# Wisconsin Economic Data Consortium (WEDC)

# State Level Carbon Leakage Application using blueNOTE

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# Collaboration with EDF (2017)

*An important byproduct of our project will be an open-source dataset suitable for analysis of energy-economy-environment issues in North America. We begin with the national input-output table and downscale to the county level using regional economic statistics from the Bureau of Economic Analysis (sectoral value added and price household expenditure). We also employ data from Census Bureau's (foreign trade statistics) and International Trade Administration for bilateral trade statistics.*
*Input-output tables will further be complemented by physical energy quantities and energy prices from the Department of Energy's State Energy Data System (SEDS) of EIA.*

# Overview

**Research question:** Can we build a set of transparent tools for producing subnational economic accounts for general equilibrium and input output analysis for the United States?

- Equilibrium analysis relies on *constructed* datasets.
- In this work, we reconcile national and state level economic data to produce a *micro-consistent* state level dataset for the United States.
- Publicly available regionalized accounts are not freely available, limiting the scope of equilibrium analysis.

# Objectives

The Wisconsin Economic Data Consortium is being created to facilitate the coordination and implementation of:

- Open source build stream (which can be modified by users to produce their own version of regional social accounting matrices).
- Value shares, tax and trade margins based on public data.
- Estimated elasticities based on proprietary Census data with public code but restricted data.
- Connections to other international data sets.
- Accessible build stream which runs on NEOS (optimization server not requiring GAMS license).
- Clean connection to canonical models which run in both GAMS and Julia/JUMP.

The aim is to provide *options* for building a policy specific dataset and a foundational structure from which to base an analysis from.

# Motivation

Existing subnational models have largely relied on a commercial database (IMPLAN) to characterize base year state and county-level economic activity in the United States.

- IMPLAN sells both state- and county-level national datasets which are based on public data
- Lack of transparency in regionalizing data. Outside options are expensive and proprietary. No way to look "under the hood".
- No mechanisms for understanding how data related assumptions impact model results.

The open-source tools for combining data and building a benchmark equilibrium database will be useful to many research groups across the country. Provide means for making more quantitative evidence based research possible.

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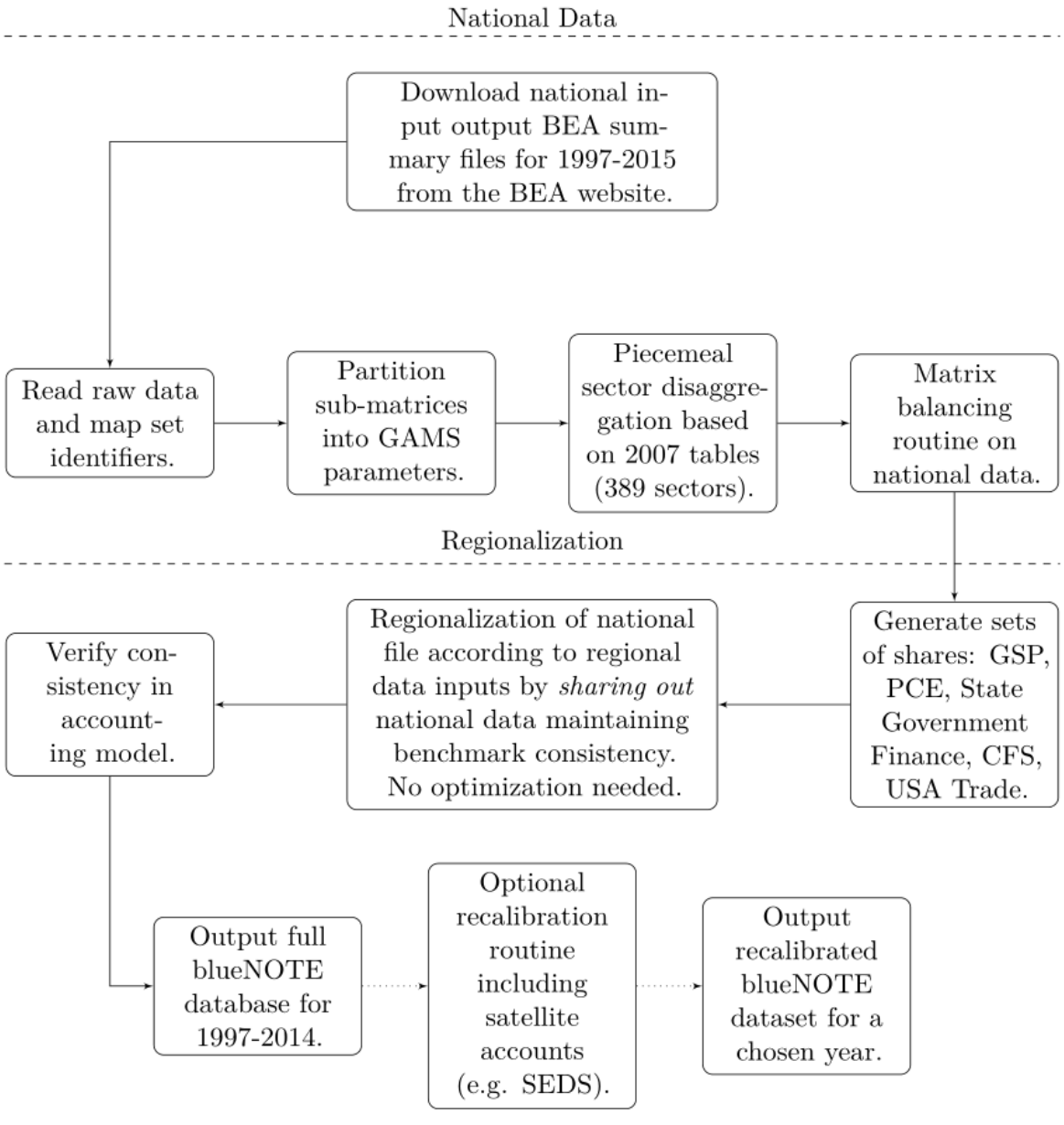
# Build Stream



# National Tables

National level summary files from 1997-2015:

- Supply tables – byproduct matrices with aggregate imports and trade/transport margins.
- Use tables – includes aggregate intermediate inputs, total taxes, exports, and demand accounts (aggregate household, government purchases and investment).

Use of GAMS to define submatrices and partition into CGE based parameters.

# Sector Disaggregation

The routine provides options on the preferred level of sector disaggregation. Sector level detail is leveraged from the 2007 tables with 389 sectors. Level of disaggregation would depend on analysis. Options in the code include:

- *tot*: full disaggregation,
- *non*: no disaggregation,
- *eng*: energy related sectors,
- *agr*: agricultural sectors,
- *gtp*: GTAP disaggregation

For data in the 2007 tables, disaggregation shares are generated through linking disaggregate sector data with aggregate sector data through particular parameters. Data not in the disaggregate data (margins) are shared according to equal weight. Can use satellite data as well (oil and gas extraction).

# Matrix Balancing: Huber vs. Least Squares

Optimization techniques used only once in the core build process – to balance the *national* tables to satisfy accounting identities (zero profit, market clearance, and income balance).

- Problem: *how can we minimize changes in the underlying data while enforcing accounting constraints?*

Two options are provided:

- Least squares – minimize the sum of squared percent changes in the data.
- Hybrid approach – minimize percent change in the data subject to a piecewise objective function. The loss function is quadratic in the neighborhood of the data and becomes linear further from the target.

