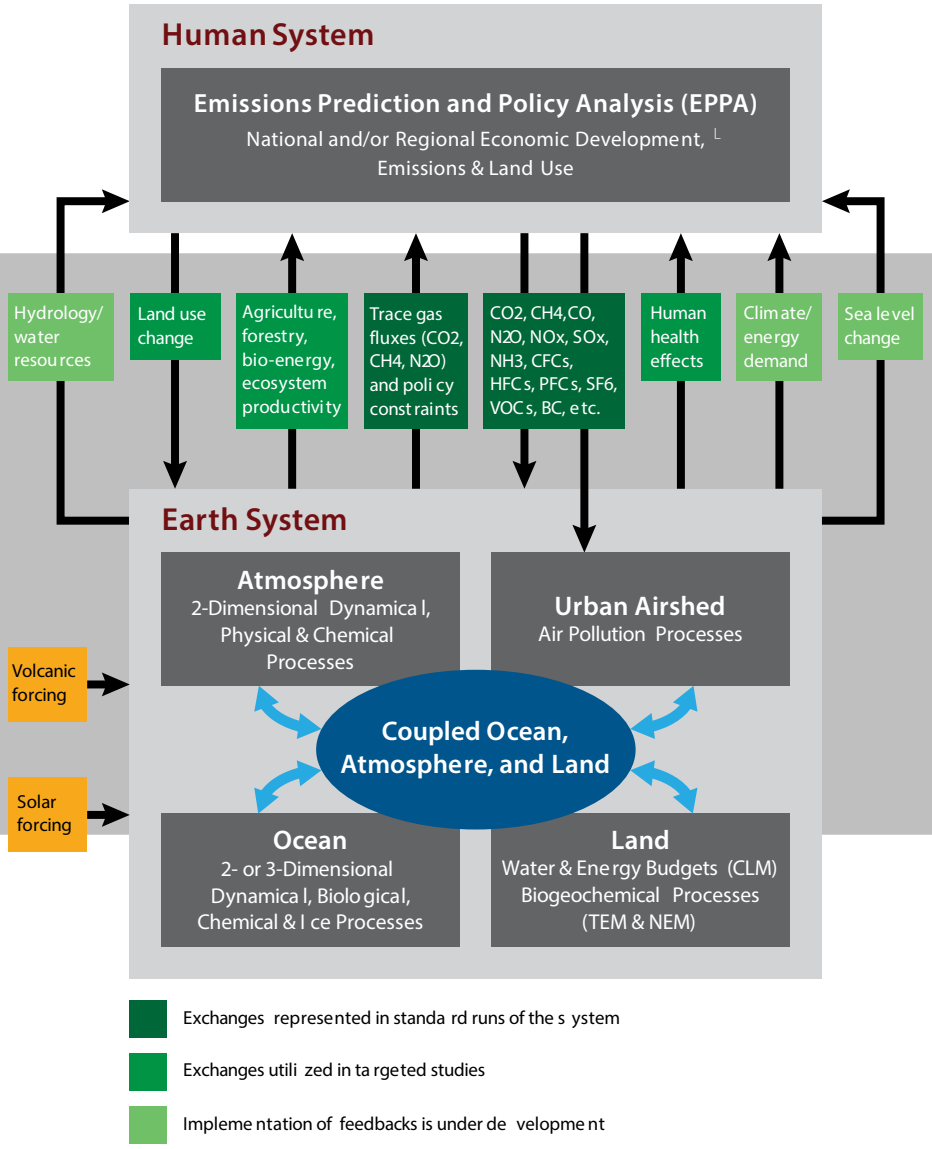
Massachusetts Institute of Technology

Cambridge, MA

Outline

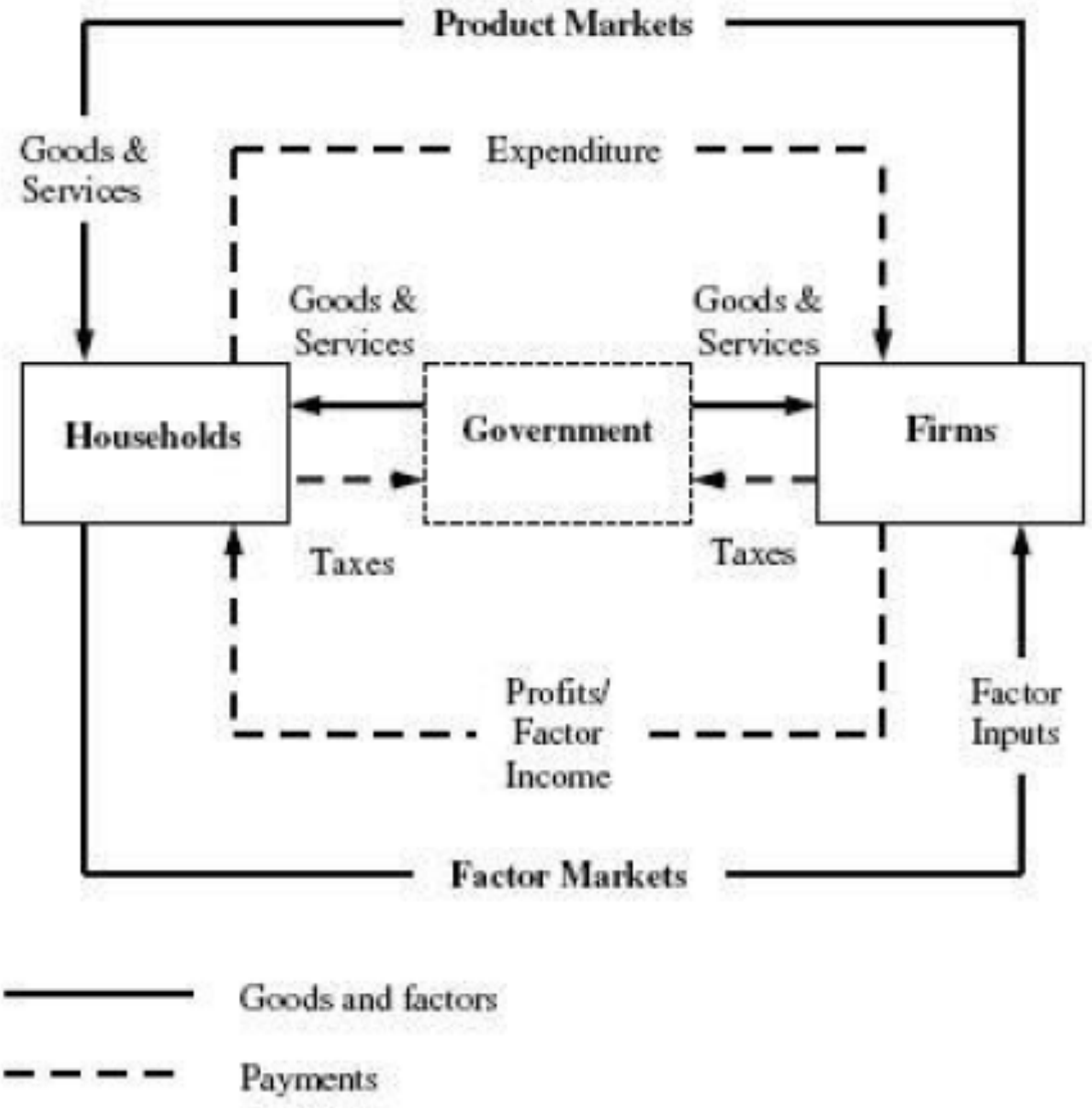
1. Overview of EPPA and the IGSM
2. General equilibrium models
3. A social accounting matrix
4. The EPPA model
5. Aggregation in the EPPA model
6. Biofuel production

The Emissions Prediction and Policy Model (EPPA) and the Integrated Global System Model (IGSM)



General equilibrium models

- Characterize producer and consumer behavior based on economic theory
- Consider equilibrium in all markets
- Explicitly model interrelationships between different markets and different sectors
- Include markets that mediate behavior of economic agents (e.g., prices adjust until supply and demand are equal)
- Built on a Social Accounting Matrix (SAM)
  - Represents flows of all economic transactions that take place within an economy
  - Matrix representation of national accounts


Product Markets
Goods & Services
Expenditure
Goods & Services
Goods & Services
Households
Government
Firms
Taxes
Taxes
Profits/ Factor Income
Factor Inputs
Factor Markets
Goods and factors
Payments

A Social Accounting Matrix

		INTERMEDIATE USE by Production Sectors				FINAL USE				OUT-PUT
		1	2	...j...	n	Private Consump.	Government Consumption	Investment	Export	
Domestic Production	1	A				B				C
	2									
	:									
	i									
	:									
	n									
Imports	1	D				E				F
	2									
	:									
	i									
	:									
	n									
Value added:	-labor	G				H				I
	-capital									
	- natural resources									
INPUT		J								

