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Estimating Local Economies for Infrastructure Studies

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Agenda

Aims & Scope

- Why do we need to research the estimation of fine scale data for local economies?

Models & Data of Local Economies

- The most common problems of existing approaches and a possible solution

Infrastructure - Economy Interfaces

- How to connect local economies with local infrastructure, water and power

Applications

- Some possible applications

Aims & Scope

The starting point

- Knowing regional economic data is fundamental for researching infrastructure:
    - Value, cost-benefit analyses
    - Resilience, hardening, expansion
    - Economic development
    - National, energy security

- Representing dynamics happening within and between regional economies, and about how shocks propagate from infrastructure to industries and back is important too

- Infrastructure is usually considered “just” an economic sector, but it is different both within and on impacts

What do we need?

- We need **regional input-output tables and domestic** (inter-regional) **trade flows**
- Regional input–output tables and trade flows are rarely observed and they must be estimated using up-to-date information
- Estimation approaches vary widely but consider tables and flows independently
- We need a **quantitative interface between infrastructure and the local economy**
- This is usually *ad hoc* and weakly based on quantitative measures, not scaled to regions

Aims

- We want to verify if different approach based on a joint estimation method is possible and accurate

regional i-o tables + trade flows between regions

- We want to investigate whether it is possible deriving “standard” quantitative Infrastructure/Economy interfaces that allow accurately modeling shock propagation from the infrastructure to the economy

quantitative interface from infrastructure to industries

Models & Data of Local Economies

Established methods

- Start form National I-O tables, then regionalize them
- Most of the methods used to regionalize IO tables, whether non-survey methods, hybrid methods, or ready-made or short-cut techniques, have some common features:
  - they rely on national IO tables and regional-level labor market data
  - they are based on two main theoretical assumptions: (1) that regional and national technologies are very much similar; and (2) that customers have very similar preferences within a nation
  - they are implemented using a similar procedure

Standard regionalization procedure - 1

- Compute direct coefficients of the most recent national IO table at disposal

- Using one of the many variants of the approach of location quotients (LQs), for each industry compute an LQ-based measurement

- If the measurement points out that the industry is relatively smaller at the regional level than at the national one, the national coefficients are decreased accordingly along the row that represents the industry of focus

Standard regionalization procedure - 2

- Final demand vector estimated on homogenous preferences

- Finally, resulting regional transaction matrix must be balanced (e.g., iterative proportional fitting – RAS, cross entropy, etc.)

- Ongoing and long-lasting debate in the literature on the cons of this approach

Standard domestic trade flows approach

- The standard approach is to use gravity models

$$t_{s,ij} = Su_{s,i}^{\alpha} De_{s,j}^{\beta} Tr_{ij}^{\gamma}$$

- Data requirements may be problematic
- Behind there is the idea of preferences for non-domestic products
- Require calibration on the past and assumption of no change

Integrated approach

- Two steps of the same estimation problem:
  1. Estimate unbalanced transaction table
  2. Estimate trade flows that balance tables

- The first step is a constrain for the second

Details on unbalanced regional tables

- The regional transactions table is filled with intermediate demand for each industry (and in each industry) using the supply ratio (region/nation), and with value added, determining the total regional supply

- The net regional demand of final goods is estimated with income ratio

- Regional imports from and exports to foreign countries can be also estimated using these two approaches: exports by the first step, imports as in the second step

Details on domestic trade flows estimation

- For each region *i* and for each sector:

$$\begin{aligned}
\min_{d} \quad & \sum_{j=0}^{N} t_{ji} d_{ji} \\
\text{s.t.} & \sum_{j=0}^{N} d_{ij} = S_i, \quad \forall\, i \\
& \sum_{j=0}^{N} d_{ji} = D_i, \quad \forall\, i \\
& d_{ji} \geq 0, \quad \forall\, i, j
\end{aligned}$$

- Sequential decision making (cross-hauling) in a random order and without coordination and competition.

Necessary data for US counties estimation

- National supply and make tables (BEA – summary level 65/67 industries)

- Employment data, Quarterly Census of Employment and Wages (BLS)

- County to county transport cost (results from impedance minimization in the intermodal transportation network by Oak Ridge National Lab – 1 highway mile as impedance unit)

Evaluation of estimated regional tables

Table 2. Comparison of type I multipliers in the state of Washington, 2007.