Alternatives that could eventually be implemented? (e.g. RAS, entropy)

# Matrix Balancing: Huber vs. Least Squares

Least squares:

$$\min_{A_{rc}} \quad \sum_{\Phi_{rc}} |\overline{a_{rc}}| \left( \frac{A_{rc}}{\overline{a_{rc}}} - 1 \right)^2 + \gamma \sum_{\Phi^c_{rc}} A^2_{rc}$$

$$\text{s.t} \quad F_i(A, \overline{a}) = 0 \quad \forall i$$

Hybrid approach based on Huber (1981):

$$\min_{A_{rc}} \quad \sum_{rc} L(A_{rc}, \overline{a_{rc}})$$

$$\text{s.t} \quad F_i(A, \overline{a}) = 0 \quad \forall i$$

$$L(A_{rc}, \overline{a_{rc}}) = \begin{cases} \overline{a_{rc}}\theta \left( \frac{A_{rc}}{\overline{a_{rc}}} - 1 \right) & \frac{\overline{A_{rc}}}{\overline{a_{rc}}} - 1 \geq \theta \\ \overline{a_{rc}} \left( \frac{A_{rc}}{\overline{a_{rc}}} - 1 \right)^2 & \theta \geq \frac{\overline{A_{rc}}}{\overline{a_{rc}}} - 1 \geq -\gamma \\ \overline{a_{rc}}\gamma(1-\gamma) \log \left( \frac{A_{rc}}{\overline{a_{rc}}} \right) & \frac{\overline{A_{rc}}}{\overline{a_{rc}}} - 1 \leq -\gamma \end{cases}$$

where $\Phi_{rc}$ denote the subset of $(r, c)$ with non-zero elements and $\Phi^c_{rc}$ are zero elements.

In the hybrid barrier method we retain Huber's loss function for increases from the target value and we add a log term to penalize values which go to zero:

# Regionalization Process

The process to go from consistent national tables to state level tables relies on *sharing* data parameters. Shares are based on:

- gross state product (GSP)
- personal consumer expenditures (PCE)
- state government finance tables (SGF)
- USA trade statistics from Census
- commodity flow survey (CFS)

In the first four cases, data are given in aggregate categories. Categories are mapped to sectors in national data. Shares are generated such that:

$$\sum_{r} \delta_{yr,r,s} = 1 \quad \forall \quad (yr, s)$$

# Regionalization Process

- Use GSP shares to separate production data: sectoral supply with byproducts, intermediate demand and value added. Split aggregate value added based on labor and capital accounts in GSP data.
- Use PCE shares to separate household final consumption.
- Use SGF shares to separate government expenditures.
- GSP shares separate investment demand.
- USA trade shares based on Census data to separate state exports.
- For a given year then, total domestic absorption must equal:

$$= HHDem_{r,g} + GovDem_{r,g} + Inv_{r,g} + \sum_{s} IDem_{r,g,s}$$

- Generate implicit shares based on absorption totals to enforce identities:

$$= Abs_{r,g} / \sum_{rr} Abs_{rr,g}$$

- Use implicit shares to separate imports and margin demand.

# Regionalization Process

In order to maintain zero profit and market clearance in the data, we determine demand/supply from/to the state vs. national markets by imposing *regional purchase coefficients* based on commodity flow survey data or a gravity model of trade.

- Regional purchase coefficients (RPC) are found by assigning aggregate categories in CFS data to blueNOTE sectors or through estimated bilateral trade flows. The dataset provides a metric on how much of a given good is retained in a given state or shipped to other states.
- $RPC_{r,g} \in [0, 1]$. I.e. an $RPC_{r,g} = 0.4$ would indicate 40% of a given good's domestic demand was sourced in the state. The rest came from the national market.

State level or national level domestic demand is defined by either the supply or demand side of the market to maintain zero profit in either the export or absorption markets.

Margins are supplied by both the state and national markets.

The benchmark dataset is structured for either a pooled national market or gravity based estimates. Explicit bilateral trade flows cannot be determined using CFS data:

- Wittwer (2017) shows that CFS data provide information on the value of goods between transport nodes, which may or may not be in line with production origins or consumption destinations.
- Points to need of gravity based estimates.

# Bilateral Trade

Estimated with Canadian D-Level input output data for 2014 for each blueNOTE sector. Trade from region $i$ to $j$ depends on economic forces in both origin and destination nodes, and forces that aid or restrict the flow of goods from origin to destination.

$$lnY_{ij} = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(Dist_{ij}) + \sum_f \beta_f X_{ij}^f + \epsilon_{ij}$$

| | (1) *all* | (2) *adm* | (3) *agr* | (4) *air* | (5) *alt* | (6) *amb* | (7) *amd* |
|---|---|---|---|---|---|---|---|
| lnFromGDP | 0.713*** | 1.014*** | 0.437*** | 1.132*** | 0.428*** | 0.597*** | 0.703*** |
| | (0.0638) | (0.0782) | (0.0687) | (0.0617) | (0.0637) | (0.0852) | (0.0540) |
| lnToGDP | 0.549*** | 0.810*** | 0.551*** | 0.739*** | 0.369*** | 0.553*** | 0.768*** |
| | (0.0603) | (0.0816) | (0.0735) | (0.0813) | (0.0604) | (0.0795) | (0.0637) |
| lnDist | -1.339*** | -1.370*** | -1.322*** | -1.089*** | -0.759*** | -1.469*** | -1.220*** |
| | (0.121) | (0.145) | (0.148) | (0.141) | (0.128) | (0.167) | (0.0990) |
| Contiguity | -0.302 | 0.284 | 0.188 | -0.575 | -0.185 | -0.532 | 0.0805 |
| | (0.272) | (0.393) | (0.302) | (0.349) | (0.286) | (0.412) | (0.254) |
| Language | 0.483*** | 0.393* | 0.798*** | 0.719*** | 0.199 | 0.625*** | 0.674*** |
| | (0.159) | (0.224) | (0.196) | (0.214) | (0.147) | (0.225) | (0.161) |
| Constant | -6.618*** | -8.854*** | -5.622*** | -11.26*** | -8.374*** | -5.381*** | -7.816*** |
| | (0.909) | (1.423) | (0.909) | (1.436) | (0.825) | (1.268) | (0.781) |
| Observations | 49100 | 700 | 2000 | 300 | 600 | 400 | 200 |
| R2 | 0.439 | 0.594 | 0.510 | 0.522 | 0.415 | 0.552 | 0.585 |

**Notes:** Standard errors, clustered by origin destination pairs, are in parentheses with * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Sectors are described as follows: all - all sectors, adm - administrative and support services, agr - farms, air - air transportation, alt - apparel and leather and allied products, amb - ambulatory health care services, amd - accommodation.

# Data Overview

The build routine provides:

- Social accounting matrices for all 50 states plus D.C. from 1997-2014.
- Based on summary files of 71 sectors.
- Option for disaggregation using the 2007 389 sectoring scheme and additional satellite accounts.
- Regionalization achieved mainly regional level gross state product and expenditure accounts.
- Trade is imposed in national pooled market using regional purchase coefficients generated by commodity flow survey data or through gravity based estimates.
- Option for recalibrating dataset to match totals from satellite accounts.