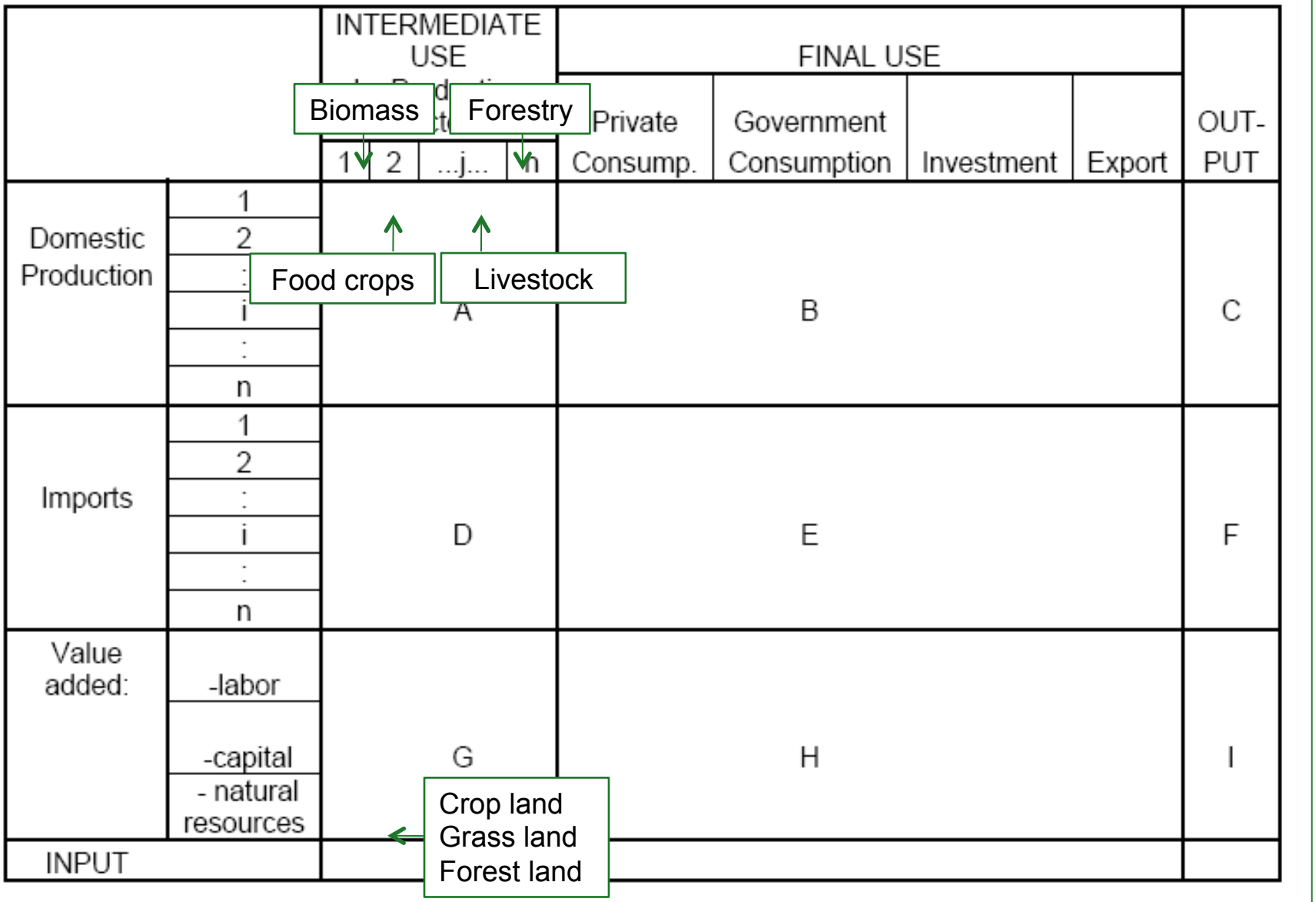
A Social Accounting Matrix

		INTERMEDIATE USE by Production Sectors				FINAL USE				OUT-PUT
		1	2	...j...	n	Private Consump.	Government Consumption	Investment	Export	
Domestic Production	1 2 : i : n	A				B				C
Imports	1 2 : i : n	D				E				F
Value added:	-labor -capital - natural resources	G				H				I
INPUT		J								

A Social Accounting Matrix

		INTERMEDIATE USE by Production Sectors				FINAL USE				OUT-PUT
		1	2	...j...	n	Private Consump.	Government Consumption	Investment	Export	
Domestic Production	1	A				B				C
	2									
	:									
	i									
	:									
	n									
Imports	1	D				E				F
	2									
	:									
	i									
	:									
	n									
Value added:	-labor	G				H				I
	-capital									
	- natural resources									
INPUT		J								

