

SAGE v1.2.0

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National Center for Environmental Economics
U.S. Environmental Protection Agency



Outline

1. Model Overview
2. Package Contents
3. Versioning
4. Potential Near-Term Updates

Model Overview

SAB Guidance on CGE Best Practices

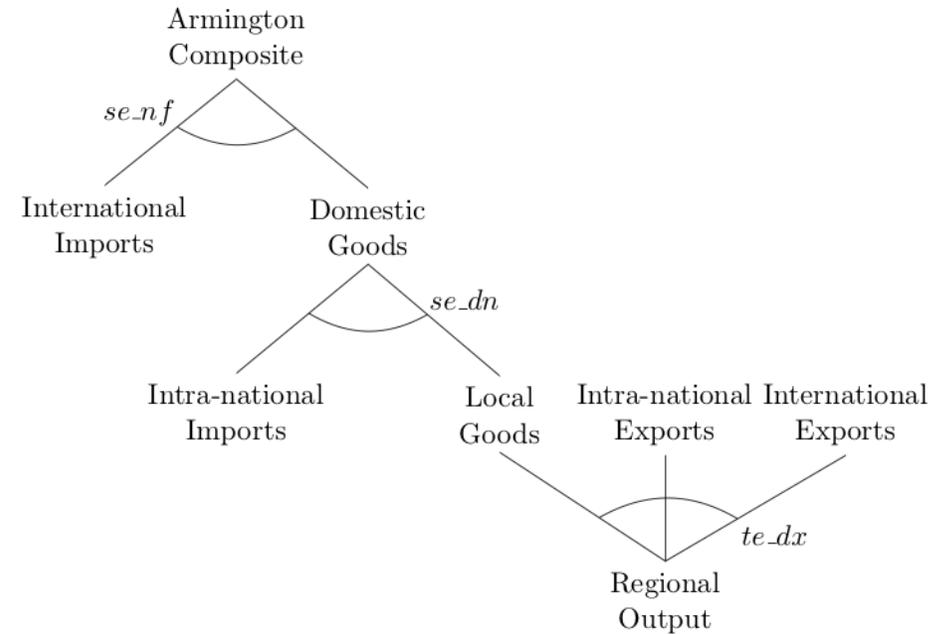
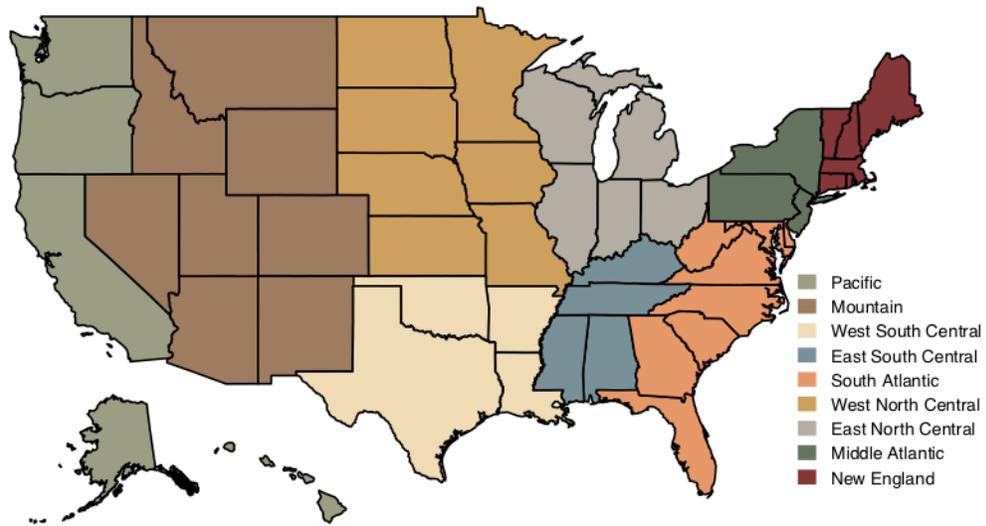
- Building from the SAB's advice, the EPA opted to build and maintain its own model, which allowed us to directly address the SAB's guidance on best practices:
 1. "Availability, completeness, and transparency of data and model documentation;
 2. Public access to the model, including its source code and all other material components;
 3. A theoretically consistent structure based on microeconomic foundations that represents the behavior of producers and consumers;
 4. Theoretically and empirically sound justifications for the choice of functional forms and parameter values;
 5. Verification that several essential theoretical properties hold;
 6. Exploration of underlying reasons for any markedly different results from other models;
 7. Peer-reviewed publications for the model or its closely-related antecedents;
 8. Substantial evidence of robustness with respect to alternative plausible assumptions, model specifications, and data."