Office of Financial Management (OFM) sectors	US Bureau of Economic Analysis (BEA) sectors (summary level)	OFM multiplier	Integrated approach multiplier
Crop Production; Animal Production	Farms	1.391	1.486
Forestry and Logging; Fishing, Hunting, and Trapping	Forestry – Fishing – and Related Activities	1.516	1.344
Mining	Mining	1.456	1.050
Electric Utilities; Gas Utilities; Other Utilities	Utilities	1.363	1.287
Highway and Street Construction; Other Construction	Construction	1.464	1.404
Food, Beverage and Tobacco Manufacturing	Food and Beverage and Tobacco Products	1.470	1.485
Textiles and Apparel	Textile Mills and Textile Product Mills; Apparel and Leather and Allied Products	1.384	1.142
Wood Product Manufacturing	Wood Products	1.734	1.486
Paper Manufacturing	Paper Products	1.439	1.497
Printing	Printing and Related Support Activities	1.361	1.165
Petroleum and Coal Products	Petroleum and Coal Products	1.238	1.408
Chemical Manufacturing	Chemical Products	1.236	1.117
Nonmetallic Mineral Products Manufacturing	Nonmetallic Mineral Products	1.276	1.239
Primary Metals	Primary Metals	1.469	1.260
Fabricated Metals	Fabricated Metal Products	1.361	1.124
Machinery Manufacturing	Machinery	1.454	1.138
Computer and Electronic Product	Computer and Electronic Products	1.479	1.334
Electrical Equipment	Electrical Equipment – Appliances – and Components	1.317	1.181
Aircraft and Parts; Ship and Boat Building; Other Transportation	Motor Vehicles – Bodies and Trailers – and Parts; Other Transportation Equipment	1.136	1.778
Furniture	Furniture and Related Products	1.342	1.266
Other Manufacturing	Miscellaneous Manufacturing; Plastics and Rubber Products	1.399	1.189
Wholesale	Wholesale Trade	1.204	1.154
Non-Store Retail; Other Retail	Retail Trade	1.194	1.214
Air Transportation	Air Transportation	1.367	1.367
Water Transportation	Water Transportation	1.470	1.573
Truck Transportation	Truck Transportation	1.483	1.286
Other Transportation/Postal Offices	Rail Transportation; Transit and Ground Passenger Transportation; Pipeline Transportation	1.465	1.272
Support Activities for Transportation, Warehousing and Storage	Other Transportation and Support Activities; Warehousing and Storage	1.527	1.206
Software Publishers and Internet Service Providers	Publishing Industries (includes Software)	1.208	1.482
Telecommunications	Broadcasting and Telecommunications	1.442	1.459
Other Information	Motion Picture and Sound Recording Industries; Information and Data Processing Services	1.126	1.206
Credit Intermediation and Related Activities	Federal Reserve Banks – Credit Intermediation – and Related Activities	1.605	1.233
Other Finance and Insurance	Securities – Commodity Contracts – and Investments; Insurance Carriers and Related Activities; Funds – Trusts – and Other Financial Vehicles	1.718	1.217
Real Estate and Rental and Leasing	Real Estate; Rental and Leasing Services and Lessors of Intangible Assets	1.153	1.257
Legal/Accounting and Bookkeeping/ Management Services	Legal Services; Management of Companies and Enterprises	1.108	1.185
Architectural and Engineering/ Computer Systems Design and Related Services	Computer Systems Design and Related Services; Miscellaneous Professional – Scientific – and Technical Services	1.191	1.198
Educational Services	Educational Services	1.614	1.324
Ambulatory Health Care Services	Ambulatory Health Care Services	1.491	1.250
Hospitals; Nursing and Residential Care Facilities, Social Assistance	Hospitals and Nursing and Residential Care Facilities; Social Assistance	1.395	1.282
Arts, Recreation, and Accommodation; Food Services and Drinking Places	Performing Arts – Spectator Sports – Museums – and Related Activities; Amusements – Gambling – and Recreation Industries; Accommodation	1.456	1.259
Food Services and Drinking Places	Food Services and Drinking Places	1.473	1.339
Administrative/Employment Support Services	Administrative and Support Services	1.116	1.187
Waste Management/Other, and Agriculture Services	Waste Management and Remediation Services; Other Services – except Government	1.503	1.349
	Federal General Government; Federal Government Enterprises; State and Local General Government; State and Local Government Enterprises	n.a.	1.267

(Continued)

Table 2. Continued.

Note: n.a., Not available.

Evaluation of estimated trade flows

Table 1. Domestic trade flows comparison: flows between and within 50 US states, 2002 and 2007.

No cross-hauling ↘ (t1)

Yes competition ↙ (t3)

	Average state-level trade flows (US$, millions)					R^2			
	CFS	***gm***	***t1***	***t2***	***t3***	***gm***	***t1***	***t2***	***t3***
Agriculture–Food–Forestry	394.0	116.0	265.0	605.0	280.0	.582	.860	.892	.868
Chemical Products	300.0	115.0	116.0	238.0	123.0	.160	.581	.654	.573
Electronic and Electrical Products	298.0	193.0	103.0	174.0	110.0	.529	.755	.713	.738
Fabricated Metal Products	105.0	63.7	58.7	180.0	62.3	.378	.632	.830	.643
Furniture and Related Products	43.0	33.1	25.3	52.7	27.5	.464	.417	.645	.502
Machinery	184.0	127.0	57.3	142.0	61.3	.476	.535	.733	.638
Mining – Except Oil and Gas	13.7	7.2	34.0	46.7	35.0	.152	.272	.294	.302
Motor Vehicles – Bodies and Trailers – and Parts	249.0	156.0	112.0	235.0	118.0	.488	.468	.639	.441
Nonmetallic Mineral Products	54.2	26.2	25.7	68.5	27.2	.353	.737	.826	.743
Oil–Gas–Coal – and Products	321.0	84.5	325.0	374.0	340.0	.570	.762	.835	.743
Other Transportation Equipment	20.3	28.5	43.6	91.8	45.5	.141	.110	.368	.125
Paper Products	72.5	46.6	45.0	85.3	48.7	.432	.593	.803	.696
Plastics and Rubber Products	141.0	95.6	55.4	112.0	58.0	.292	.546	.686	.623
Primary Metals	126.0	92.7	60.7	127.0	65.9	.502	.770	.844	.812
Printed Products	48.0	33.9	24.6	67.6	26.2	.508	.522	.702	.497
Textile and Leather Products	133.0	107.0	34.1	57.2	35.6	.377	.530	.627	.547
Wood Products	56.9	31.8	33.7	65.4	35.3	.466	.687	.843	.701
All industries	151.0	80.0	83.5	160.0	88.2	.319	.680	.735	.680

Summary of the integrated approach

- Pros:
  - The aggregation of results in step 1 and 2 (unbalanced tables + trade flows) provide perfectly balanced tables
  - The assumptions are the same as for other regionalization of tables, homogeneity of technology and preferences, and less for trade flows (only minimization of transport cost)
  - Scalability
  - Integration of detailed local knowledge benefits the entire set of estimations

- Cons:
  - Computational weight

Infrastructure/Economy Interfaces: water and power

Infrastructure/Economy interfaces

- Must be:
  - By infrastructure
  - At the regional scale
  - Taking advantage of available data

- Aims at quantifying the relationship between the physical service provided by the infrastructure and the economic value that depends on it (not its price!)