A Social Accounting Matrix

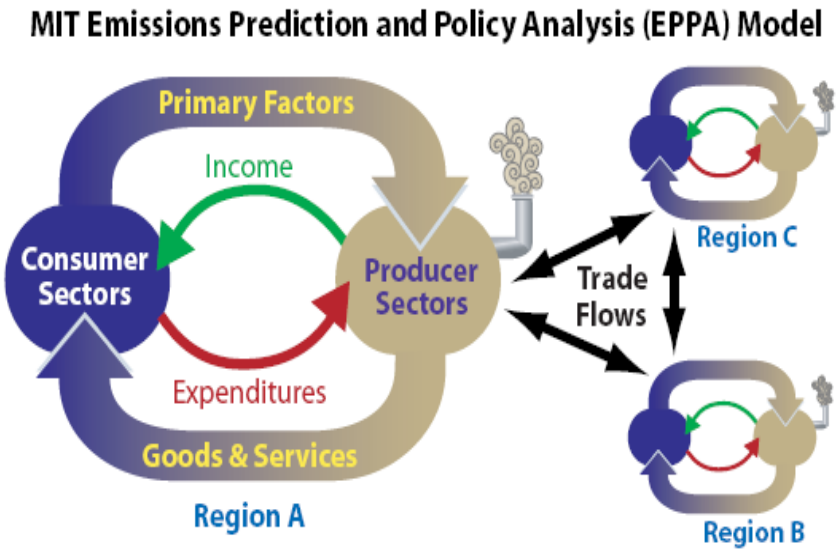


Prices and Quantities In CGE

- Observed data for the SAM, from National Income and Product Account data, are expenditures in $$
- How do you add together apples and oranges as an economist?
  - ~~1 ton of apples + 3 tons of oranges = 4 tons of fruit~~ **NO!**
  - 1 ton of apples *$100/ton + 3 tons of oranges * $300/ton = $1000 of fruit
- Implications:
  - We don't have acres of land, barrels of oil, tons of coal, number of workers
  - We have expenditures on things.
  - Environmental effects—emissions, illness cases, etc.—are based on physical accounts—we need to create Supplemental Physical Accounts, or one way or another relate engineering, agronomic, epidemiology effects as we understand from physical relationships to economic data
- Further Implications:
  - Prices are arbitrary in the benchmark data—we choose them all to be one, and then the "quantity" is just the total expenditure

The EPPA model

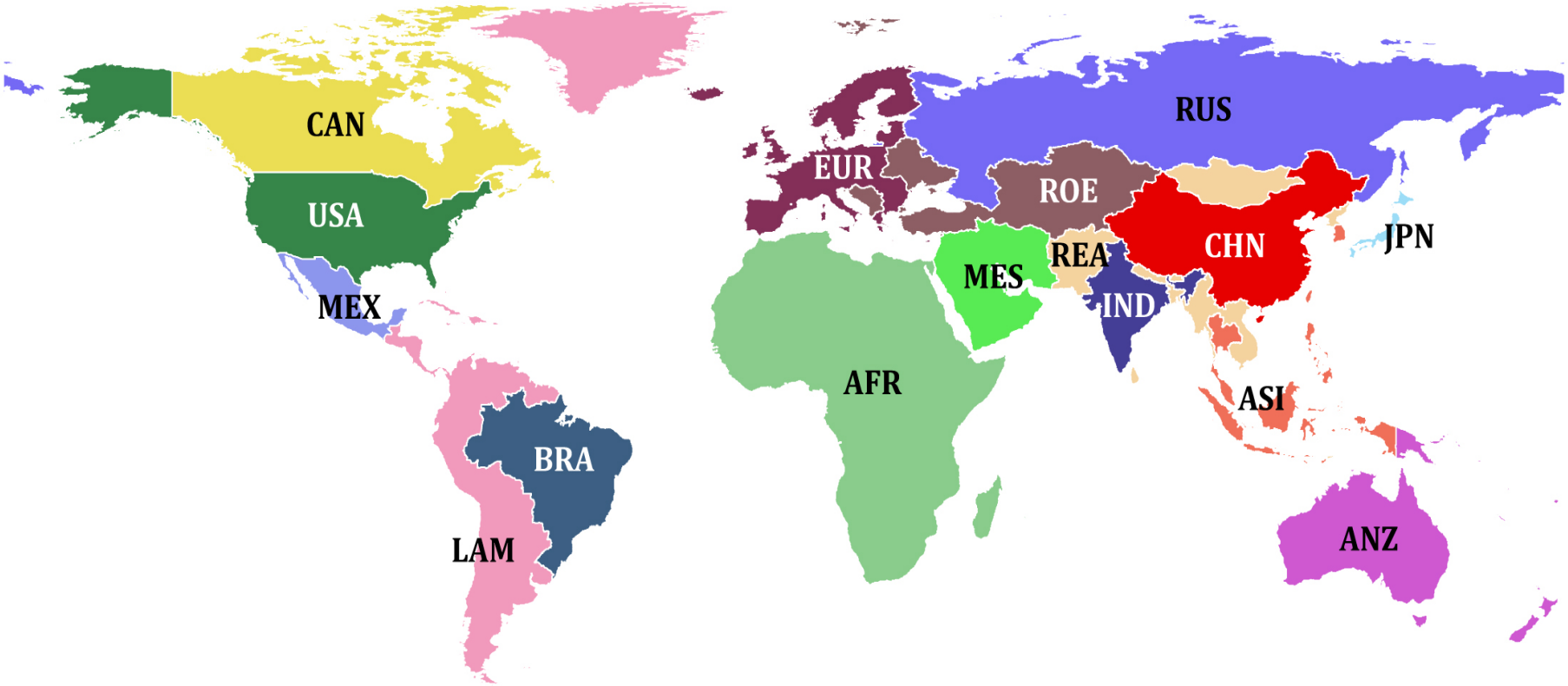
- Computable General Equilibrium (CGE) model of the world economy with regional and sectoral detail
- Fully treats demand/supply, capital/investment, and trade implications of growth, policies, and alternative technologies
- Alternative energy technologies and energy sources compete with conventional energy



