BEAR Essentials

Overview of the Berkeley Energy and Resources Model

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Objectives

1. Estimate direct and economywide indirect impacts and identify adjustment patterns (BEAR).
2. Inform stakeholders and improve visibility for policy makers.
3. Promote empirical standards for policy research and dialogue.

Why a state model?

1. California needs research capacity to support its own policies
   - A first-tier world economy
2. California is unique
   - Both economic structure and emissions patterns differ from national averages
3. California stakeholders need more accurate information about the adjustment process
   - National assessment masks interstate spillovers and trade-offs

Why a General Equilibrium Model?

1. *Complexity* - Given the complexity of today's economy, policy makers relying on intuition and rules-of-thumb alone are assuming substantial risks.
2. *Linkage* - Indirect effects of policies often outweigh direct effects.
3. *Political sustainability* - Economic policy may be made from the top down, but political consequences are often felt from the bottom up. These models identify stakes and stakeholders *before* policies are implemented.

Primary Components

The Berkeley Energy And Resource (BEAR) modeling facility stands on two legs:

1. Detailed economic and emissions data
2. A dynamic GE forecasting model

Economic Data

California Social Accounting Matrix (2013)

An economy-wide accounting device that captures detailed income-expenditure linkages between economic institutions. An extension of input-output analysis.

- 195 sectors/commodities
- 24 factor types
  - Labor (22+ occupational categories)
  - Capital
  - Land
- Households (10 by income decile)
- Fed, State, and Local Government (very detailed fiscal instruments, 45 currently)
- Consolidated capital account
- US and ROW trading partners

Other Data

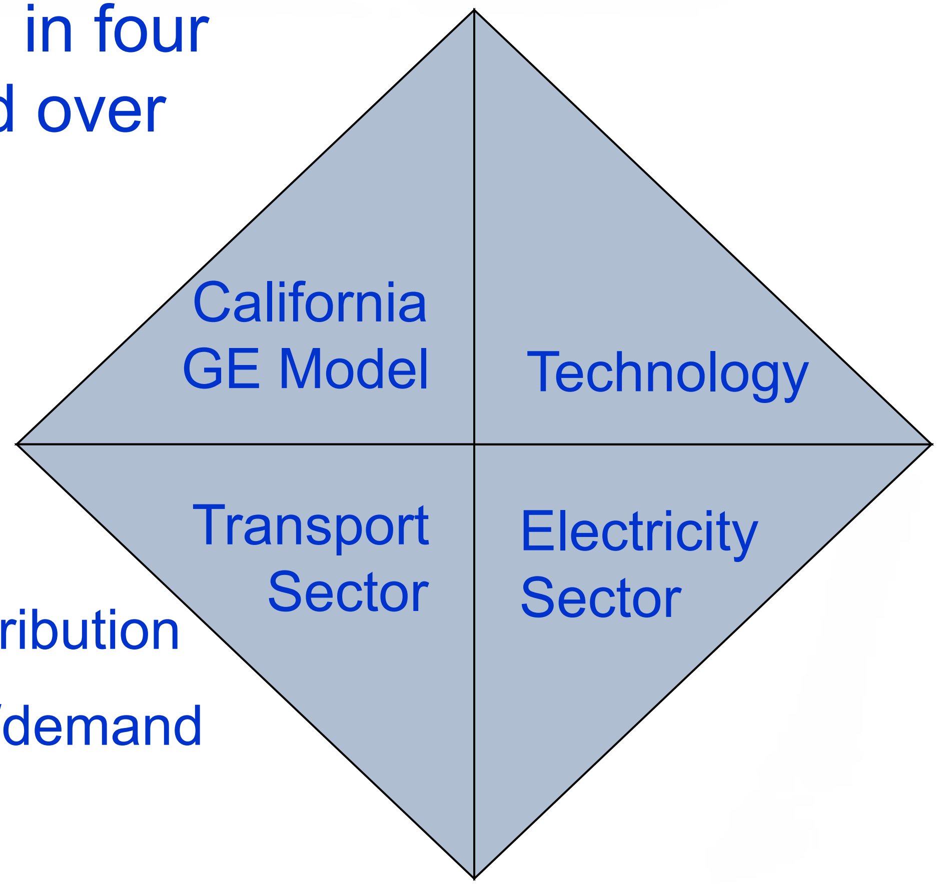
- Employment
- Technical data (MACs, emission rates, etc.)
- Estimated structural parameters
- Trends for calibration
  - Population and other labor force composition
  - Independent macro trends (CA, US, ROW, etc.)
  - Productivity growth trends
  - Exogenous prices (energy and other commodities)
  - Baseline ("business as usual") emissions trends

How we Model

BEAR is being developed in four areas and implemented over two time horizons.