- Supports the investigation of a) infrastructure; b) events; and c) scenarios of sustainable economic growth, changing natural hazards

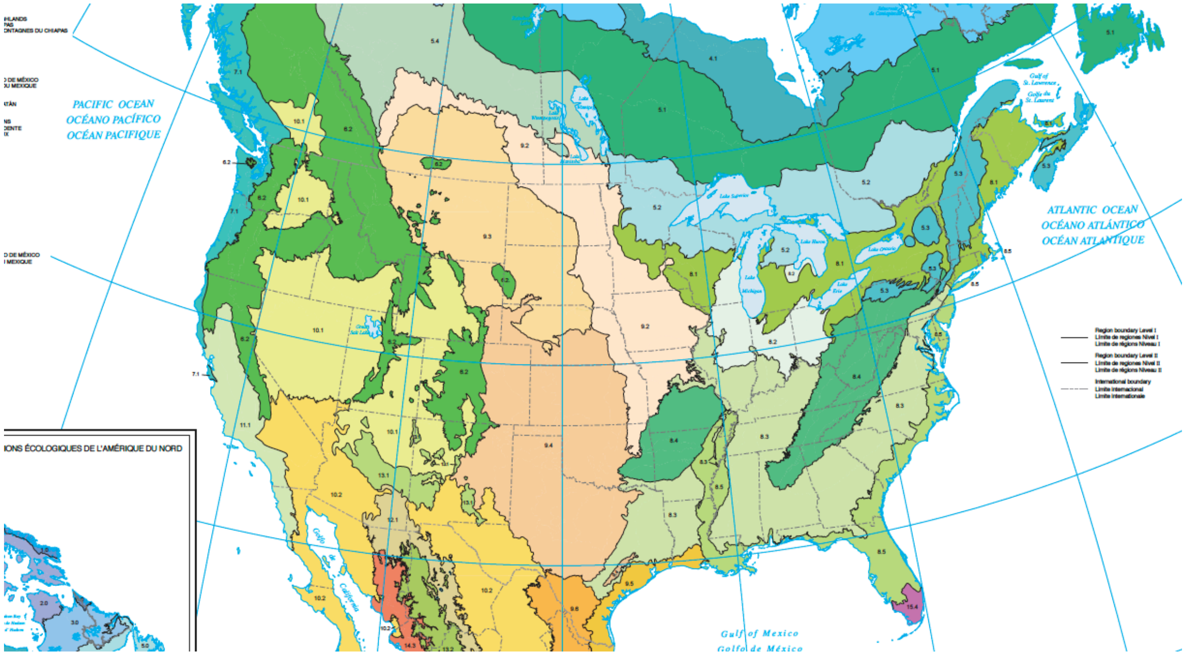
Water coefficients: state of the art

- Most are case studies
- Often use life cycle inventories
- Limited to a few industries
- The few exceptions are at the national level (regional heterogeneity is due to the economy only)
- Some of these latter use utility industry information of I/O tables for estimating water coefficients

- I.E., limited in terms of data used, time (not replicable or too expensive to replicate), space (either national or for a small case study), and level of industrial detail

Water coefficients: our approach

- Aggregate USGS Water Use survey information in a meaningful and consistent way, county level, annual
- Relate water uses with economic value
- Use non linear regression approaches to estimate coefficients for EPA level II ecological regions



Water coefficients and withdrawals

- Ecological region coefficients can be transformed to coefficients for any administrative unit

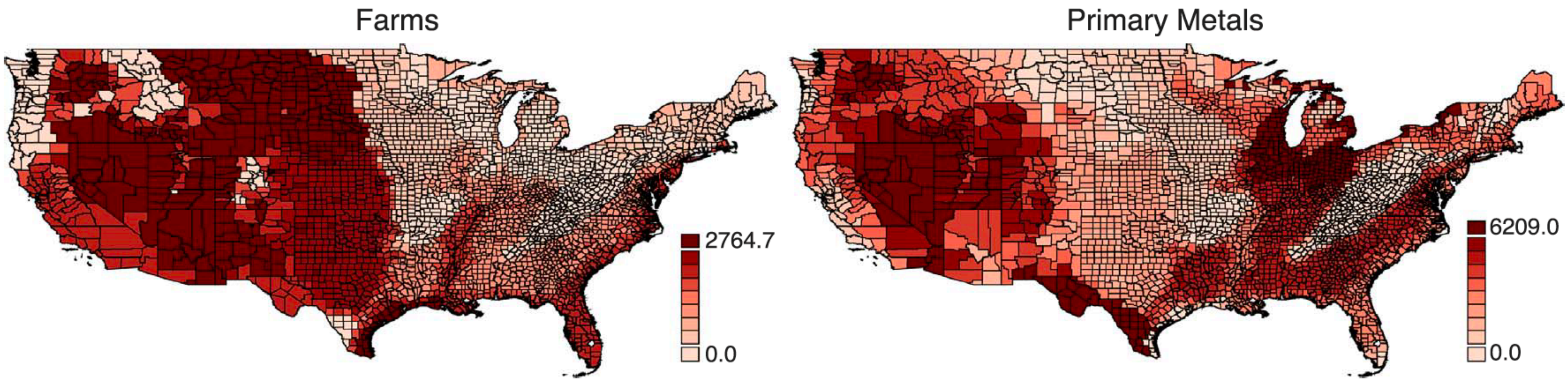


Fig. 1. Estimated county level water coefficients (water gal per GDP $) for the sectors "farms" and "primary metals".