SAGE CGE Model

- SAGE is an Applyed General Equilibrium model of the United States
- Key features:
 - Dynamic inter-temporal model: 2016-2061, 5-year interval
 - Sectors: 23 with manufacturing and energy detail
 - Regions: 9 census divisions - no labor & capital mobility, but new investment is mobile
 - Trade: Armington, national pool
 - Capital: partial putty-clay, single extant vintage
 - Households: disaggregation by national income “quintiles”
 - Baseline calibrated to EIA’s Annual Energy Outlook
- Designed to be flexible

Trade Structure

- International trade
 - Small open economy
 - Armington specification
 - Differentiation of commodities by origin



- Domestic trade
 - Nine census divisions
 - Single national market (pooled trade)
 - No labor mobility

Default Sectoral Resolution

Manufacturing

bom Balance of manufacturing
cem Cement, concrete, & lime manufacturing
chm Chemical manufacturing
con Construction
cpu Electronics and technology
fbm Food & beverage manufacturing
fmm Fabricated metal product manufacturing
pmm Primary metal manufacturing
prm Plastics & rubber products manufacturing
tem Transportation equipment manufacturing
wpm Wood & paper product manufacturing
wsu Water, sewage, & waste management

Energy

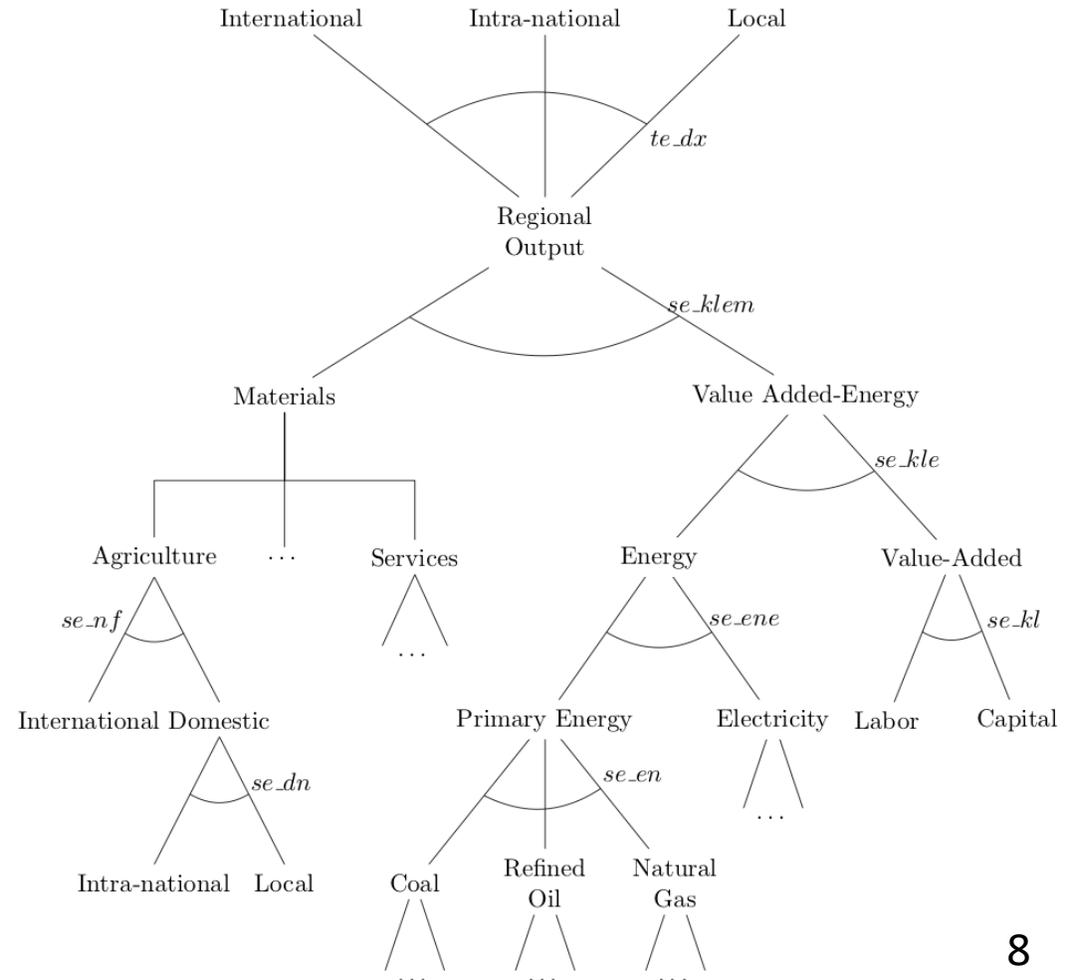
col Coal mining
cru Crude oil extraction
ele Electric power
gas Natural gas extraction & distribution
ref Petroleum refineries