Components:

1. Core GE model
2. Technology module
3. Electricity generation/distribution
4. Transportation services/demand



What is a General Equilibrium Model?

- Detailed market and non-market interactions in a consistent empirical framework.
- Linkages between behavior, incentives, and policies reveal detailed demand, supply, and resource use responses to external shocks and policy changes.

Technology

- Technology is a primary determinant of resource use patterns
- Currently, all technical efficiency is exogenously specified (share, elasticity, and productivity parameters)
- Future versions of the model will incorporate endogenous technological change

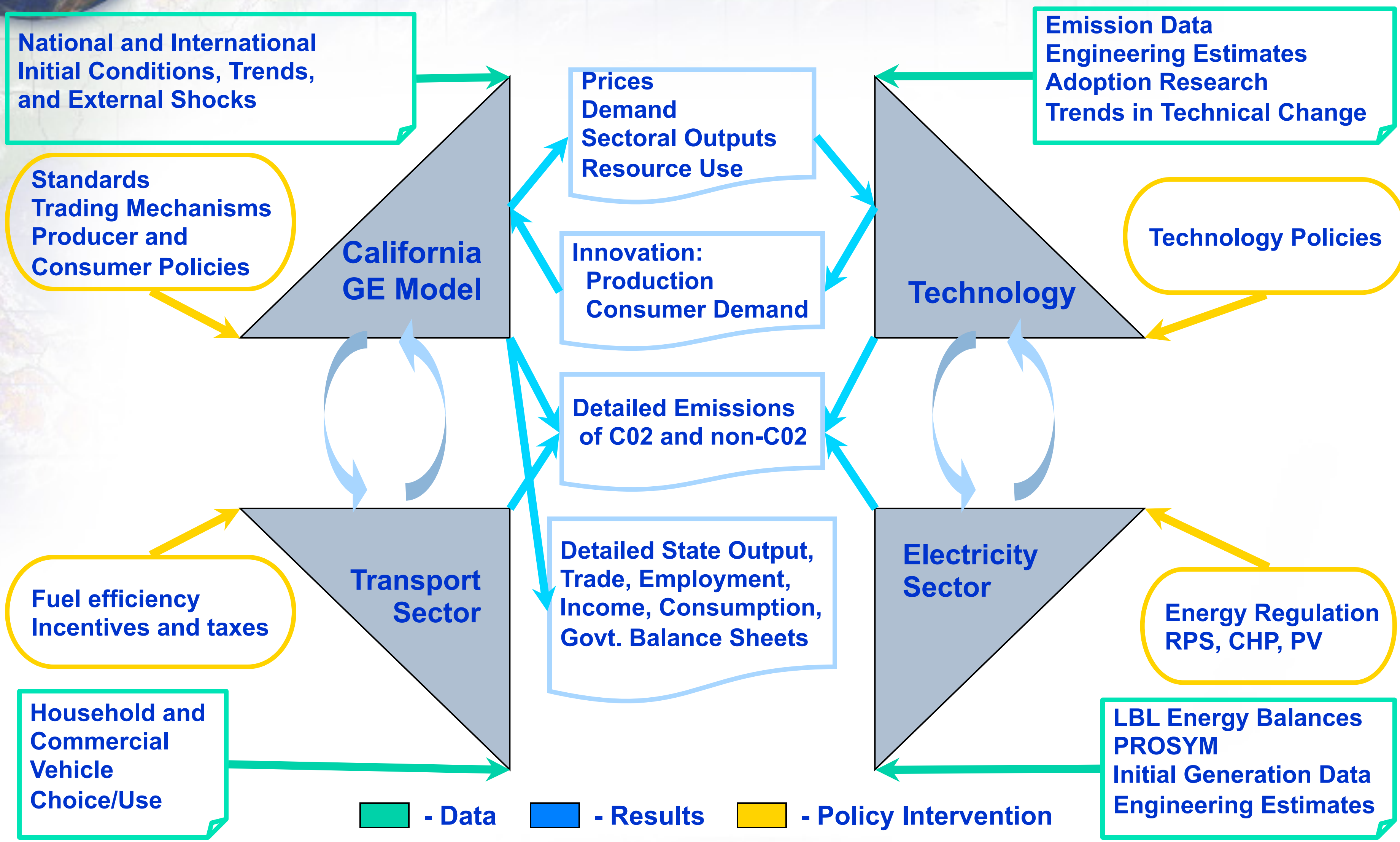
Electricity Sector Modeling

- Power generation accounts for a significant percentage of C02 emissions within California.
- To understand how this sector will adjust to policy changes, it is essential to capture its economic and technical heterogeneity
- Based on detailed producer data from CEC/ PIER/PROSYM, we model technology and emissions in California's electricity sector
  - Eight generation technologies
  - Eleven fuels

Transportation Modeling

- The transport sector accounts for up to 48% of California C02 emissions
- To elucidate the path to our emission goals, patterns of vehicle use and adoption need to be better understood
- We are currently working to estimate these relationships with newly acquired household survey data: www.carchoice.org

Detailed Structure



Time Horizons

BEAR is being developed for scenario analysis over two time horizons:

1. **Policy horizon**: 2015-2030

   Detailed structural change:

   1. 60 sectors
   2. 10 household income groups
   3. Labor by occupation, land, and capital by vintage

2. **Climate horizon**: 2015-2100

   Aggregated:

   1. 10 sectors
   2. 3 income groups
   3. labor, land, and capital

BEAR
Model Structure

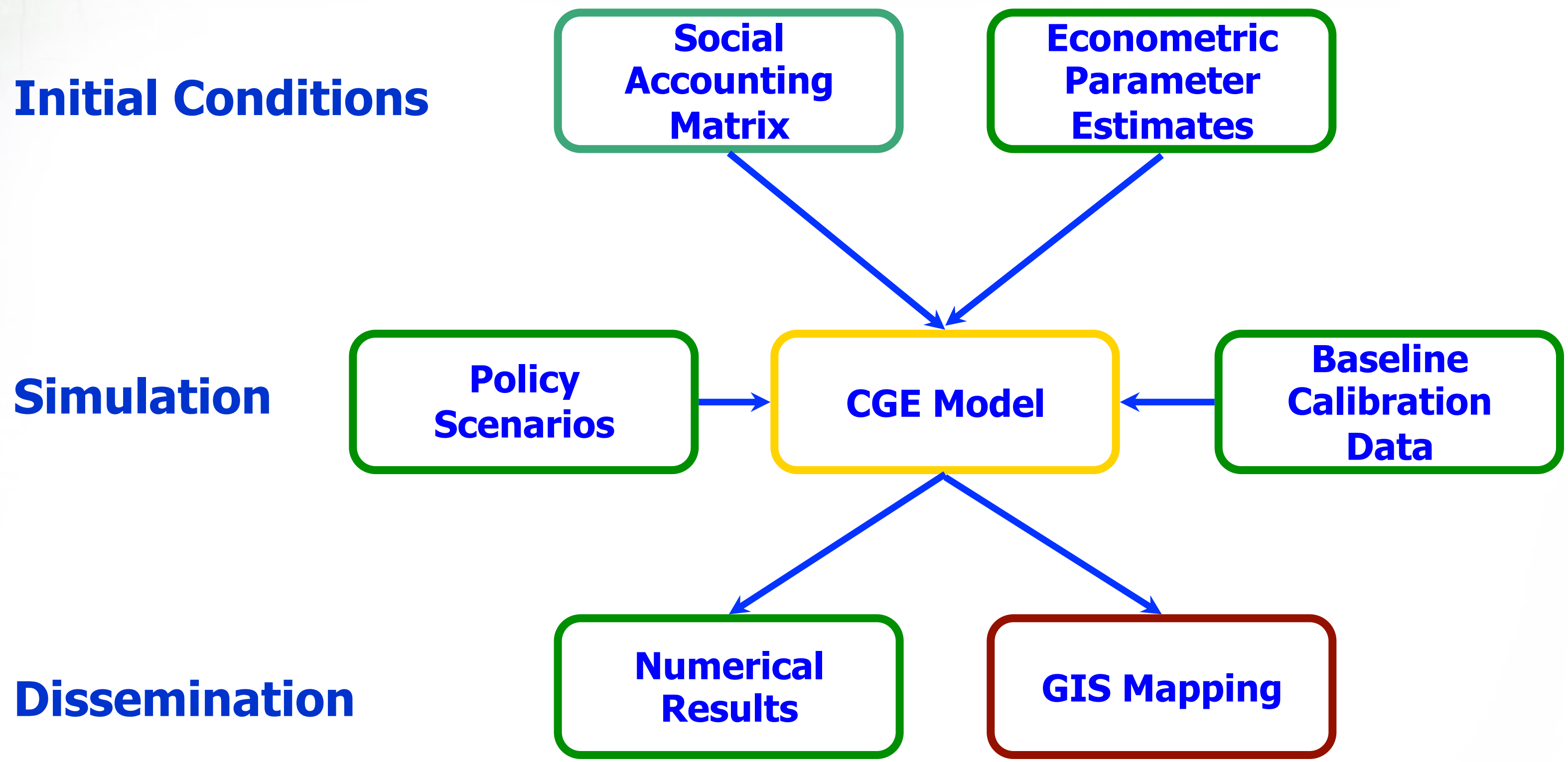
Basic Modeling Tenets

Policy makers need visibility about trends and linkages. Economic models can make a significant contribution to this provided:

1. They incorporate detailed and up-to-date data and methods.
2. Their results must be transparent.
3. They are locally implemented.

In order to achieve these three goals, BEAR uses a three tier modeling facility.