# Web Page Snapshot of the Database

Secure | https://aae.wisc.edu/blueNOTE/

## blueNOTE: National Open source Tools for general Equilibrium analysis

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EDF ENVIRONMENTAL DEFENSE FUND

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A byproduct of a recently completed research project conducted with Gökçe Akin-Olçum (from Environmental Defense Fund) and Christoph Böhringer (from the University of Oldenburg) is an open-source dataset suitable for analyzing economy-wide issues in North America. We begin with the Bureau of Economic Analysis' (BEA) national input-output table and downscale to the regional level using publicly available economic statistics from governmental agencies. We use additional data from the BEA on regional gross product and consumer expenditures and data from the Census Bureau on foreign trade, bilateral trade and state government expenditures . For illustrative purposes, we show how to complement the core input-output tables with physical energy quantities and energy prices from the Department of Energy's State Energy Data System (SEDS) of EIA.

We call the utilities for producing our dataset *blueNOTE*. blueNOTE is a collection of GAMS programs for producing subnational economic accounts for input-output or computable general equilibrium models of the United States economy. All code and data necessary for producing subnational accounts are provided in this repository. Currently, the routine can produce state level accounts.

### Getting Started

You can peruse the build routine files in this directory:

https://aae.wisc.edu/blueNOTE/build

These include all GAMS programs and defines files for sets and mappings. You may download the full build including the intermediate data files from here (69

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# Data syntax: Sets & Parameters

*Table 1: Set Notation in the Regional CGE Model*

| Type | Item | Description |
|---|---|---|
| **Sets:** | $s, g$ | Sectors/Goods |
| | $r$ | Regions |
| | $m$ | Margin type |

*Table 3: Parameters in the Regional CGE Model*

| Parameter | Description |
|---|---|
| $\bar{ys}_{r,g,s}$ | Sectoral supply |
| $\bar{id}_{r,s,g}$ | Intermediate demand |
| $\bar{ld}_{r,s}$ | Labor demand |
| $\bar{kd}_{r,s}$ | Capital demand |
| $\bar{s}_{r,g}$ | Aggregate supply |
| $\bar{xn}_{r,g}$ | National supply |
| $\bar{xd}_{r,g}$ | State level supply |
| $\bar{x}_{r,g}$ | Foreign exports |
| $\bar{nm}_{r,m,g}$ | National margin supply |
| $\bar{dm}_{r,m,g}$ | State level margin supply |
| $\bar{m}_{r,g}$ | Imports |
| $\bar{nd}_{r,g}$ | National demand |
| $\bar{dd}_{r,g}$ | State level demand |
| $\bar{md}_{r,m,g}$ | Margin demand |
| $\bar{a}_{r,g}$ | Armington supply |
| $\bar{ta}_{r,g}$ | Tax net subsidy rate on intermediate demand |
| $\bar{tm}_{r,g}$ | Import tariff |
| $\bar{cd}_{r,g}$ | Final demand |
| $\bar{yh}_{r,g}$ | Household production |
| $\bar{bop}_{r}$ | Balance of payments |
| $\bar{g}_{r,g}$ | Government demand |
| $\bar{i}_{r,g}$ | Investment demand |

*Table 4: Regional Social Accounting Matrix*

| | | **Production** | **Exports** | **Absorption Composite** | **Margins** | **Output Market** | **Regional Market** | **National Market** | **Domestic Composite** | **Factors** | **Margins Market** | **Trade** | **Agents** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Y_{r,s}$ | $X_{r,g}$ | $A_{r,g}$ | $M_{r,m}$ | $p^Y_{r,g}$ | $p^D_{r,g}$ | $p^N_s$ | $p^A_{r,g}$ | $p^L_r, p^K_{r,s}$ | $p^M_{r,m}$ | $p^{FX}$ | |
| **Production** | $Y_{r,s}$ | | | | | $\bar{ys}_{r,s,g}$ | | | | | | | |
| **Exports** | $X_{r,g}$ | | | | | | $\bar{xd}_{r,g}$ | $\bar{xn}_{r,g}$ | | | | $\bar{x}_{r,g}$ | |
| **Absorption Composite** | $A_{r,g}$ | | | | | | | | $\bar{a}_{r,g}$ | | | | |
| **Margins** | $M_{r,m}$ | | | | | | | | | | $\bar{md}_{r,m,g}$ | | |
| **Output Market** | $p^Y_{r,g}$ | | $\bar{s}_{r,g}$ | | | | | | | | | | |
| **Regional Market** | $p^D_{r,g}$ | | | $\bar{dd}_{r,g}$ | $\bar{dm}_{r,m,g}$ | | | | | | | | |
| **National Market** | $p^N_g$ | | | $\bar{nd}_{r,g}$ | $\bar{nm}_{r,m,g}$ | | | | | | | | |
| **Domestic Composite** | $p^A_{r,g}$ | $\bar{id}_{r,g,s}$ | | | | | | | | | | | $\bar{cd}_{r,g}$, $\bar{g}_{r,g}, \bar{i}_{r,g}$ |
| **Factors** | $p^L_r, p^K_{r,s}$ | $\bar{ld}_{r,s}, \bar{kd}_{r,s}$ | | | | | | | | | | | |
| **Margins Market** | $p^M_m$ | | | $\bar{md}_{r,m,g}$ | | | | | | | | | |
| **Trade** | $p^{FX}$ | | | $\bar{m}_{r,g}$ | | | | | | | | | |
| **Agents** | | | | | | $\bar{yh}_{r,g}$ | | | | $\bar{ld}_{r,s}, \bar{kd}_{r,s}$ | | $\bar{bop}_r$ | |

