Presentation of EMPAX-CGE Model To SAB

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March 15, 2007

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EMPAX-CGE: Briefing Summary

- Overview
- Baseline Data
- Sector and Regional Detail
- Structure and Calibration
- Intertemporal Dynamics
  - Savings
  - Sources of Growth and Technology Change
  - Capital Accumulation and Mobility
- Policy Evaluation
- Tax Interactions
  - Distortions from Taxes
  - Labor Supply Elasticities
- Recent Applications and Example Outputs

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EMPAX-CGE: External Peer Review

- Dr. Charles Ballard, Economics Professor, Michigan State University
  - In many ways, the model described there is an impressive piece of work… generally speaking, I believe that this model is capable of providing insights into the effects of environmental policy changes.
- Dr. Christoph Bohringer, Professor, Center for European Economic Research
  - Overall, the model documentation conveys the impression of solid competent work.
- Dr. Hillard Huntington, Stanford Energy Modeling Forum
  - The model will be very useful for deriving regional and sectoral impacts of environmental policies that use economic instruments that directly affect the costs of using different energy types.
- Suggestions for Improvement:
  - Provide results from analyses – at the time, there were no publicly available findings.
  - Conduct sensitivity analyses to illustrate model reactions.
  - Consider adjusting some of the elasticity parameters
  - Add additional descriptions of policy evaluation techniques.

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EMPAX-CGE: Overview

- Dynamic regional economic model of US economy
- 5 Regions (Currently)
  - Aggregation of 10 NERC regions along state lines
- 17 Sectors (Currently)
  - 6 energy sectors (e.g., coal, electricity (fossil & nonfossil), natural gas, etc.)
  - 8 manufacturing sectors (7 energy intensive & 1 non-energy intensive)
  - 3 non-manufacturing sectors (e.g., services, agriculture, etc.)
- Baseline conditions characterized by:
  - IMPLAN state-level economic data
  - DOE/EIA energy data and forecasts
- Intertemporal optimization with perfect foresight

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EMPAX-CGE: Baseline Data Summary

- Economic and energy data sources:
  - IMPLAN state-level economic data (information on 528 industries and 9 household types)
  - Energy Information Administration at Department of Energy (AEO, MECS, State Reports, Industry Annuals)
- AEO energy and industrial output forecasts
  - Production and consumption by industry and fuel
  - Incorporate baseline energy efficiency improvements
- Natural resources (coal, crude oil, natural gas)
  - Match resource prices to AEO forecast (as feasible)
  - Set supply elasticity (from MIT) around resulting price path

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EMPAX-CGE: Sectoral Detail

- 17 Sectors in each of 5 Regions:

Energy Production	**Energy-Intensive Sectors**	**Others**
Coal	Food	Agriculture
Crude oil	Paper	Other Manufacturing
Electricity *(fossil and nonfossil)*	Chemicals	Services
Natural Gas	Glass	Transportation
Refined Petroleum	Cement	
	Iron and Steel	
	Aluminum	

- All sectors are interconnected
- Model distinguishes between fossil and nonfossil electricity so costs can be applied separately

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EMPAX-CGE: Current Regional Detail

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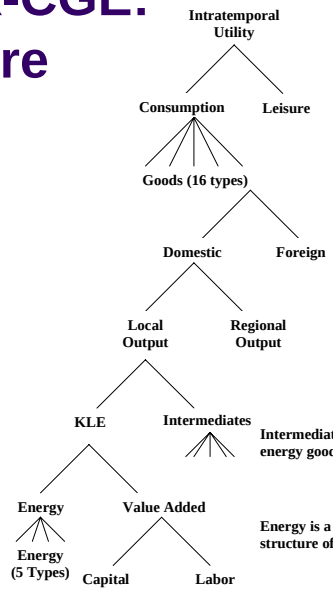
EMPAX-CGE: Structure



Household utility within a time period is a CES function of consumption and leisure.

Consumption is a Cobb-Douglas composite of the 16 types of goods.

Each consumption good is a CES composite of foreign and domestically produced goods.

Domestic goods are a CES composite of locally produced goods and goods from other regions.

Most producer goods use fixed proportions of intermediate inputs and a capital-labor-energy (KLE) composite.

Intermediate materials inputs are the 11 types of non-energy goods, in fixed proportion for each industry.

The KLE composite is a CES function of energy and value-added (KL).

Energy is a CES composite of 5 types of fuel. The structure of this function varies across industries.

Value added is a Cobb-Douglas composite of capital and labor.