Schematic Modeling Facility



Software Implementation:
Excel GAMS ArcGIS

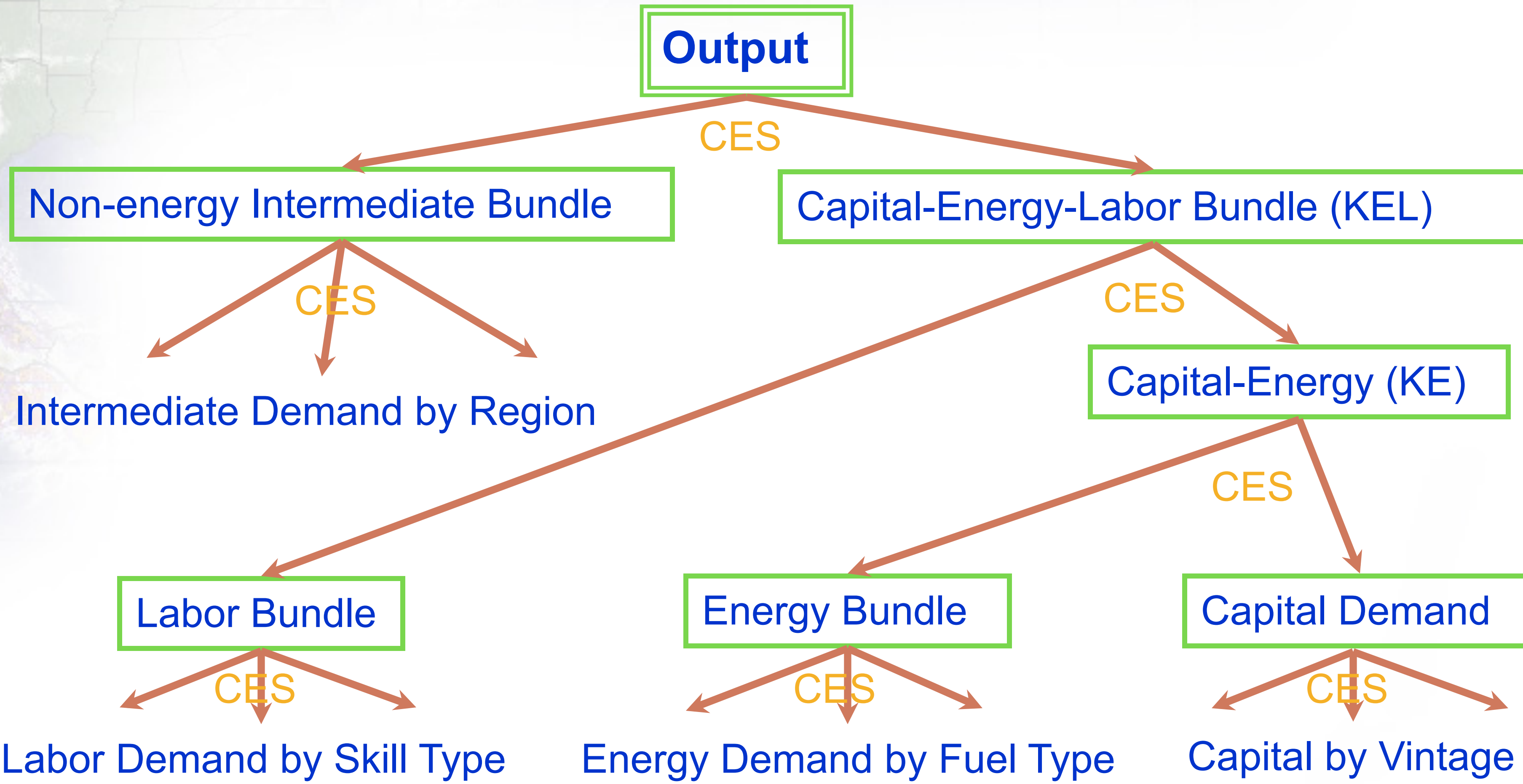
I. Overview

- Multi-sectoral and possibly multi-regional
- Constant-returns-to-scale and perfect competition
- Recursive dynamic
- Ten representative households
- Government and investment activities
- Detailed emissions

II. Production

- Supply – Firm-level production technology with Leontief intermediate use.
- Two production archetypes:
  - Agriculture (extensive vs. intensive), including land, energy and agricultural chemicals as substitutable inputs
  - Other (standard capital-labor substitution)
- Labor, Capital, Land, and Energy (by fuel type) are factors of production

Nested Production Structure



III. Capital and Land

- Two vintages of capital, old (sector specific) and new (mobile), each with its own productivity and relative price
- Land is specific to agriculture, but "mobile" between agricultural products

IV. Labor