Other

agf Agriculture, forestry, fishing & hunting
hlt Healthcare services
min Metal ore & nonmetallic mineral mining
srv Services
trn Non-Truck transportation
ttn Truck transportation

Production

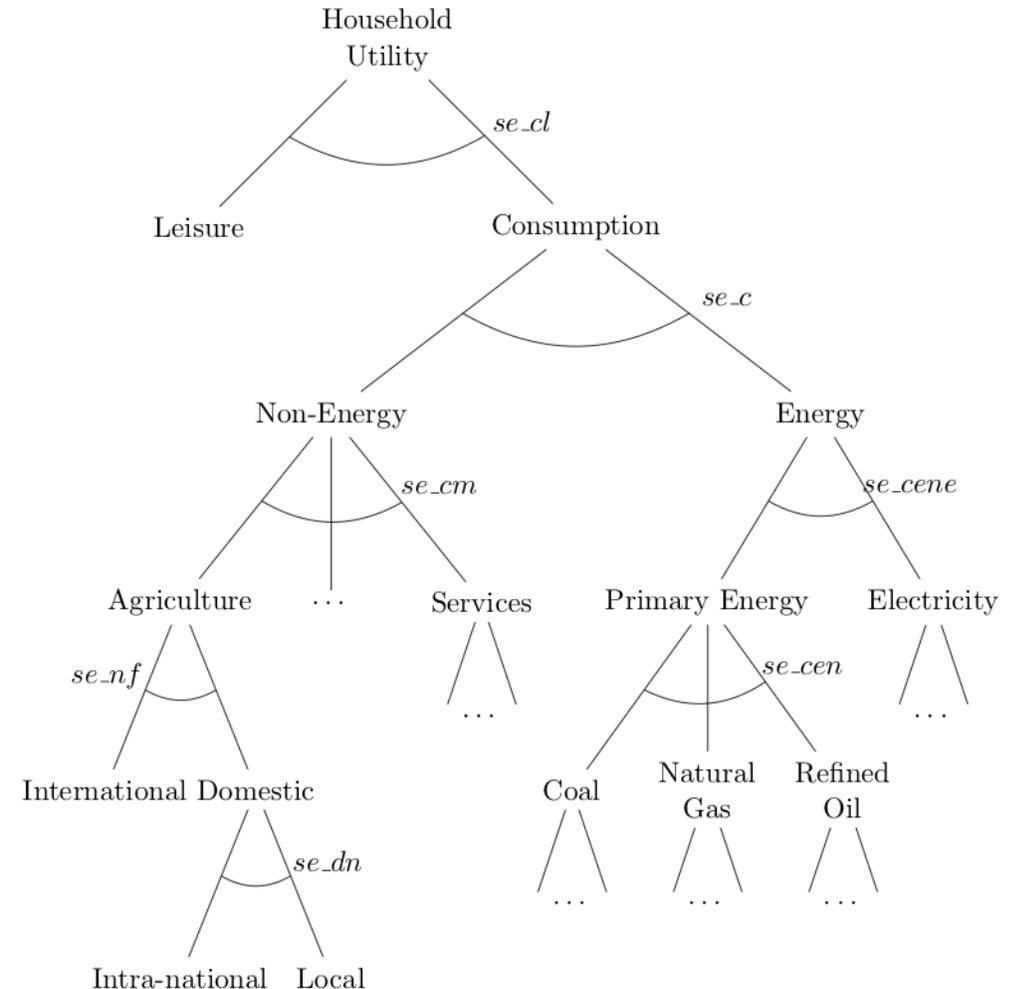
- Partial putty-clay representation of capital
 - Existing capital is sector specific w/ Leontief production at benchmark cost shares
 - New capital is mobile across sectors w/ nested CES production functions
- Resource extraction sectors, along with the agriculture and forestry sector, include fixed factors accounting for the natural resources