Evaluation of regional water coefficients

- Computing total water withdrawals at the county level (for the USGS comparison), our approach is +68% more accurate than national water coefficients (IO method), and +39% than the national GDP regression method

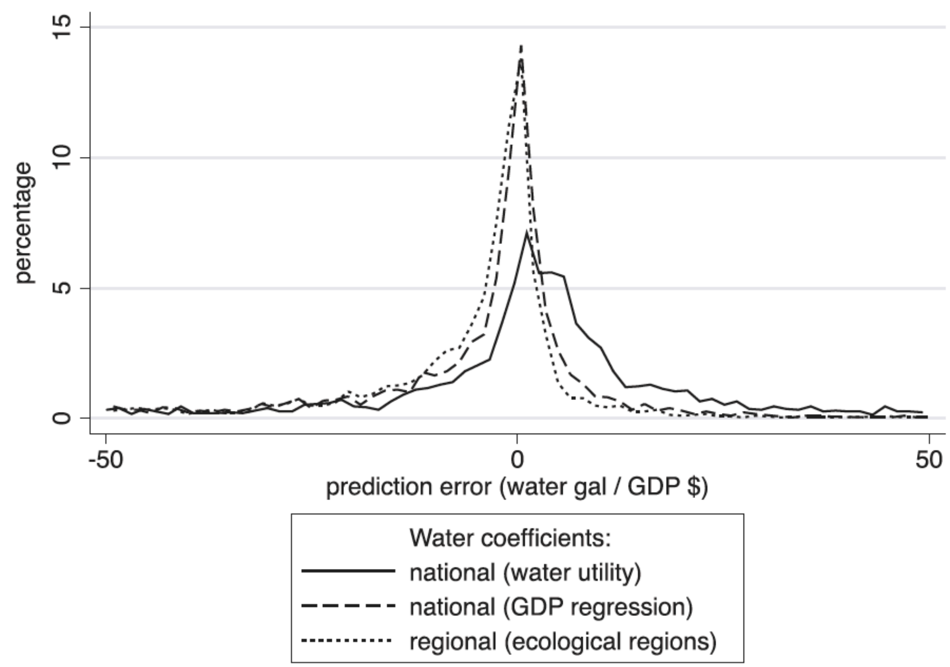


Fig. 2. Distribution of the prediction error of county level total water withdrawals by dollar of GDP.

Evaluation of regional water coefficients

- What is the impact for regional analyses?
- The Moran's I measure of global spatial autocorrelation of the prediction error for contiguous counties and with regional coefficients is -12.4% of national approaches

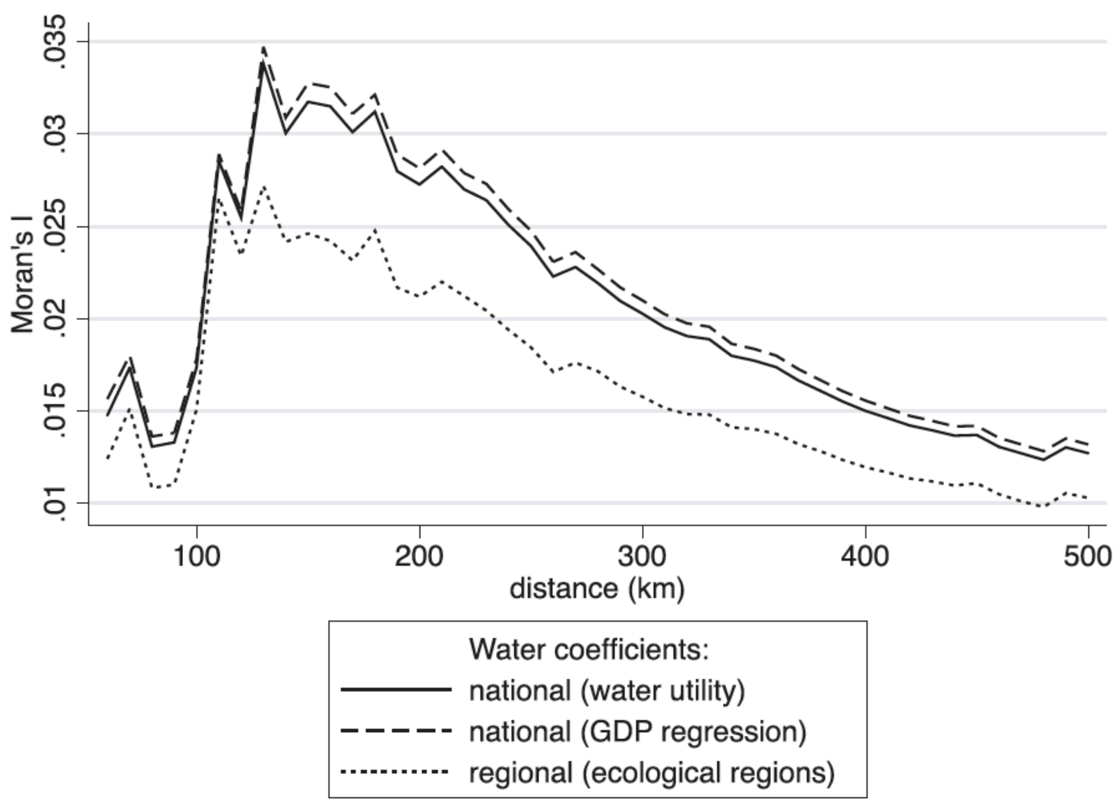


Fig. 3. Moran's I measure of global spatial autocorrelation over distance between counties.