- Supplied by households in response to a labor-leisure choice
- Employed by sector and occupation, with perfect mobility between the former and none (currently) between the latter
- Labor markets are perfectly competitive
- Migration is not currently modeled

V. Households

- Ten representative household categories, but state income tax bracket
- Income from all factors, enterprises, public and private transfers
- Consumption modeled with the Extended Linear Expenditure System
- Extensive tax and transfer mechanisms
- Demographic dynamics (population, labor force participation)

VI. Other Final Demand

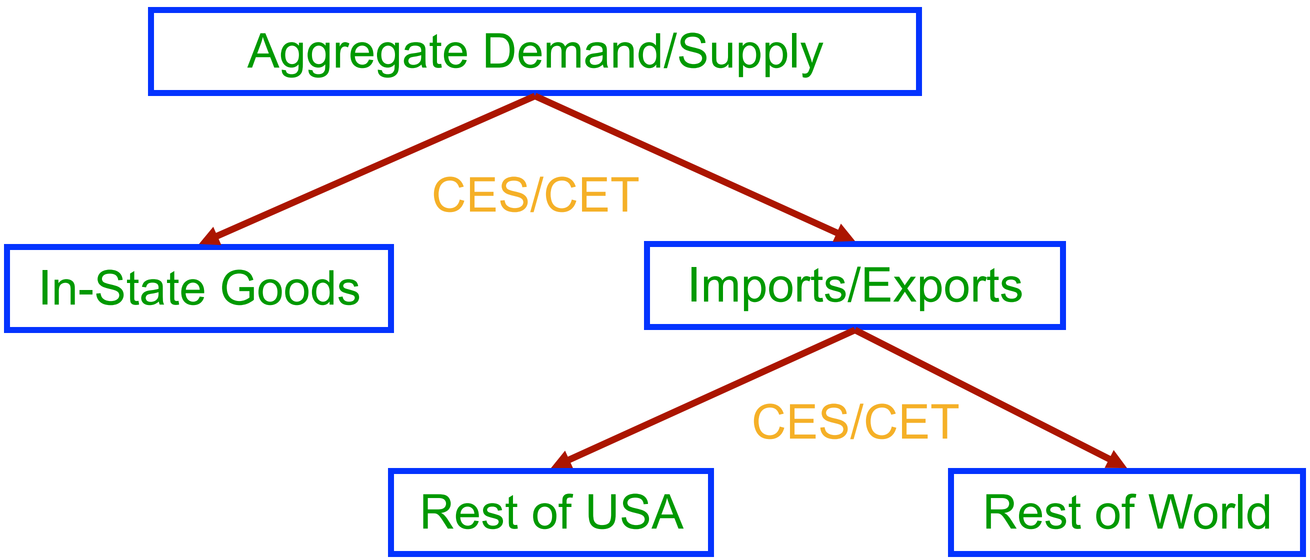
- Other final demand accounts are represented by a single demand matrix.
- Examples are
  - government current spending
  - government capital spending
  - private capital spending
  - trade and transport margins for domestic and imported goods
- All these final demand vectors are presently assumed to have fixed expenditure shares .