Households

- Each region has five representative households based on income, approximately aligned with national income quintiles
- Maximize inter-temporal welfare
 - Discounted isoelastic utility function over full consumption (consumption & leisure)
- Intra-temporal preferences based on nested CES function

Household	Benchmark Year Income [2016\$]
hh1	< \$30,000
hh2	\$30,000 - \$50,000
hh3	\$50,000 - \$70,000
hh4	\$70,000 - \$150,000
hh5	> \$150,000



Government

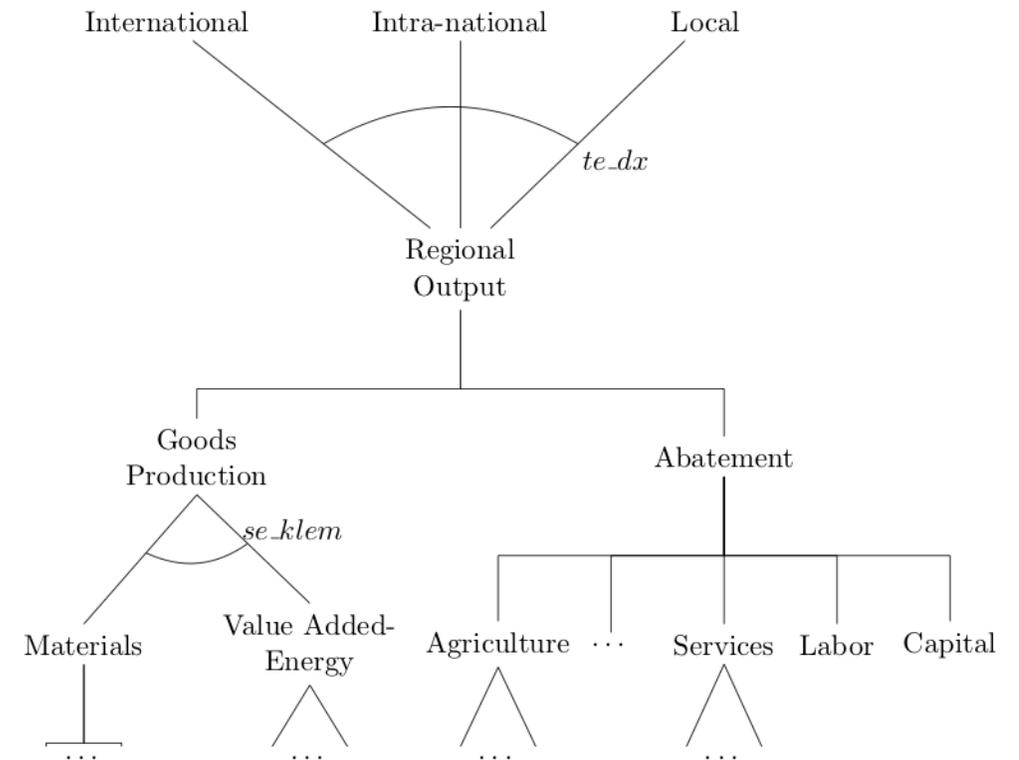
- Single government agent
- Levies ad valorem taxes on:
 - Labor earnings
 - Capital earnings
 - Production (net of business, excise, and sales taxes, and subsidies)
- Makes government purchases and transfer payments

Dynamics and Baseline

- Inter-temporal model with perfect foresight
 - Default version covers 2016 to 2061 in 5 year timesteps
- Periods are connected through the capital stock
- Key characteristics calibrated to AEO 2018
 - Labor productivity growth rate
 - Population growth rate
 - Energy intensity of production and consumption
 - Primary energy consumption shares for electricity generation
- Calibration designed to match long term trends, not year-to-year variation in AEO