Aggregation in the EPPA model

Regions	Industries	Production factors
United States	Crops	Capital
Canada	Livestock	Labor
Japan	Forestry	Coal resources
Australia-New Zealand	Food	Oil resources
European Union	Coal	Gas resources
Eastern Europe	Crude Oil	Crop land
Russia plus	Refined Oil	Harvested Forest land
Mexico	Gas	Natural forest land
China	Electricity	Managed pasture
India	Energy Intensive Industry	Natural grass land
East Asia	Other Industry	Production factors
Rest of Asia	Services	
Africa	Commercial Transportation	
Middle East	Household Transportation	
Brazil		
Latin America		

Aggregation in the EPPA model



Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

Coal
Gas
Refined oil
Hydro
Nuclear
Wind
Solar
Biomass
Natural gas combined cycle
Integrated gasification combined cycle

Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

Conventional gas
Gas from shale
Gas from sandstone
Gas from coal
Synthetic gas

Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

ICE vehicles
Plug-in hybrids
Electric vehicles
CNG vehicles

Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

Conventional crude
Oil from shale
Oil sands

Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

From crude oil

1st gen biofuels

Thermochemical

Biochemical

Aggregation in the EPPA model

Regions	Industries
United States	Crops
Canada	Livestock
Japan	Forestry
Australia-New Zealand	Food
European Union	Coal
Eastern Europe	Crude Oil
Russia plus	Refined Oil
Mexico	Gas
China	Electricity
India	Energy Intensive Industry
East Asia	Other Industry
Rest of Asia	Services
Africa	Commercial Transportation
Middle East	Household Transportation
Brazil	
Latin America	

- Corn
- Sugar beet
- Sugar cane
- Wheat
- Palm fruit
- Rapeseed
- Soybean

Aggregation in the EPPA model

Regions	Industries	Production factors
United States	Crops	Capital
Canada	Livestock	Labor
Japan	Forestry	Coal resources
Australia-New Zealand	Food	Oil resources
European Union	Coal	Gas resources
Eastern Europe	Crude Oil	Crop land
Russia plus	Refined Oil	Harvested Forest land
Mexico	Gas	Natural forest land
China	Electricity	Managed pasture
India	Energy Intensive Industry	Natural grass land
East Asia	Other Industry	Production factors
Rest of Asia	Services	
Africa	Commercial Transportation	
Middle East	Household Transportation	
Brazil		
Latin America		

A Static Model—Key Inputs and Data

- Observed data for the SAM, from National Income and Product Account data, are expenditures in $$
- The SAM gives us levels of activities in the base year and "factor" shares from the I-O structure "intermediate input" shares.
  - Share parameters
  - Leontief—fixed coefficient production block components
  - Constant Elasticity of Substitution production Components
- Industry, Households, Trade, Government
  - "Household Production"
  - Armington and Heckscher-Ohlin Trade
  - Government a relative passive actor—taxing, consuming, transfers
- GDP, GNP, NNP, Welfare
  - See Reilly, Green Growth and the Efficient Use of Natural Resources, Report 221