VII. Government

- Government is a passive actor in the baseline, adhering to established expenditure patterns and fiscal programs
- The model details extensive accounting for transfer relationships between institutions (fiscal, capital flows, remittances, etc.).
- Government behavior is a primary driver of scenarios, but this behavior remains largely exogenous (subject to fiscal closure)

VIII. Trade

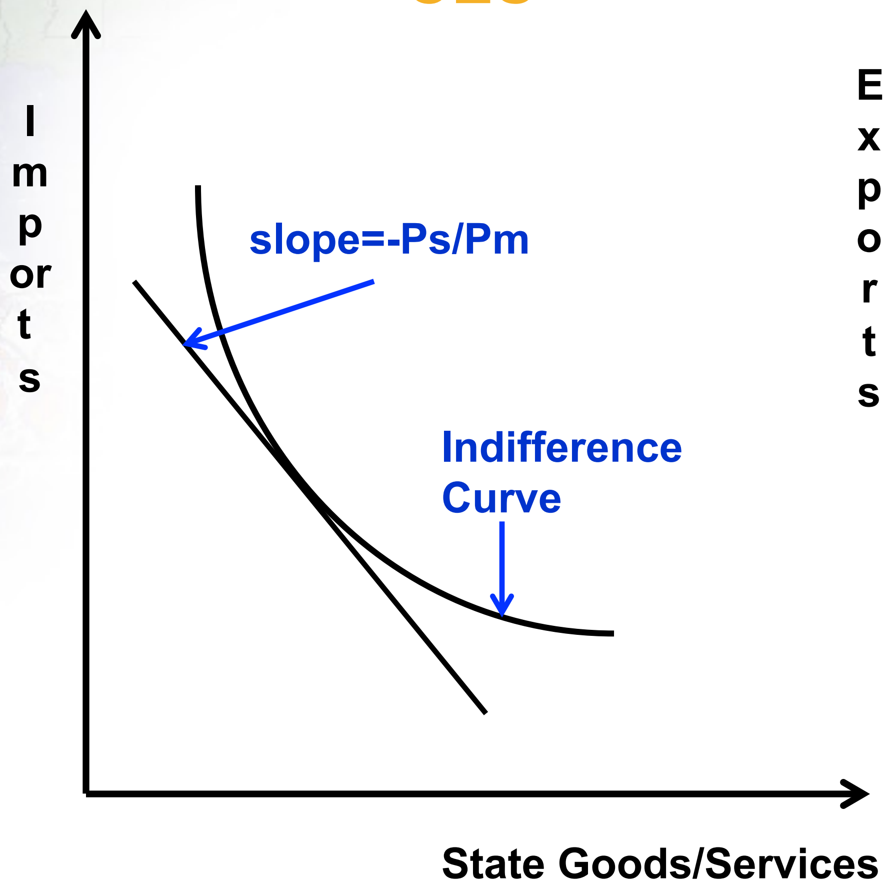
- Demand is thought to combine in-state and imported goods in each product category with a nested CES aggregation