Electric power consumption coefficients

- Form EIA-826 “Monthly Electric Utility Sales and Revenue Report with State Distributions” provide sales of electric power from a statistically chosen sample of electric utilities
- Data are published monthly for each state and for four macro sectors.
- Within each macro-sector we compute single industry e.p. coefficients using input-output information relative to the “electric utility” industry and the relative macro sector

$$c_{i,k}^{t} = \frac{P_{i,k}^{t}}{GDP_{i,k}^{t}} \qquad P_{i,k}^{t} = P_{s,k}^{t} \times \frac{SU_{i,k}^{t}}{\sum_{j\in S} SU_{j,k}^{t}}$$

Evaluation of e.p. consumption coefficients

- Annual Survey of Manufacturers (ASM) by U.S. Census is based on about 50k establishments
- It measures electric power needs
- Limited to national scale and manufacturing industries

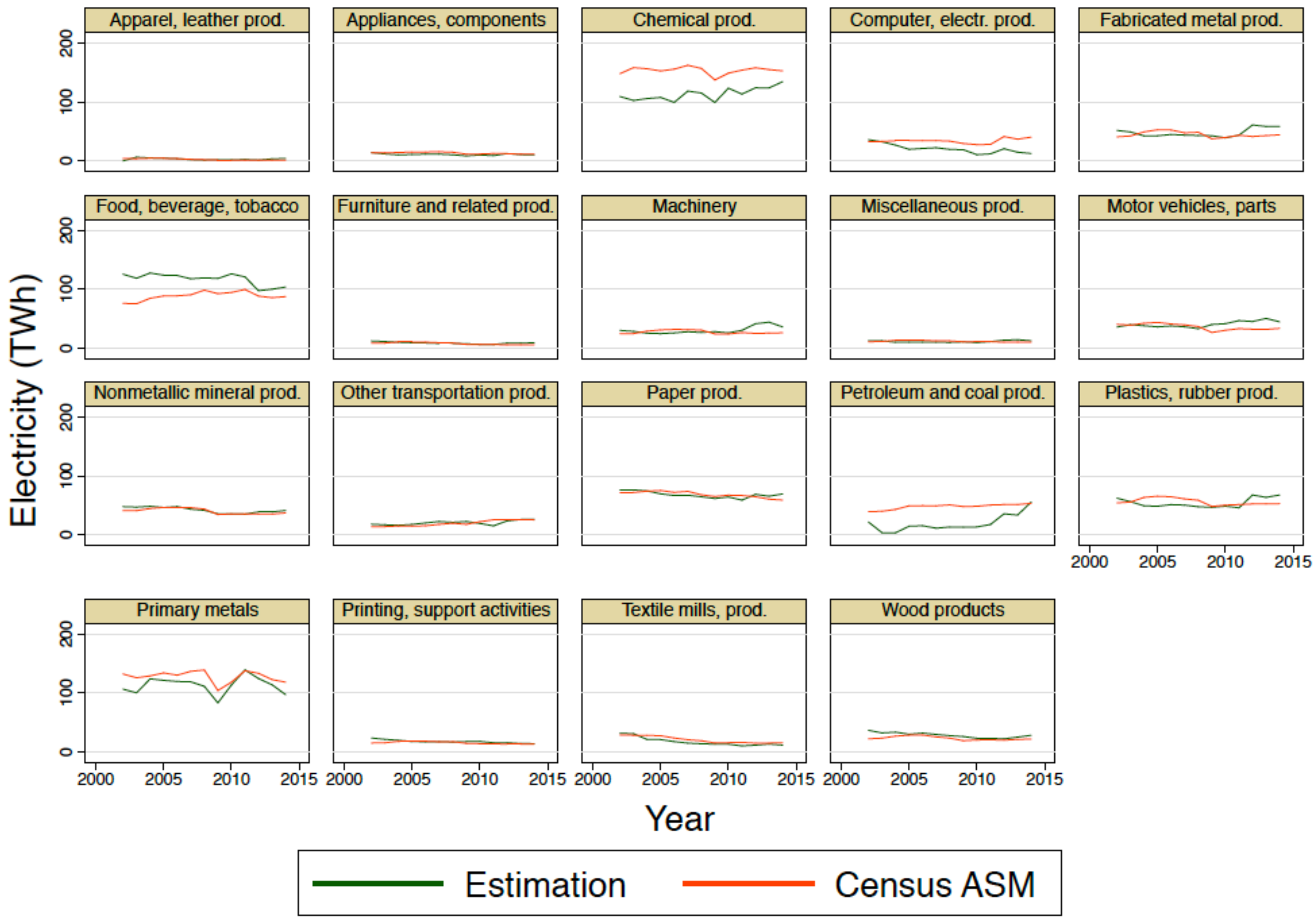


Figure 1. Annual electric power consumption in manufacturing sectors, U.S. total 2002-2014