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EMPAX-CGE: Calibration

- Model uses nested constant elasticity of substitution (CES) equations
  - Data show inputs currently used to produce output
  - CES functions show options for and ease of substitutions
- Calibrated to production functions & elasticities of MIT's CGE model, EPPA (engineering estimates)
- Initial model year of 2005 - AEO forecasts (regional GDP, energy production, industrial output & energy consumption, energy prices)

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EMPAX-CGE: Intertemporal Dynamics

- Arrow-Debreu general equilibrium theory
- Intertemporally optimizing with foresight
  - Households maximize PV of future consumption subject to budget (and time) constraints. Savings behavior endogenous to the model.
  - Firms maximize PV of future profits subject to technology constraints
- Initial year of 2005, usually solves to 2050
- Time periods at 5-year intervals connected by savings-investment decisions of households

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EMPAX-CGE: Intertemporal Dynamics

- Sources of Growth:
  - Technology change
    - Technological progress & energy efficiency improvements from AEO forecasts
    - Increases in energy prices encourage industrial efficiency and substitution to K/L as well as household substitution to out of energy goods
  - Increases in natural resources (stocks are modeled)
  - Capital accumulation
  - Labor supply and productivity (regional GDP forecasts)
- Includes capital installation costs that determine adjustment dynamics over time
  - Capital stock levels do not adjust instantly or costlessly
  - Quadratic costs control how fast economy responds (Goulder, McKibbin/Wilcoxen)

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EMPAX-CGE: Policy Evaluation

- Environmental expenditures (e.g., compliance costs from the IPM electricity model or AirControlNet) must be allocated to purchases of inputs from other industries within CGE model
  - In absence of other data, Nestor and Pasurka (1995) information on environmental protection expenditures forms basis of this allocation
- Allows model to capture ripple effect to other sectors associated with environmental expenditures by linking them to purchases of their goods and services (and factors of production)

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EMPAX-CGE: Tax Interactions

- Includes distortions from taxes:
  - Labor (FICA) and sales/excise taxes – IMPLAN data
  - Personal income taxes – based on NBER TAXSIM data
  - Capital – Applies user cost of capital formulation (e.g., Fullerton)
- Labor supply elasticities control willingness of households to switch between labor and leisure
  - Compensated elasticity of 0.4, uncompensated elasticity of 0.15 (based on Goulder, Williams, Fullerton, others)
- Estimates of baseline tax distortions in model:
  - MCPF – marginal cost of public funds (~1.22)
  - MEB – marginal excess burden (~0.31)

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EMPAX-CGE: Use for 812 Analysis and Economic Impact Analyses

- Goal: Estimate Cost and Benefit Spillover Effects
  - Costs: Consistency with IPM and AirControlNet
    - Allow these models to determine industrial actions and abatement costs
    - Extend these findings to rest of economy
  - Benefits: Exogenously enter labor productivity increases from health improvements
    - Still under discussion. Has not been applied yet
- Can incorporate results from these models on any or all of the following:
  - Changes in costs (annual, fixed, variable)
  - Changes in electricity prices
  - Changes in fuel (i.e., coal and gas) prices and use

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EMPAX-CGE: Applications

- Predecessor model used for combustion MACTS and SAMI (Southern Appalachian Mountain Initiative)
  - Largely, partial equilibrium approach
- Recent applications as CGE Model
  - Clean Air Interstate Rule, Economic Impact Analysis
    - Applied 'side-by-side' with IGEM for comparison purposes
  - Clean Air Visibility Rule, Economic Impact Analysis
  - PM NAAQS Final, EIA
  - Will be used for Ozone NAAQS EIA (PM NAAQS as baseline)

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EMPAX-CGE and IGEM

- Jorgenson's Intertemporal General Equil. Model
  - Intertemporally-optimizing households with foresight
  - Econometrically estimated parameters
  - Used to analyze benefits of the CAAA (among many other topics)
  - National with 35 industries
  - Tax Interactions included
  - Unconstrained capital movements
  - Natural resource stocks not modeled explicitly
- EMPAX-CGE
  - Intertemporally-optimizing households with foresight
  - Calibrated parameters (based on MIT)
  - Regional with 17 industries
  - Tax Interactions included
  - Changes in investment constrained by capital adjustment costs
  - Natural resource stocks modeled (along with their price paths)

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EMPAX-CGE: Outputs

- General: GDP, welfare, trade, investment
- Production
  - Output by sector ($ and %)
  - Labor use by sector ($ and %)
  - Capital earnings by sector ($ and %)
- Households
  - Consumption of goods ($ and %)
  - Labor supply decisions
- Energy
  - Production by type ($ and BTU and %)
  - Industrial consumption by fuel ($ and BTU and %)
  - Household consumption by fuel ($ and BTU or kWh and %)
  - Heatrates in electricity generation (BTU per kWh)

(Currently generate around 100 tables and 25 US/regional graphs)

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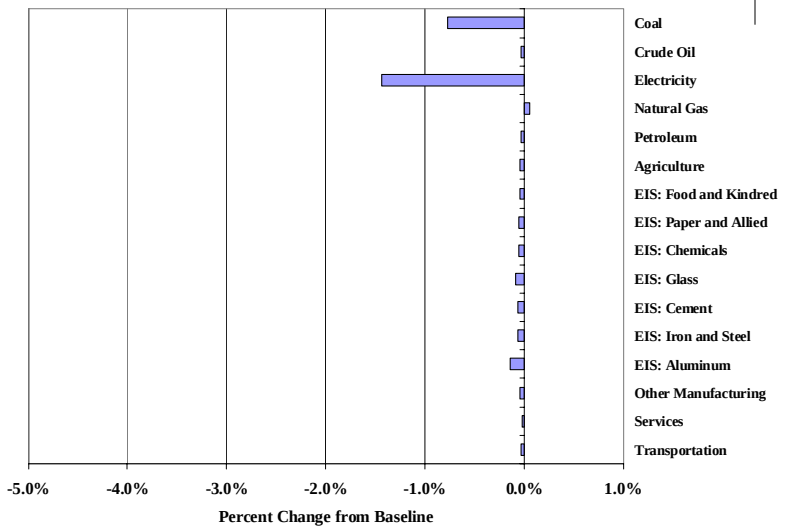
EMPAX-CGE Output