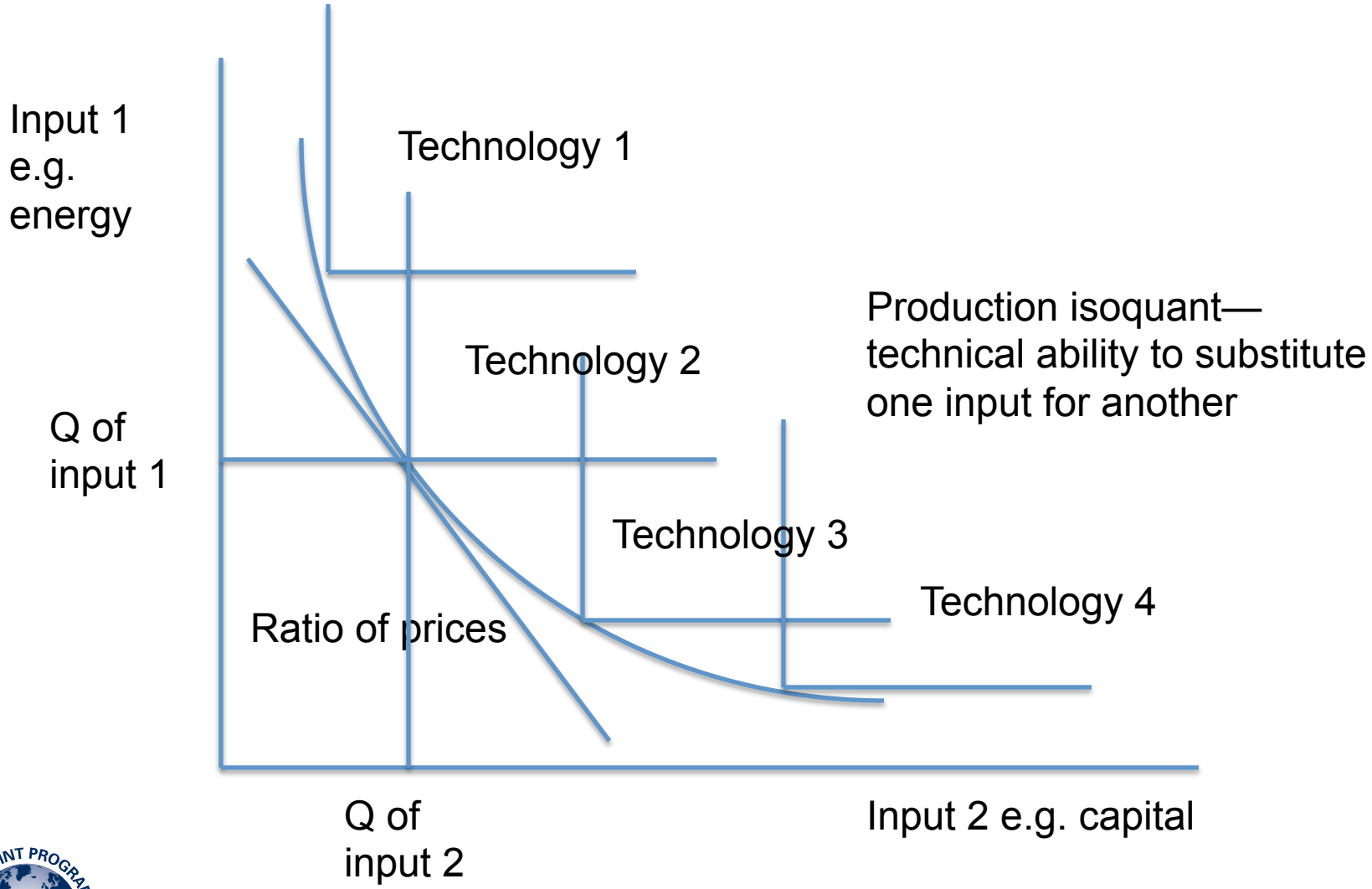
A Static Model—Solution

- The static model will reproduce the benchmark data exactly.
- The Equilibrium Concept
  - Disequilibrium in the Benchmark data
  - Short Run equilibrium
  - Run as a dynamic model we are never really in long run equilibrium
- Analysis with a Static model
  - Counterfactuals.
  - What would have been the case in benchmark year of 2007 if there had been a carbon tax…or ???

Elements of the Dynamic Model

- Population Growth—labor force growth—demand growth.
- Savings, Investment, Capital Accumulation
- Depletion of Resources, Limited annual flows of Renewable Resources, graded resources
- Technological Change
  - Labor Productivity Improvement.
  - Land Productivity Improvement
  - Energy Productivity Improvement—Autonomous Energy Efficiency Improvement (AEEI)
  - Explicit Advanced Technologies

Technical Change Versus Substitution



Technology Penetration

- Many observations of high price at initial commercialization that falls over time/with more production, S-shaped penetration
  - Learning..
  - R&D that improves technology
  - Patent/intellectual property rents
  - Bottlenecks to expansion, limited expertise for construction of factories/ plants
- EPPA approach is to specify a long run…nth plant cost, bottlenecks, and rents
- Represented as a technology-specific, fixed factor input.
  - Necessary for production, initial scarcity generates rents.
  - Allow substitution for other inputs
  - Fixed factor grows as a function of previous period production, eventually becoming non-limiting..rents to zero

Expanding the Accounts for "Non-Market" Activities

		INTERMEDIATE USE						*HOUSEHOLD SERVICES*		FINAL USE				OUTPUT
		1	2	…	*j*	…	*n*	*Mitigation of Pollution Health Effects*	*Labor-Leisure Choice*	Consumption	Investment	Government Purchase	Net-export	
DOMESTIC PRODUCTION	1													
	2													
	:													
	i													
	:													
	Medical Services for Health Pollution							*Medical Services*		*Health Services*				
	n													
IMPORTS	1													
	2													
	:													
	i													
	:													
	n													
LEISURE									*Leisure*	*Leisure*				
VALUE-ADDED	Labor							*Labor*	*Labor*					
	Capital													
	Indirect Taxes													
	Resources													
INPUT														

Figure 1. Social Accounting Matrix for EPPA-HE. Source: Nam *et al*. (2010), p. 5016.