Evaluation of e.p. consumption coefficients

- DOE EERE (2008) reports that buildings accounted for 72% of electric power used in 2005. Energy use in non-residential building has increased steadily, with a 70% increase between 1980 and 2005.
- Most energy intensive industries:
  - chemical production processes (Worrell et al. 2000)
  - the manufacturing sectors that produce food, paper, chemical, petroleum and coal products, nonmetal mineral products, and primary metals (Mukherjee 2008)

Evaluation of e.p. consumption coefficients

Table 1. Industries consuming most electric power for U.S. states (2014)

Industry	State (total consumption in TWh)
Mining, except oil and gas	NV (4.8), WV (6.2), WY (6.3)
Primary metals	IN (12.4)
Food, beverage, and tobacco products	IA (5.1)
Chemical products	LA (10.7)
Real estate	AK (0.9), AL (9.1), AR (4.0), AZ (14.7), CA (62.2), CO (10.3), CT (5.8), DC (4.8), DE (1.7), FL (50.4), GA (22.6), HI (1.5), ID (2.2), IL (24.3), KS (5.7), KY (6.6), MA (13.2), MD (16.1), ME (1.6), MI (15.6), MN (12.0), MO (12.0), MS (4.6), MT (1.7), NC (21.9), ND (1.7), NE (3.6), NH (1.7), NJ (16.7), NM (3.1), NY (46.8), OH (18.6), OK (6.6), OR (7.2), PA (17.0), RI (1.5), SC (9.8), SD (1.4), TN (14.2), TX (73.2), UT (5.2), VA (23.4), VT (0.7), WA (14.3), WI (7.7)

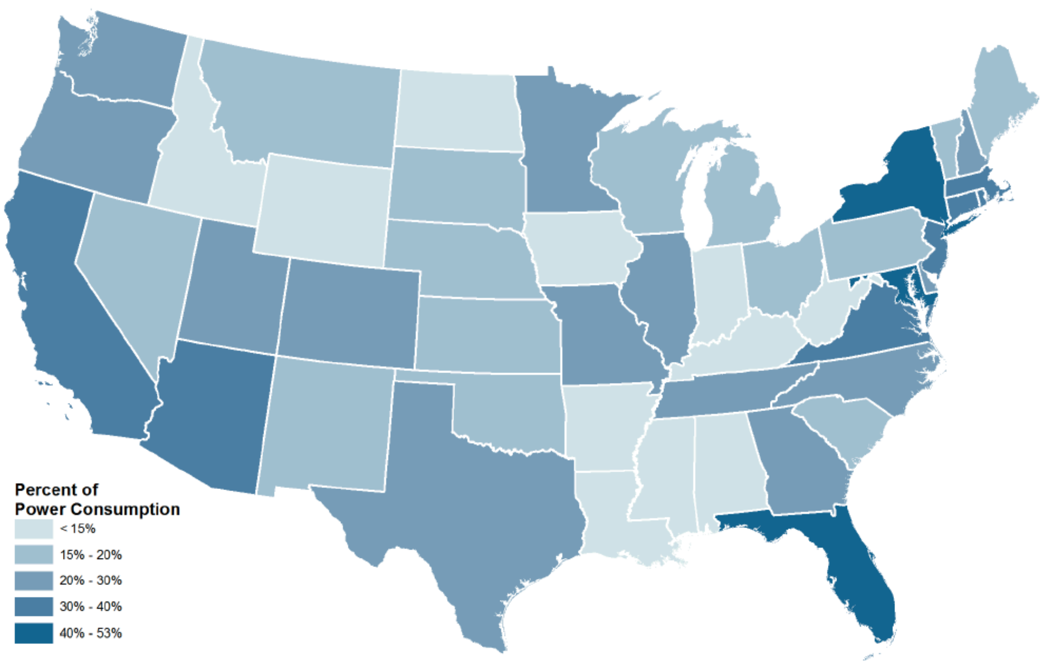


Figure 2. Percentage of non-residential electric power consumption by real estate sector in the continental United States. (2014)

- In California between 1997 and 2014:
  - –coefficients decreased on average by 0.02 kWh/$ at 2014 prices
  - –coefficients decreased in 40 industries
  - –total use has increased by 18.4 TWh
  - –total use in 35 industries decreased
- Energy efficiency, GDP growth, and retail e.p. prices explain these dynamics

Applications

Vast amount of possible applications

- Regional economic models following the I/O approach, CGE, etc.
- Analysis of cost/benefits, investments selection
- Adaptation, climate change impacts
- Natural resource management & policies
- Resilience and expansion planning