(CAIR: Production Changes - US)



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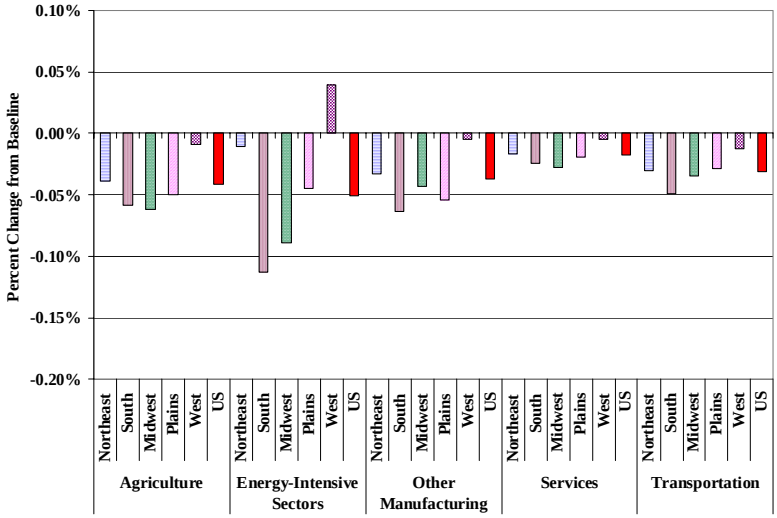
EMPAX-CGE Output

(CAIR: Regional Production Changes)



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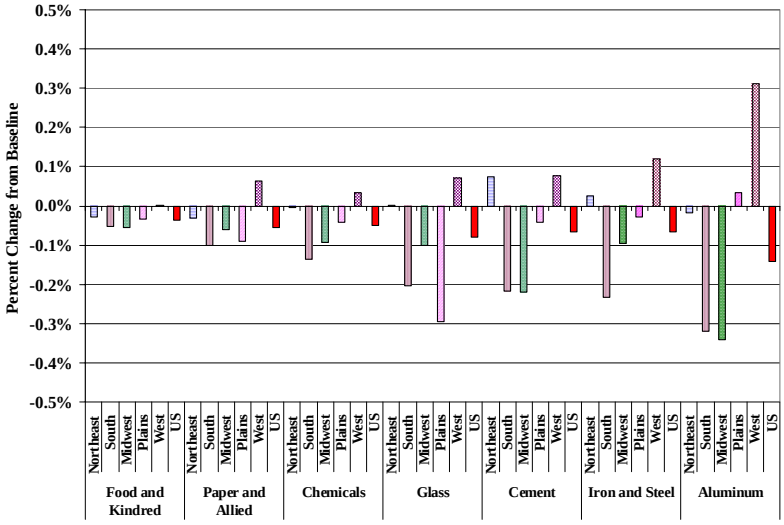
EMPAX-CGE Output

(CAIR: Regional Production Changes)



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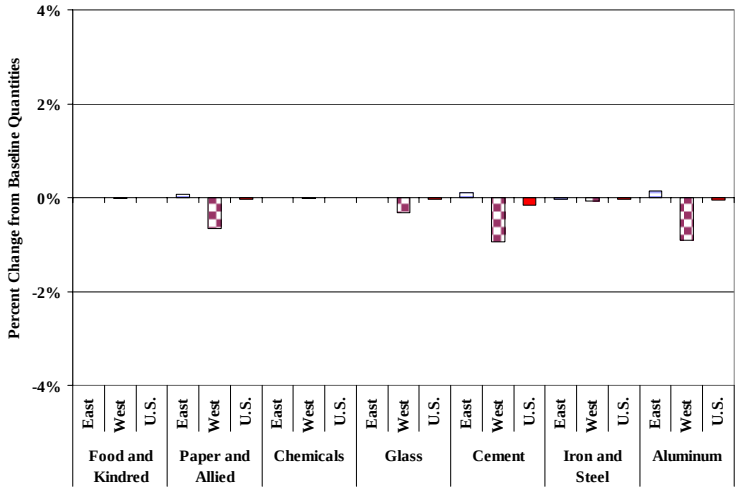
EMPAX-CGE Output

(PM NAAQS 15/35: Regional Production Changes)



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EMPAX-CGE: Preparation and Runtime

- Automated link to IPM & AirControlNet results on:
  - Costs (annual, fixed, variable)
  - Fuel use (coal and gas)
  - Fuel prices (coal and gas)
  - Electricity prices
- Provided with existing preformatted input files, results can be generated in a few hours
  (not counting interpretation and write-ups)
- Timeline only influenced by any need for model development to address new issues

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