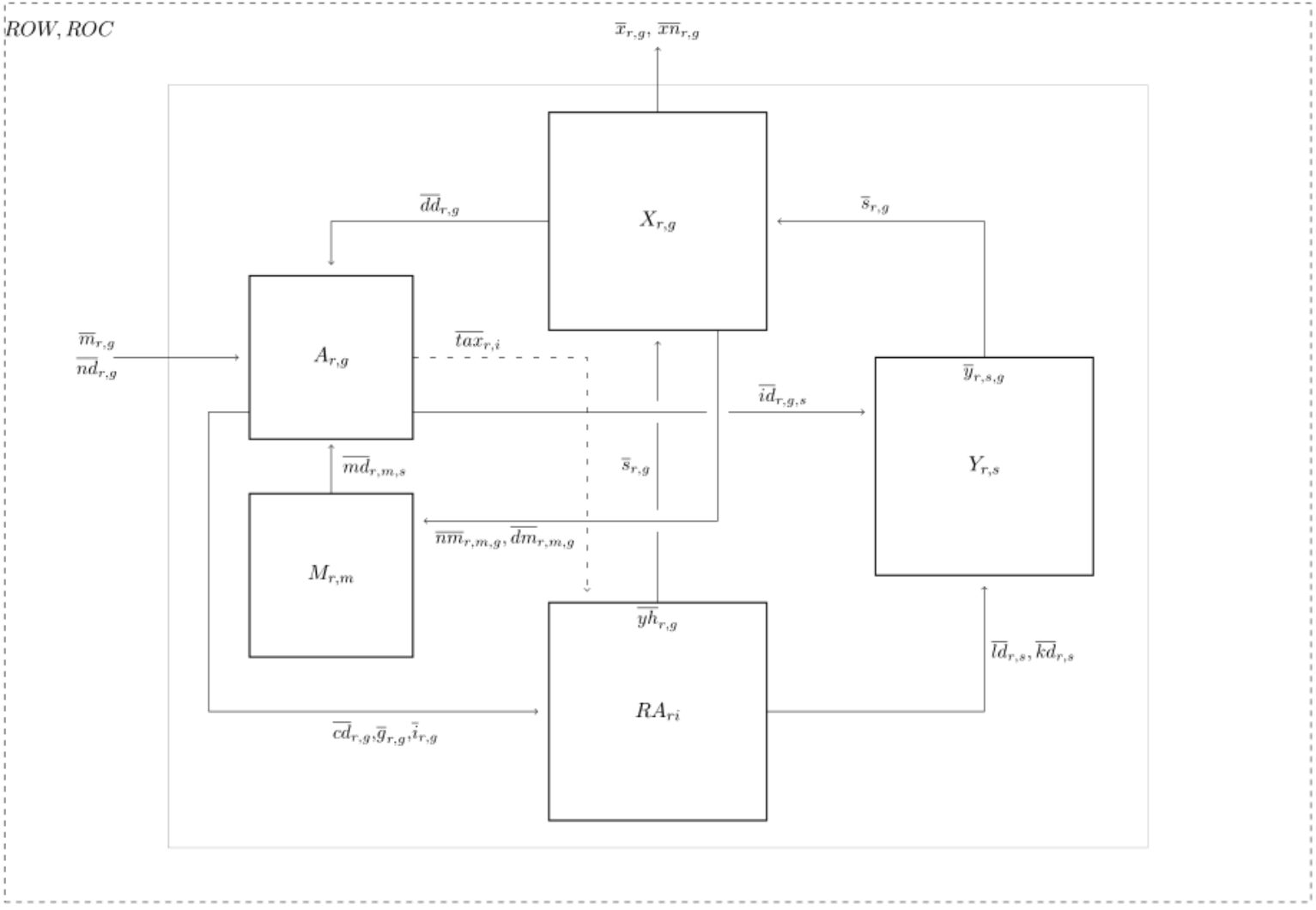
# Model/Data Syntax: Variables

*Table 2: Nomenclature in the Regional CGE Model*

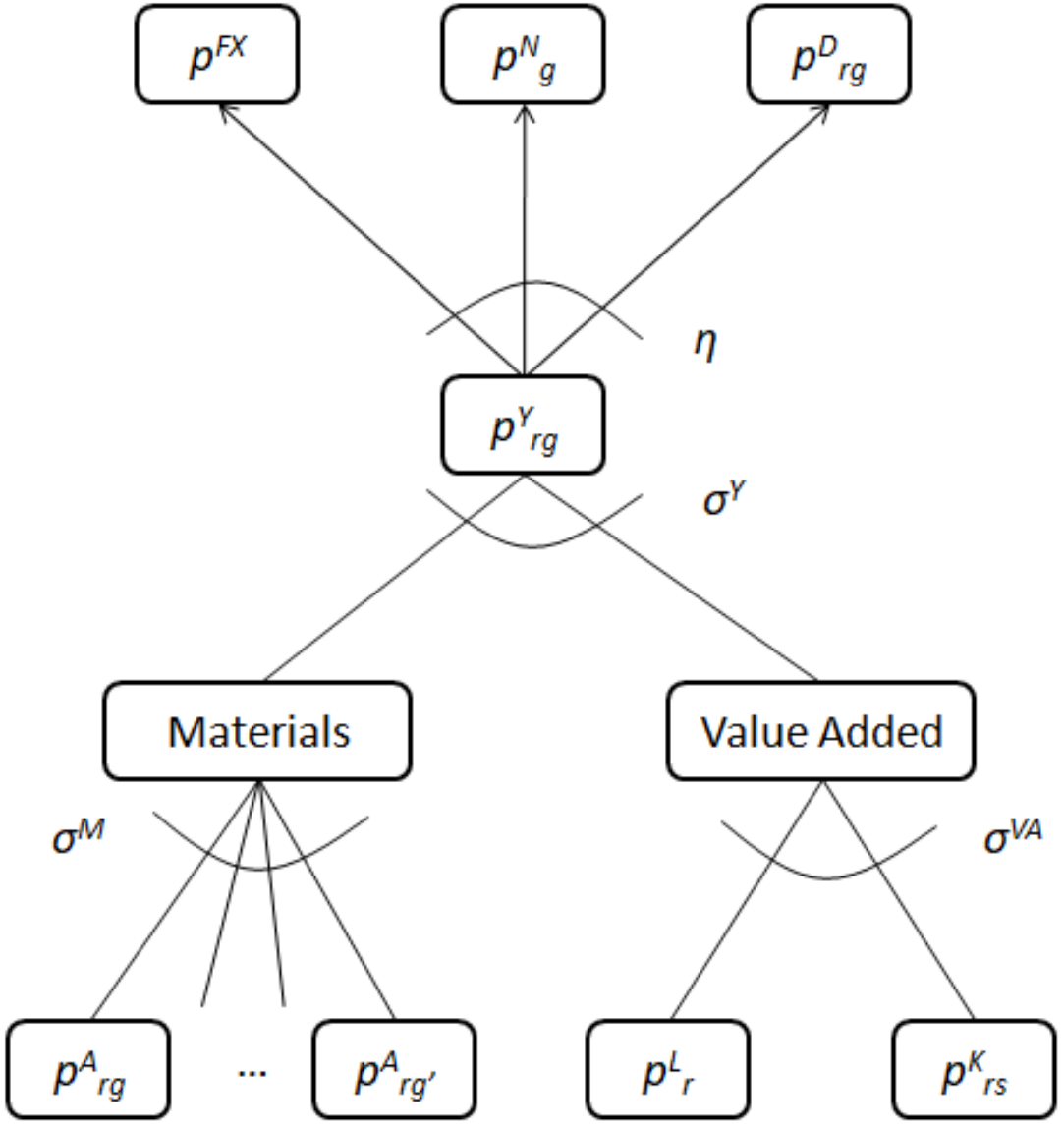
| Type | Item | Description |
|---|---|---|
| **Activity Levels:** | $Y_{r,s}$ | Sectoral output |
| | $A_{r,g}$ | Armington composite |
| | $X_{r,g}$ | Supply allocation |
| | $MS_{r,m}$ | Margin supply |
| **Prices:** | $p^{Y}_{r,g}$ | Output market price |
| | $p^{A}_{r,g}$ | Armington composite price index |
| | $p^{D}_{r,g}$ | State level market price for goods |
| | $p^{N}_{g}$ | National market price for goods |
| | $p^{FX}$ | Foreign exchange rate |
| | $p^{L}_{r}$ | Wage rates |
| | $p^{K}_{r,s}$ | Capital rental rates |
| | $p^{M}_{r,m}$ | Margins markup |
| **Agents:** | $RA_r$ | Representative household |
| | $GOV_r$ | Representative government |