The case of large-scale extreme event: CGE modeling

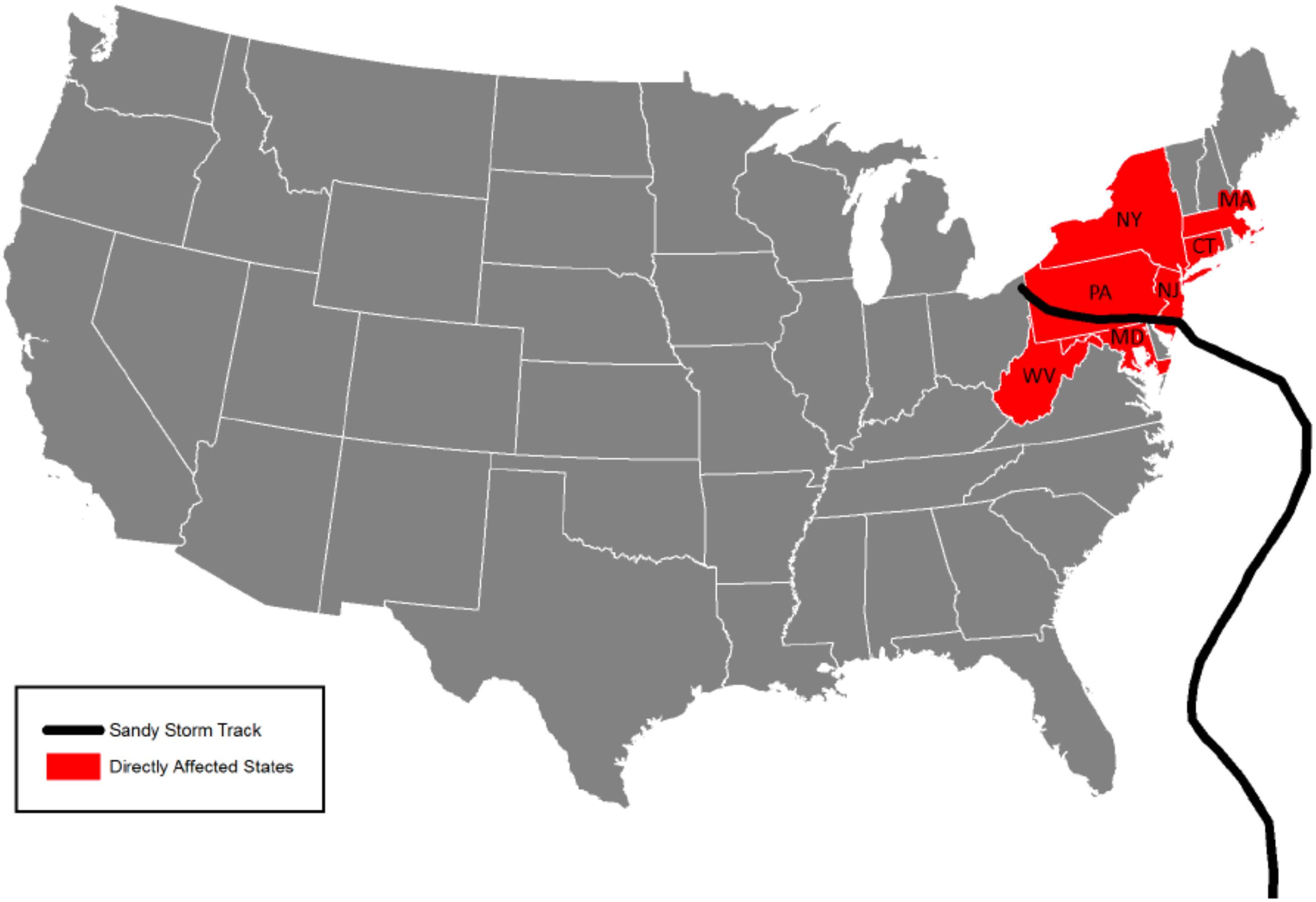


Figure 1. Hurricane Sandy center track (black) and the two regions considered: the seven states directly affected (red) and the rest of CONUS (blue).

Asset loss

- FEMA Modeling Task Force (MOTF – FEMA, 2017), New Light Technologies and ImageCat (2017) developed a comprehensive database of the buildings damaged by Hurricane Sandy
- We selected non-residential buildings through Census blocks information

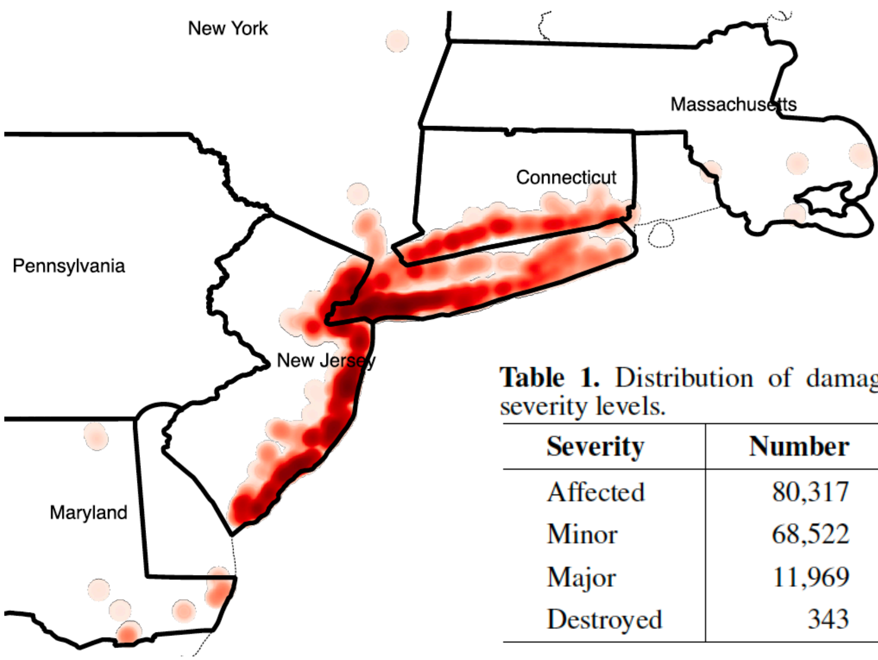


Figure 2. Spatial distribution of residential and non-residential damaged buildings (dark red indicates areas damaged buildings).

Table 1. Distribution of damaged buildings by severity levels.

Severity	Number	Percent
Affected	80,317	49.84
Minor	68,522	42.5
Major	11,969	7.43
Destroyed	343	0.21

Table 2. Annualized capital loss by industry as percentage of capital used in 2011.