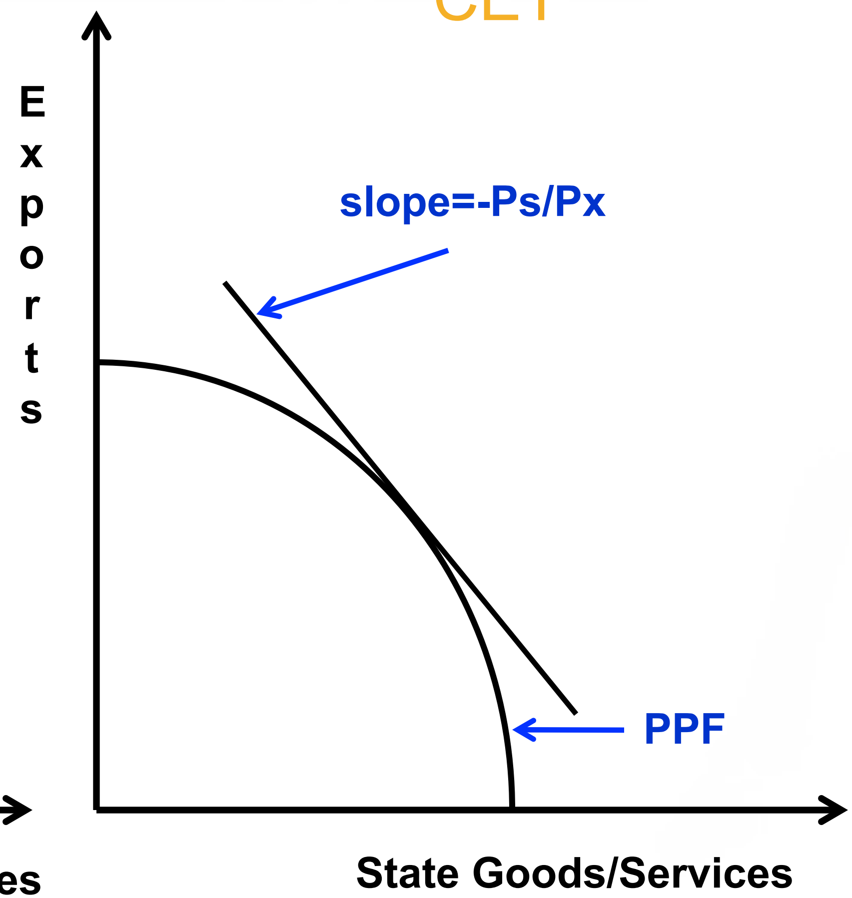
- Output is modeled symmetrically with a dual nested CET structure

Trade Schematically

CES



CET



Trade Prices

- A single domestic price equilibrates demand and supply of each domestic good.
- Each trade node clears with a market-clearing price. The model thus has (nxr)(r+1) trade prices, for n goods and r trading partners.
- FOB/CIF wedges are modeled using trade and transport margins.

IX. Equilibrium Conditions

- Combined in-state and external demand equal supply for every good and service
- In-state factor (labor, land, capital) supply equals in-state factor demand
- California’s net outflow of goods and services equals its net claims on external financial assets

X. Macroeconomic Closure

- Taxes on intermediate inputs and final demand, factors of production, output, trade, and households.
- All taxes are exogenous save household direct taxes. The latter are endogenous to hit a given fiscal balance.
- Investment is driven by savings (private, public and foreign).
- Net external savings are exogenous.
- The model numéraire is in-state manufacturing value added.

XI. Dynamics

- Labor force and population growth are currently exogenous.
- Capital stock is driven by past investments and depreciation.
- Total factor productivity is calibrated in baseline to achieve a GDP growth target.
- Productivity is currently exogenous.

XII. Emissions

Emissions are modeled as a composite of pollution in use and in process

1. *Pollution in Use* arises from per unit, intermediate and final consumption of goods and services
2. *Pollution in Process* is residual pollution, ascribed to production on a per unit of output basis

Non-CO2 Emission Categories

Air	1 Suspended particulates 2 Sulfur dioxide (SO_2) 3 Nitrogen dioxide (NO_2) 4 Volatile organic compounds 5 Carbon monoxide (CO) 6 Toxic air index 7 Biological air index
Water	8 Biochemical oxygen demand 9 Total suspended solids 10 Toxic water index 11 Biological water index
Land	12 Toxic land index 13 Biological land index

Economy-Environment Linkage

Economic activity affects pollution in three ways:

1. *Growth* – aggregate growth increases resource use
2. *Composition* – changing sectoral composition of economic activity can change aggregate pollution intensity
3. *Technology* – any activity can change its pollution intensity with technological change

All three components interact to determine the ultimate effect of the economy on environment.

Model Development Priorities

- Cap and Trade
- Electricity sector build-out
- Better modeling of vehicle and durable adoption behavior
- Renewable Energy Alternatives
- Combined Heat and Power – Moderate gains in statewide efficiency, benefits outweigh costs

XIV. Model Extensions

- Carbon sequestration – A complex portfolio choice among alternative storage media, but significant potential benefits
- Conservation – The biggest energy "resource," but technology adoption needs to be better understood
- Location/mapping
- Biofuels – ag. sector linkage

Variations

- More labor market structure and conduct (occupations, unemployment, migration, bargaining, rigidities, etc.)
- Increasing returns to scale and imperfect competition markets
- Regional/national model extensions

Discussion