Regulatory Compliance Activities

- Representation of regulatory requirements will need to account for the unique characteristics of the policy being analyzed
- However, source-level technology, performance, or workplace standards are common regulatory designs
- Two built-in methods for representing compliance requirements
 1. Explicit abatement requirements
 - Generating output requires both goods production and abatement activities
 2. Productivity “shocks”



Major Data Sources

- Social accounting matrix and related data are developed using multiple sources
- Major data sources include:

Benchmark Economic Data	IMPLAN (state level), EIA energy production data Census Foreign Trade Statistics
Population Data	Census Current Population Survey (CPS)
Taxes	Census CPS Annual Social and Economic Supplement NBER Taxsim Congressional Budget Office IMPLAN (state level)

Model Calibration

- Requires specification of numerous substitution elasticities to complete the definition of production technologies, trade opportunities, and household preferences
- In nearly all cases, conducted new reviews of the empirical literature to inform parametric assumptions, as opposed to adopting values from existing models
 - As with the literature, there are areas where parameter assumptions are more clearly supported than others
 - All assumptions, sources, and justifications are provided in the documentation

SAGE Package Contents

SAGE Package

- Directory structure/contents
 - Build stream data and code: `build/`
 - Core model code: `model/`
 - Model input data: `data/` (output from the build stream)
 - Examples of running the model: `examples/`
 - Documentation: `documentation/` (typeset version in `documentation/documentation.pdf`)
 - Utilities for working with model: `utilities/`
- Each directory contains a `readme.txt` file that contains a description of each file in the directory
- All code is designed to be run from the top-level directory of the package
 - For example, the model is run as: `> gams model/sage.gms`

Documentation

- Documentation contained in the `documentation/documentation.pdf`
- Table of Contents:
 1. Introduction
 2. Model Structure
 3. Calibration and Data
 4. Solution
 5. Modeling Regulatory Requirements
 6. Using the Model

Build Stream

- Build stream (contained in the `build/` directory)
 - Written in GAMS and R
 - Main script controlling the build process is `build/build_default_datasets.R`
- Generates all input data for the model
 - Social accounting matrix: `data/default_aggregation.gdx`
 - Input file with all other parameters: `data/parameters.gms`
 - Note that these two input data files are included in the package made available to reviewers, so one can run the model without running the build stream
- Based on data from numerous data source including: IMPLAN, EIA, Census, NBER Taxsim
 - Except for IMPLAN and data whose original source is a pdf, the build stream will download data or makes use of APIs to retrieve data so an internet connection is required when running the build stream
 - When feasible, all data work is done within the build stream code for reproducibility and transparency

Core Model and Examples

- Core model (contained in the `model/` directory)
 - Written in GAMS
- Section 6.3 of the documentation contains instructions for running the model
- Examples using the model are included in the `examples` directory
 - R or GAMS scripts that run a baseline and policy scenario and display key results
 - Basics of running the model with a sample compliance requirement
 - Sensitivity of results to model features and parameter specifications
 - Checks on behavior and calibration of the model (e.g., implicit defined labor supply elasticities)
- Output from model runs (in GDX and CSV formats) are saved in the `output/` directory