# Model Flows

*Figure 1: The Regional Economic Structure*



# Accounting Model Overview



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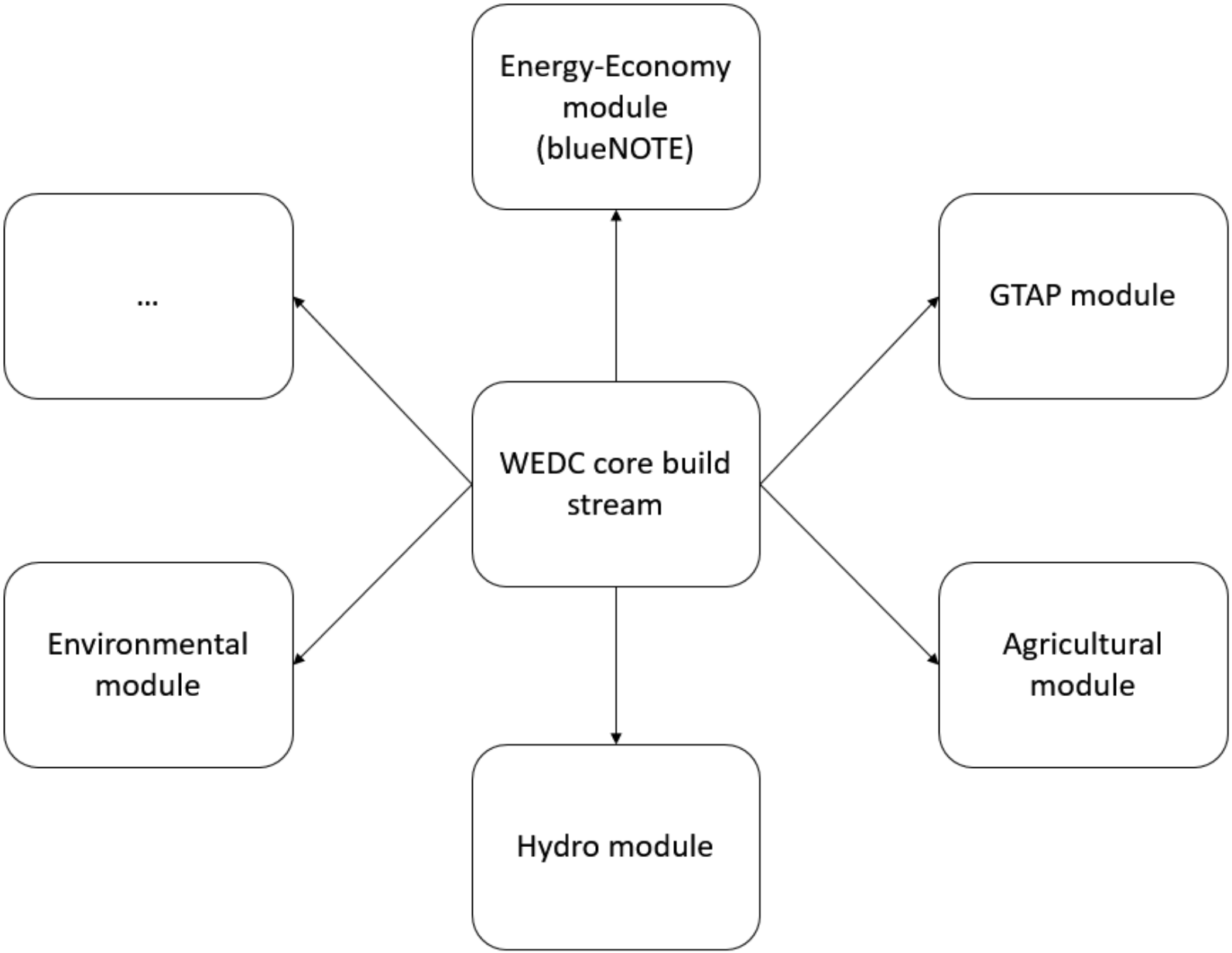
# Modules


Energy-Economy module (blueNOTE)
...
GTAP module
WEDC core build stream
Environmental module
Agricultural module
Hydro module

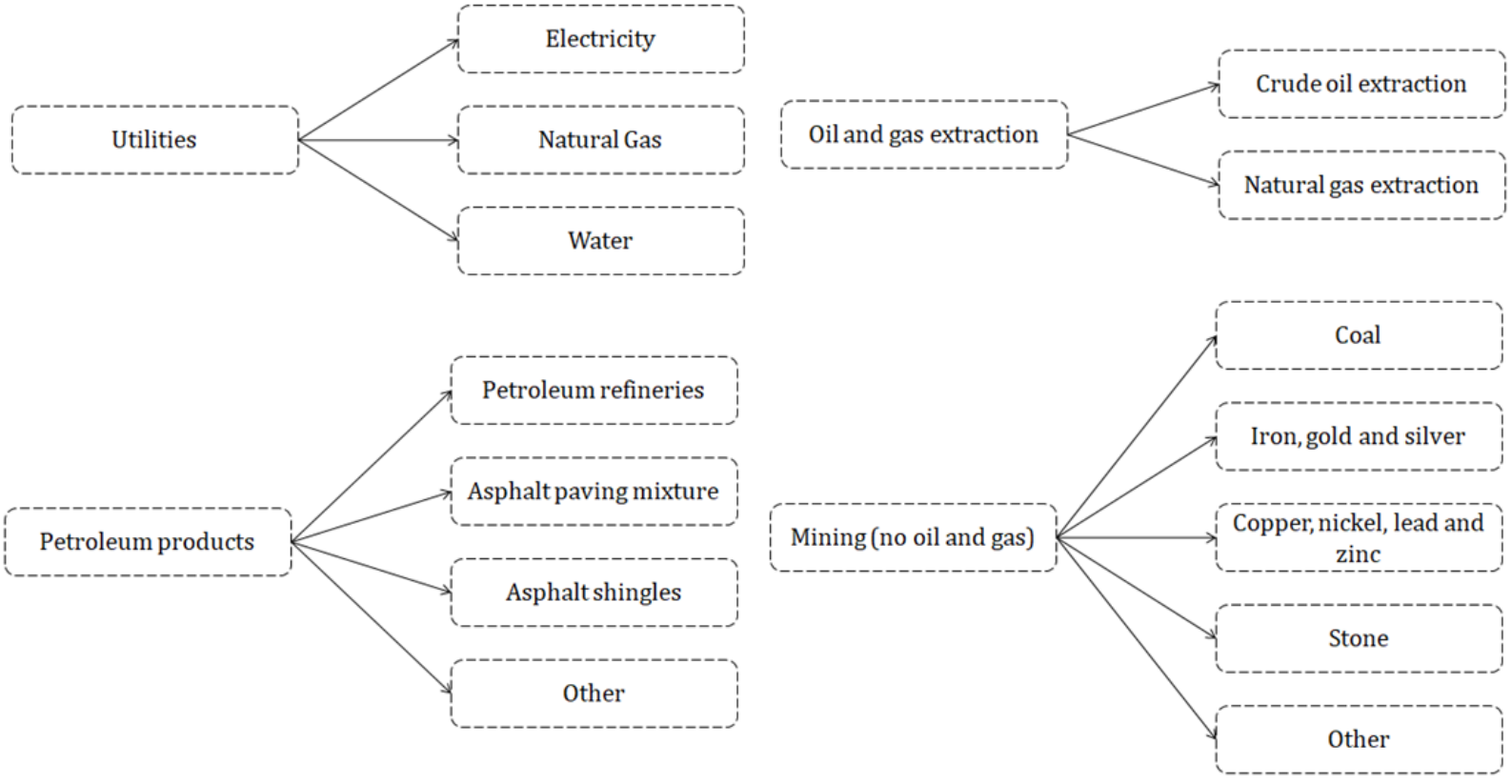
# The Energy-Economy Dataset

**blueNOTE**: **N**ational **O**pen source **T**ools for general **E**quilibrium modeling

Matrix balancing routines are provided (similar to those in the national case) which can enforce certain totals in the dataset if needed. For energy applications we use the State Energy Data System (SEDS) data.