This strategy has been used to represent household transportation, health, recreation..key is valuing leisure (non-paid work) time. Household production function is a formulation originally due to Gary Becker (and a Nobel prize).

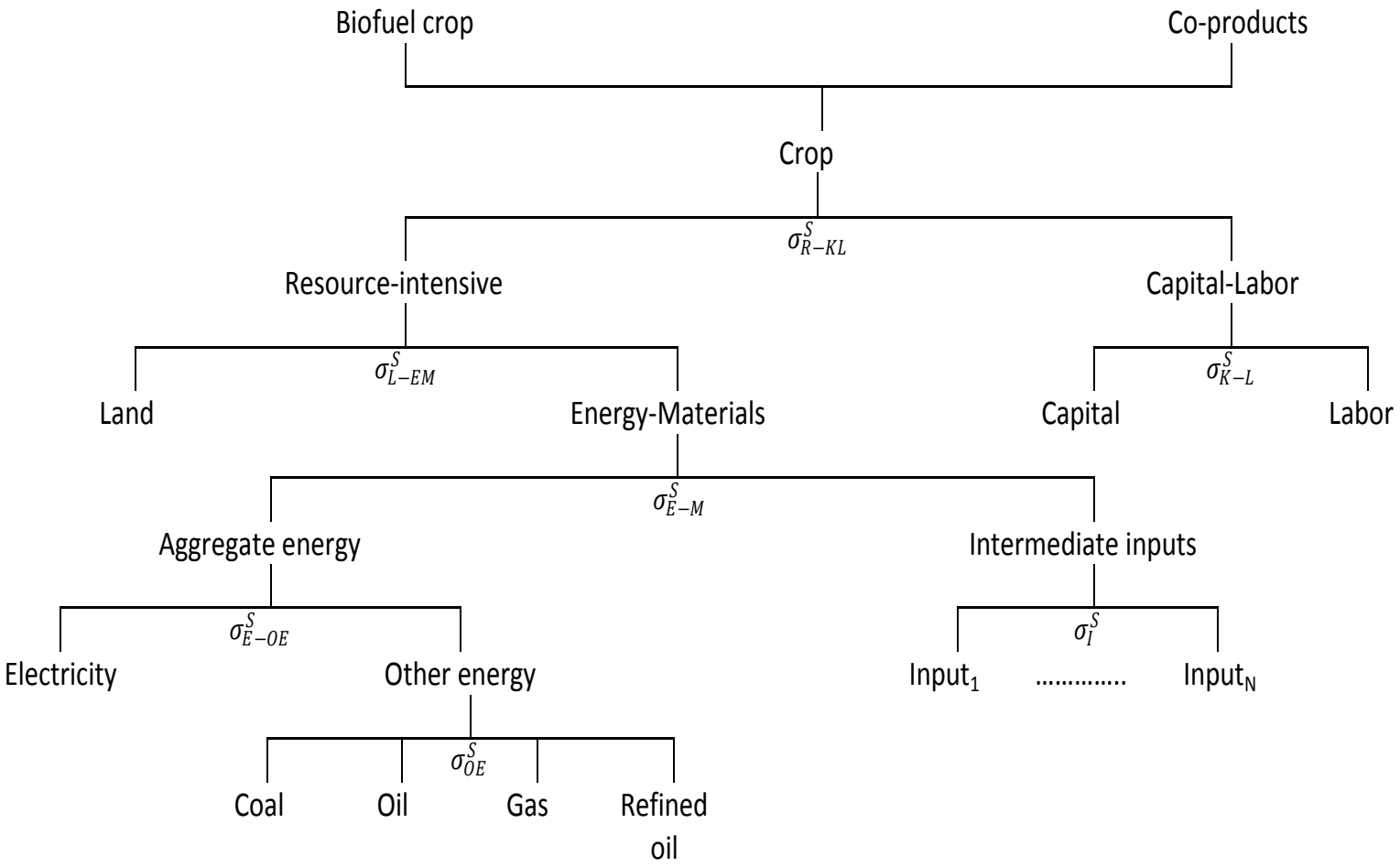
Model Solution

- MPSGE—Mixed Complementarity Algorithm
  - Not an explicit welfare maximization
  - Solves for prices that equate supply and demand for all goods, inputs, factors.
  - Under perfect competition, no distortion conditions this is equivalent to a profit maximization.
  - But distortions such as taxes exist, Armington trade, and of course uncontrolled pollution
- Recursive dynamic---myopic expectations; Fully dynamic—perfect foresight
- The CES Function