Industry	Capital Loss
Agriculture, forestry, fishing, and hunting	0.46%
Mining	0.02%
Utilities	1.57%
Construction	1.64%
Manufacturing	1.18%
Wholesale trade	2.30%
Retail trade	1.03%
Transportation and warehousing	3.89%
Information	0.66%
Finance, insurance, real estate, rental, and leasing	0.99%
Professional and business services	0.83%
Educational services, health care, and social assistance	0.94%
Arts, entertainment, recreation, accommodation, and food services	1.46%
Other services, except government	1.14%
Government	0.50%

Output loss

- Knowing the power loss (EIA, 2017) and the e.p. coefficients we can estimate the business interruption for each industry in the area

Table 3. Peak of power outage.

State	**Peak Outage** Power (as percentage over total customers)
Connecticut	38.92%
Maryland	10.26%
Massachusetts	8.23%
New Jersey	66.08%
New York	26.04%
Pennsylvania	20.45%
West Virginia	26.73%

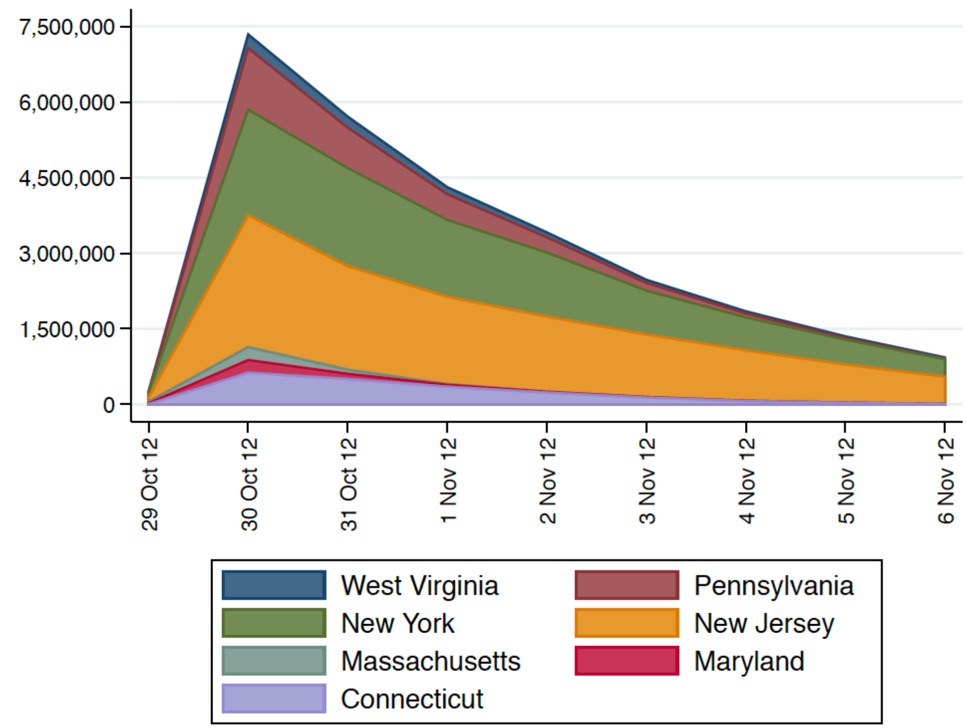


Figure 3. Customers without power by state.

Economic impacts

Table 4. Summary of Economic Impacts (billions of dollars and percent deviation from baseline).

Variable	2012	2013	2014	2015	2016
Output					
- Absolute Change	-52.77	-5.09	-4.67	-4.31	-3.94
- Percent Change	-0.83	-0.08	-0.07	-0.06	-0.05
GDP					
- Absolute Change	-31.68	-2.78	-2.43	-2.13	-1.87
- Percent Change	-0.85	-0.07	-0.06	-0.05	-0.04
Personal Consumption Expenditures					
- Absolute Change	-21.65	-2.07	-1.81	-1.59	-1.39
- Percent Change	-0.82	-0.07	-0.06	-0.05	-0.04
Investment Spending					
- Absolute Change	-2.87	-0.26	-0.23	-0.19	-0.16
- Percent Change	-0.61	-0.05	-0.04	-0.04	-0.03
Government Spending					
- Absolute Change	-7.29	-0.45	-0.39	-0.35	-0.31
- Percent Change	-0.97	-0.06	-0.05	-0.04	-0.04
Exports					
- Absolute Change	-23.48	-2.60	-2.52	-2.46	-2.33
- Percent Change	-0.82	-0.09	-0.08	-0.07	-0.07
Imports					
- Absolute Change	-23.61	-2.60	-2.52	-2.46	-2.33
- Percent Change	-0.82	-0.09	-0.08	-0.07	-0.07
Labor Expenditures					
- Absolute Change	-28.51	0.00	0.00	0.00	0.00
- Percent Change	-1.46	0.00	0.00	0.00	0.00
Capital Expenditures					
- Absolute Change	0.00	-2.87	-2.63	-2.40	-2.17
- Percent Change	0.00	-0.16	-0.14	-0.11	-0.10

Open issues

- Better data and modeling of the substitution of inputs provided by infrastructure
- Develop interfaces for other critical infrastructure sectors
- Better data for passengers' transportation cost?
- Better data for e.p. consumption?

Open projects

- Integrate monetary I/O tables with physical ones, for analyses of sustainability, circular economy, etc.
- Further downscaling of economic data to study adaptation to joint climate extremes
- Link system-level adaptation to grid-level resilience through infrastructure-level adaptation
- Integration of economic impacts with infrastructure vulnerability analyses