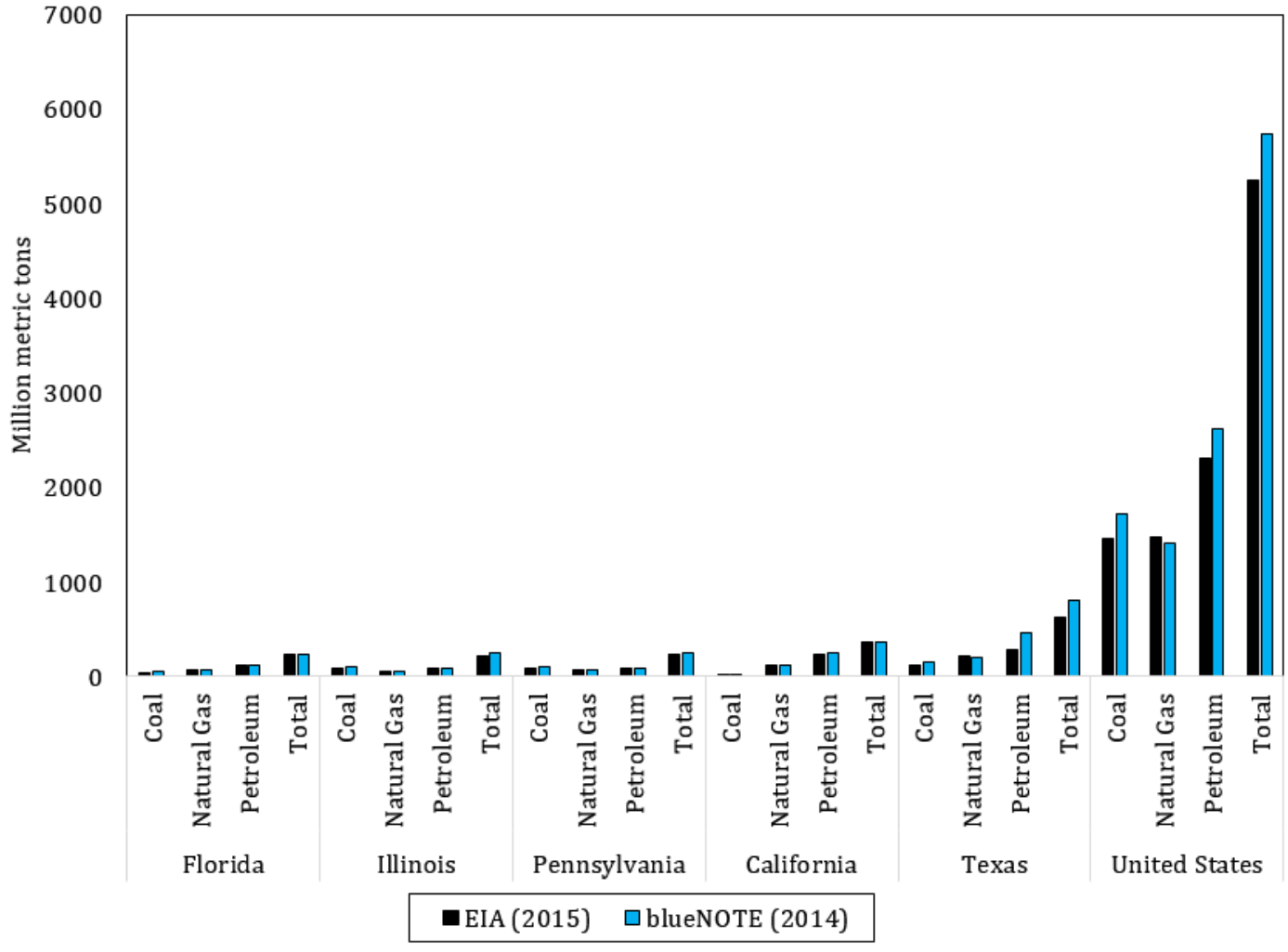
- It's been pointed out that BEA data tends to under-report energy related demands. Use SEDS to impose both energy demands (which match emission levels) and supplies.
- Potential for disaggregating electricity sector into explicit generation technologies (coal, natural gas, etc.) for rough bottom up treatment.
- Separate oil and natural gas extraction sector.
- Generate carbon emissions.
- Adjust trade margins to be in tune with electricity mark ups.

# Sector Disaggregation: Energy Sectors



# Carbon Emissions: Top 5 States

Carbon emissions are generated using CO2 coefficients (kg per million btu) matched to physical energy quantities from SEDS (in btus).



# blueNOTE vs. IMPLAN

Strengths:

- Transparency: build stream provides all code and data sources to generate regionalized dataset.
- Margin detail: markups are explicitly captured in blueNOTE which is particularly important for electricity related modeling.
- Flexibility: routine provides tools for calibrating model to satellite data tables in line with physical energy quantities and prices.

Current version of the build lacks detailed household and government accounts.

- No household groupings by income or government accounts depending on local, state or federal levels. Distinction is given by region.