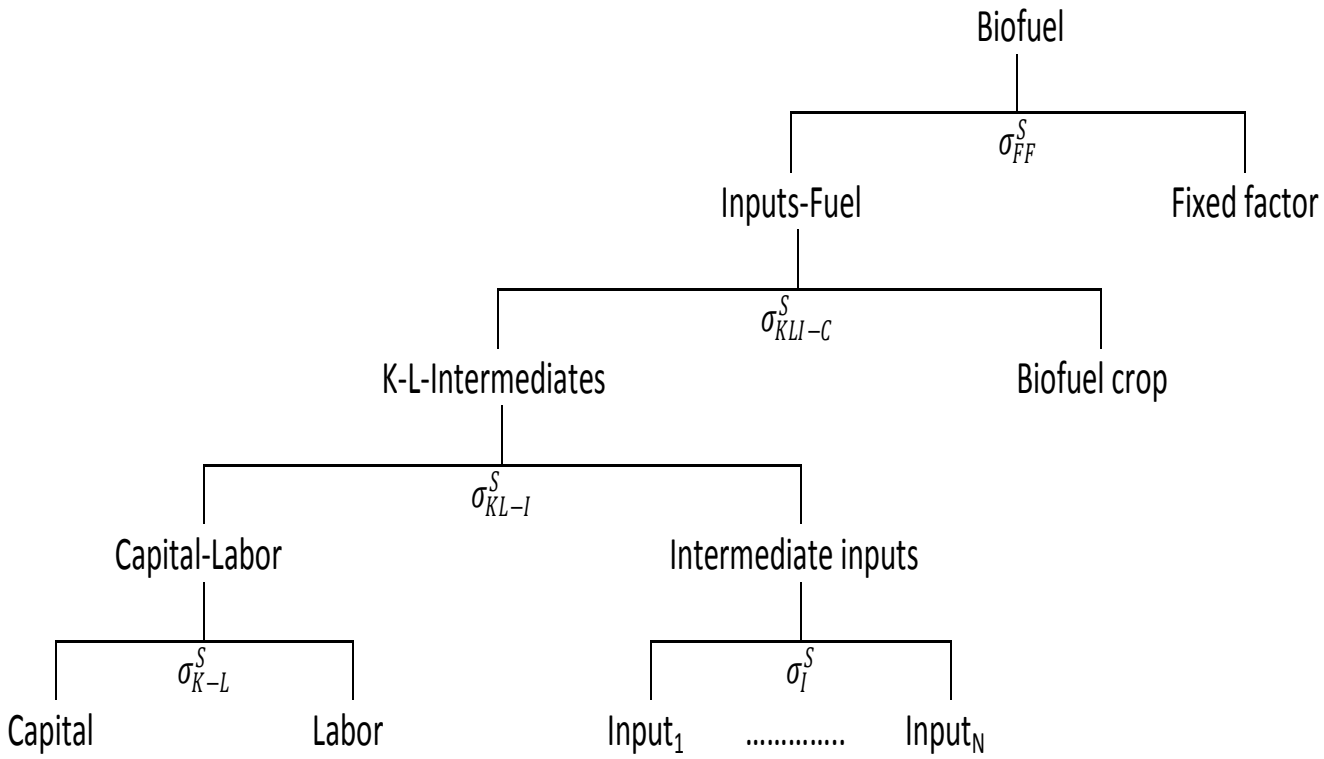
$$Y = A \left[\theta (a_K K)^{\gamma} + (1-\theta) (a_N N)^{\gamma} \right]^{1/\gamma}.$$

- Special cases and Nests

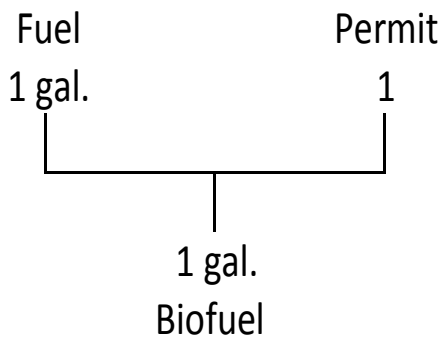
Example 1: Biofuel crop production

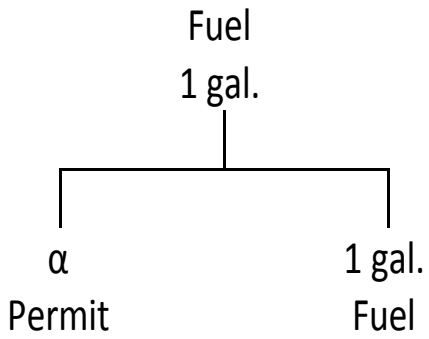


Example 2: Biofuel production w/ Fixed Factor



Example 3: Crediting system for RINs in Biofuels





Example 4: Land conversion