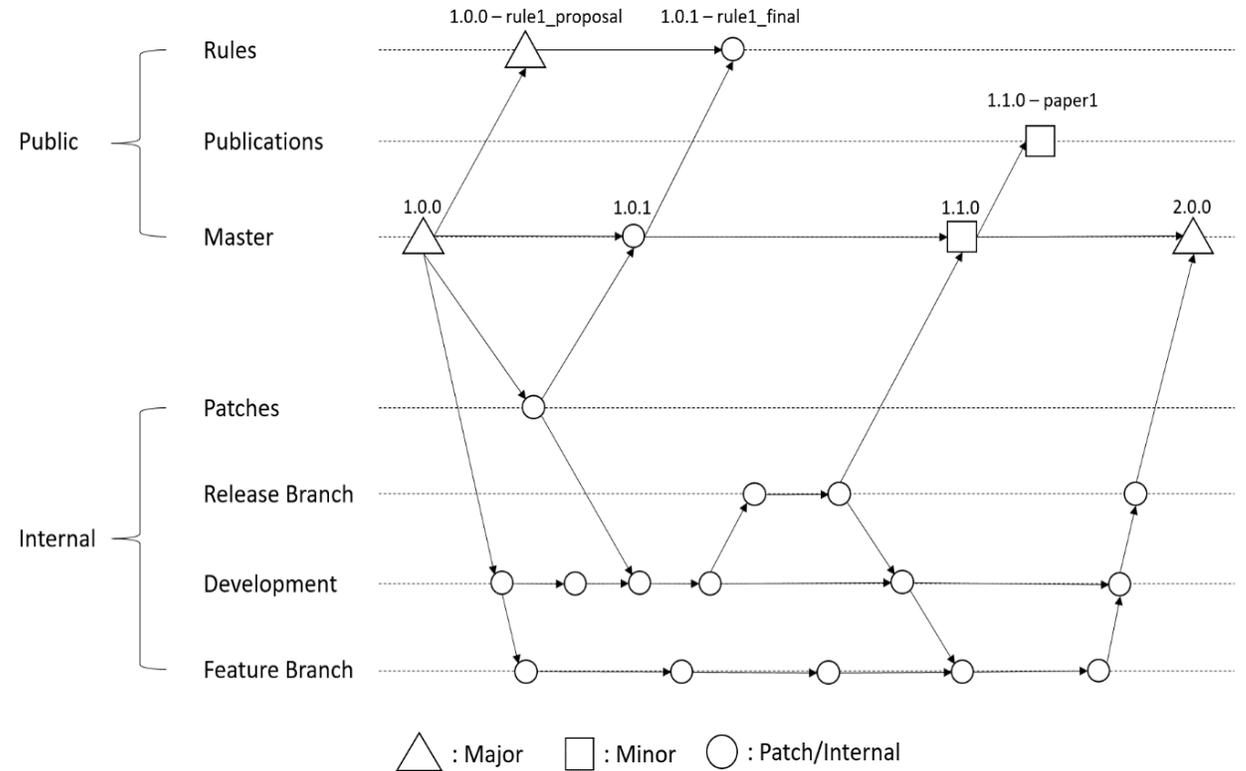
Versioning

Versioning Overview

- The “SAGE model” consists of the build stream, core model, documentation, and supporting functions
- Expect continued maintenance and development of the model over time
- Adopting a version control system to ensure transparency and consistency as updates occur
 - Also valuable to ensure transparency and reproducibility of regulatory analysis
- The potential for updates to the model brings up questions regarding the application of additional peer review in the future

Version Control System

- Symantec versioning
 - Major.Minor.Patch (e.g. 1.0.1), establishes hierarchy of releases
 - Common in software development
 - Store model versions used in regulatory applications for transparency and reproducibility
- Bring structure to internal development
 - Implemented using Git
 - Organizes development process between model releases



Versioning and Peer Review

- Version control system potentially signals whether changes are substantial enough for further peer review
- Establishing explicit criteria *a priori* is difficult.
 - Generally expected that major updates will require additional peer review
 - Whether minor updates require peer review is gray area; rely on professional judgement to some extent and may depend on model use
 - Model modifications for regulatory applications are subject to public comment and also may warrant additional peer review
- We follow EPA's Peer Review Policy outlined in the Peer Review Handbook

Potential Near-Term Model Updates

Potential Near-Term Updates

- Model updates and improvements are a continual process
- Identified three areas where we think we can make significant near-term improvements
 - Early in the process so opportunity for early feedback from the Panel on priority, methodology, relevant literature, and data sources
- 1. Consumer demand system
 - Current specification is based on homothetic nested CES functions
 - Consider use of flexible functional forms to capture more robust Engel responses and cross-price elasticities
 - Econometric estimation of the demand system parameters

Potential Near-Term Updates

2. Large open economy specification

- Current specification is a small open economy
- Consider relaxing that assumption to consider international demand and supply responses

3. Separation of production, sales, and excise taxes

- Current specification includes supply-side production tax inclusive of business, sales, and excise taxes per the IMPLAN database
- Consider separating the taxes and representing sales and excise taxes on consumption side
- Consider moving sales and excise taxes from the sector where revenue is collected to commodity being taxed