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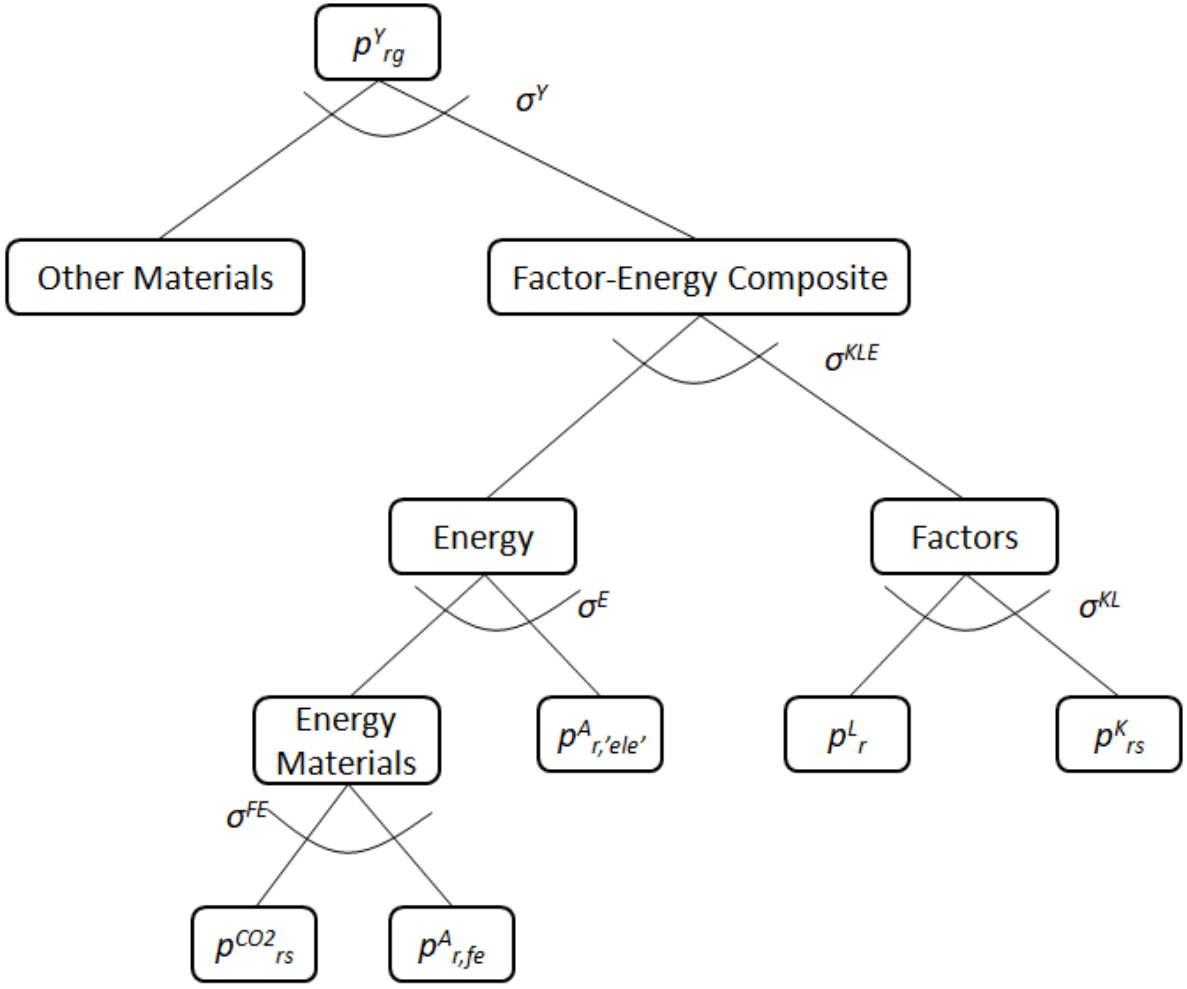
**Application:** Study the effectiveness of state level interest in climate action. Scope for subnational climate policies: AB-32, RGGI, past attempts, State Alliance, Climate Mayors, Carbon Tax Center report. Limited ability to impose border measures between one another. Carbon leakage will determine effectiveness of state level action in reducing national emissions.

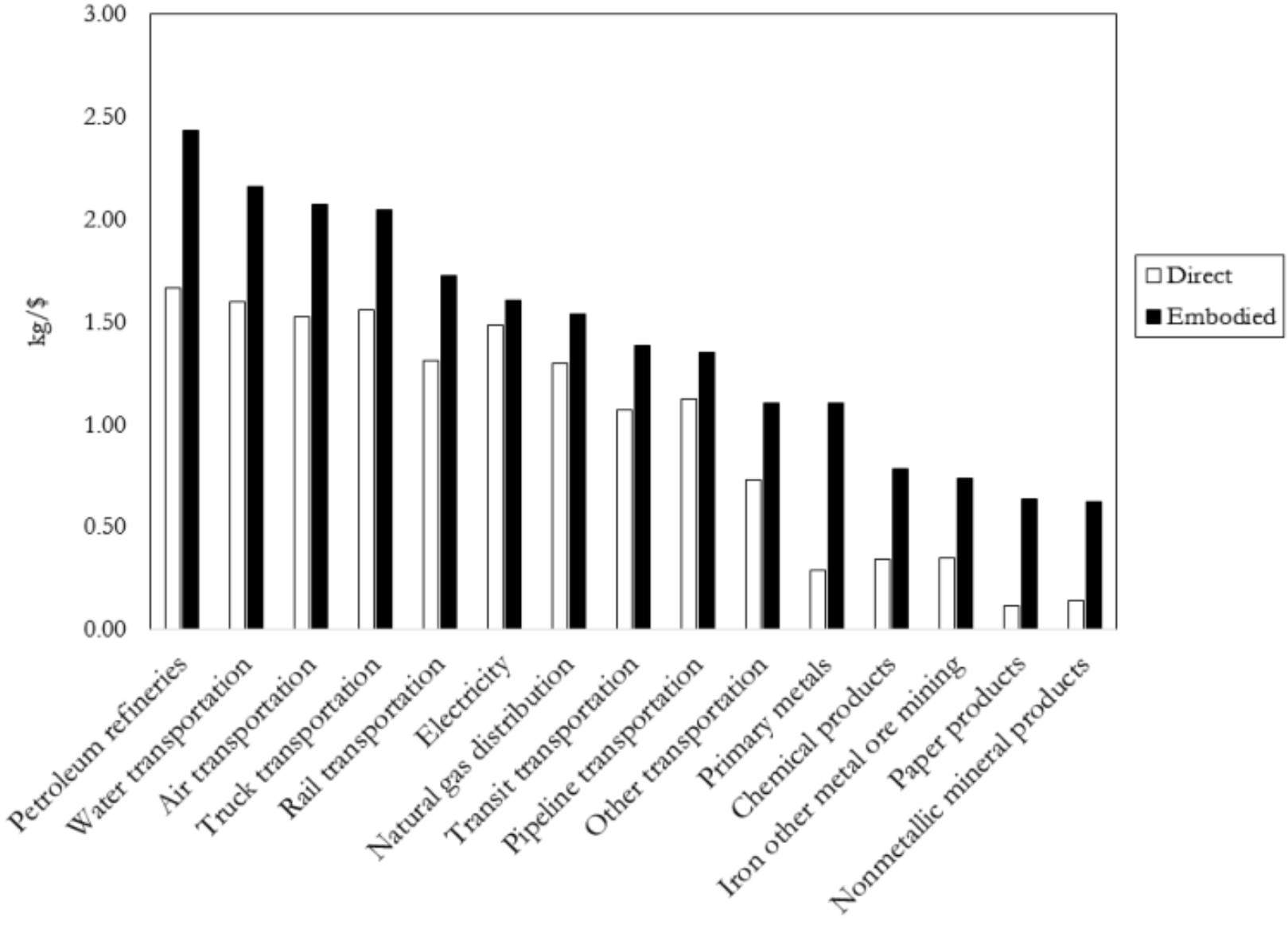
| Name | Description | Included States |
|---|---|---|
| *CA* | California | CA |
| *RGGI* | Regional Greenhouse Gas Initiative States | CT, DE, MA, MD, ME, NH, NY, RI, VT |
| *CA-RGGI* | California and RGGI States | CA, CT, DE, MA, MD, ME, NH, NY, RI, VT |
| *History* | States with a history of attempted climate action | CA, CT, DE, MA, MD, ME, NH, NY, RI, VT, WA, OR |
| *State Alliance* | States with attempted past action and those in the State Alliance | CA, CT, DE, MA, MD, ME, NH, NY, RI, VT, WA, OR, CO, HI, MN, NJ, NC, VA |
| *Carbon Center* | States with attempted past action those in the State Alliance, or those deemed with some potential or challenging per the Carbon Tax Center's report | CA, CT, DE, MA, MD, ME, NH, NY, RI, VT, WA, OR, CO, HI, MN, NJ, NC, VA DC, FL, NM, MI, NV, WI, AR, SC |
| *Climate Mayor* | States with attempted past action, in the State Alliance, in the Carbon Tax Center report, or have at least 20% of their population in cities with mayors joining Climate Mayors | CA, CT, DE, MA, MD, ME, NH, NY, RI, VT, WA, OR, CO, HI, MN, NJ, NC, VA, DC, FL, NM, MI, NV, WI, AR, SC TX, AZ, TN, AK |

# Flexible Functional Form

Re-arranging energy based inputs, we can tailor the production function for non energy sectors to match KLEM based technologies.



# Embodied Carbon



# Sectoral Aggregation

Sectoral aggregation is determined through embodied carbon calculation.

*Table 18: Sectoral Aggregation*

| Symbol | Description |
|---|---|
| *oil* | Petroleum refineries |
| *cru* | Crude oil extraction |
| *gas* | Natural gas extraction |
| *col* | Coal mining |
| *ele* | Electric power generation, transmission, and distribution |
| *trn* | Transportation |
| *pmt* | Primary metals |
| *con* | Construction |
| *eint* | Energy/Emission intensive sectors (embodied carbon > .45 kg per $) |
| *omnf* | Other manufacturing sectors |
| *osrv* | Other services |
| *roe* | Rest of the economy |

**Considered Policies:** Computed percentage changes in emissions levels and welfare for each state depending on different configurations of states reducing state level emissions by 20%. Policies differ by:

- bilateral trade flows
- permit trade
- production structure

# Gravity trade, KLEM production (Top Emis. Increases)

| | | CA | | RGGI | | CA-RGGI | | State Alliance | |
|---|---|---|---|---|---|---|---|---|---|
| | | *No Trade* | *Trade* | *No Trade* | *Trade* | *No Trade* | *Trade* | *No Trade* | *Trade* |
| **Emissions** | *Oklahoma* | 8.4 | 8.4 | 7.8 | 7.7 | 8.5 | 8.4 | 9.8 | 9.6 |
| **(% Change)** | *New Mexico* | 6.6 | 6.6 | 6.4 | 6.3 | 7.4 | 7.3 | 8.2 | 7.9 |
| | *Wyoming* | 3.3 | 3.3 | 3.1 | 3.1 | 3.3 | 3.3 | 1.5 | 0.4 |
| | *Idaho* | 0.1 | 0.1 | 3.1 | 2.8 | 3.5 | 3.3 | 5.1 | 4.4 |
| | *Kansas* | 2.3 | 2.3 | 1.2 | 1.2 | 2.0 | 1.9 | 0.6 | 0.4 |
| | *Alaska* | 1.3 | 1.3 | 1.4 | 1.4 | 1.6 | 1.6 | 1.5 | 1.6 |
| | *Utah* | 1.5 | 1.5 | 1.7 | 1.6 | 1.6 | 1.6 | 0.4 | 0.2 |
| | *Mississippi* | 1.0 | 1.0 | 0.9 | 0.8 | 1.0 | 1.0 | -0.7 | -0.9 |
| | *Minnesota* | 0.5 | 0.5 | 0.2 | 0.2 | 0.7 | 0.7 | -20.0 | -24.9 |
| | *Total* | -1.1 | -1.1 | -1.1 | -1.1 | -2.3 | -2.3 | -4.5 | -4.5 |
| **Leakage (%)** | | 12.4 | 12.4 | 22.1 | 21.3 | 15.9 | 15.6 | 10.8 | 10.2 |

# Pooled market, KLEM production (Top Emiss. Increases)

| | | CA | | RGGI | | CA-RGGI | | State Alliance | |
|---|---|---|---|---|---|---|---|---|---|
| | | *No Trade* | *Trade* | *No Trade* | *Trade* | *No Trade* | *Trade* | *No Trade* | *Trade* |
| **Emissions** | *Oklahoma* | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 |
| **(% Change)** | *New Mexico* | 0.3 | 0.3 | 0.6 | 0.6 | 0.9 | 0.9 | 1.5 | 1.5 |
| | *Wyoming* | 0.5 | 0.5 | 1.4 | 1.3 | 2.2 | 2.2 | 4.8 | 4.6 |
| | *Idaho* | 0.8 | 0.8 | 3.5 | 2.7 | 4.2 | 3.9 | 5.8 | 5.1 |
| | *Kansas* | 0.2 | 0.2 | 0.1 | 0.1 | 0.3 | 0.3 | 0.4 | 0.4 |
| | *Alaska* | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.5 | 0.5 |
| | *Utah* | 0.2 | 0.2 | 0.3 | 0.3 | 0.5 | 0.5 | 0.8 | 0.8 |
| | *Mississippi* | 0.8 | 0.8 | 1.9 | 1.8 | 2.9 | 2.9 | 4.9 | 4.7 |
| | *Minnesota* | 0.3 | 0.3 | 0.6 | 0.6 | 1.0 | 1.0 | -20.0 | -23.0 |
| | *Total* | -1.1 | -1.1 | -0.9 | -0.9 | -2.0 | -1.9 | -3.9 | -3.9 |
| **Leakage (%)** | | 18.2 | 18.2 | 39.0 | 36.7 | 27.5 | 27.6 | 22.1 | 21.5 |

# General Results:

- Leakage rates range from 4-75% depending on modeling assumptions. Canonical production without energy substitution lead to higher leakage rates.
- Policies with more states imposing climate policies have lower leakage rates. The highest calculated leakage rates are for the standalone California case or RGGI states.
- Bilateral trade allows us to "link" each region more realistically relative to a model with a pooled national market. Provides more realistic welfare costs. There are winners and losers depending on which states impose policies and their corresponding linkages.
- More comprehensive analysis should consider sensitivity tothings like: better representation of electricity sector, revenue recycling, trade elasticities/models.

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# Integration for specific policy analysis

Aside from SEDS:

NASS (National Agricultural Statistical Survey): data recalibrated to match agricultural census data on the market value of sales.

USGS (United States Geological Survey): blueNOTE (energy-economy dataset) integrated with water withdrawal data across all sectors and states. Power production fuel use paired with cooling technologies for water-energy nexus calculations.

GTAP (Global Trade and Analysis Project): blueNOTE sectors aggregated to the GTAP aggregation and recalibrated to match import and export totals. State disaggregation of bilateral trade to other countries is based on USA Trade Online data. Would provide state level distributional effects of national trade policy.

# GTAP Integration

- Mapping from BEA sectoring scheme to GTAP sectors.
- Comparing trade totals from 2011, core blueNOTE data have a 0.9 correlation coefficient across imports and exports with GTAP data. E.g. raw imports and exports are already *close* to GTAP totals.
- To enforce consistency between datasets, blueNOTE is recalibrated to match national import and export totals for the United States in GTAP. State level disaggregation of these imports and exports on origin/destination country in the GTAP database achieved using data from USA Trade Online.

# Current/Future work

Disaggregate single regional household representative agent account. *Plan:* American Community Survey provides income groups for households at the state level (PUMS). Household elasticities can be estimated using access to individual level Census data at Wisconsin.

Further regional disaggregation. *Plan:* BEA reports metro gross product. County business patterns and NASS.

Representation of a dataset with bilateral trade flows between Canadian provinces and US states

# Current/Future work

Further development of trade. *Plan:* Team up with Ed Balistreri (Iowa State University) for expertise on trade modeling and data creation.

Documentation and training materials.

Get students and other users without GAMS licenses access to the data and build stream. *Plan:* Julia/Jump (alternative free optimization software). NEOS – free optimization server housed at Wisconsin. Data set construction and reconciliation tools based on commercial modeling language, yet this should not restrict access for non-commercial users.

Thanks! For any questions or comments, email me at:

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