

The Vulnerability of the United States Economy to Electricity Price Increases

Presentation to the
Kentucky Economic Association
October 23rd, 2015

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Kentucky Energy & Environment Cabinet
502-564-7192

The White Paper this Presentation is Based on is Available Online at:

<http://1.usa.gov/1aVhOWu>

An Interactive Version of the Model is Available at:

<http://1.usa.gov/1G31BuN>

Overview

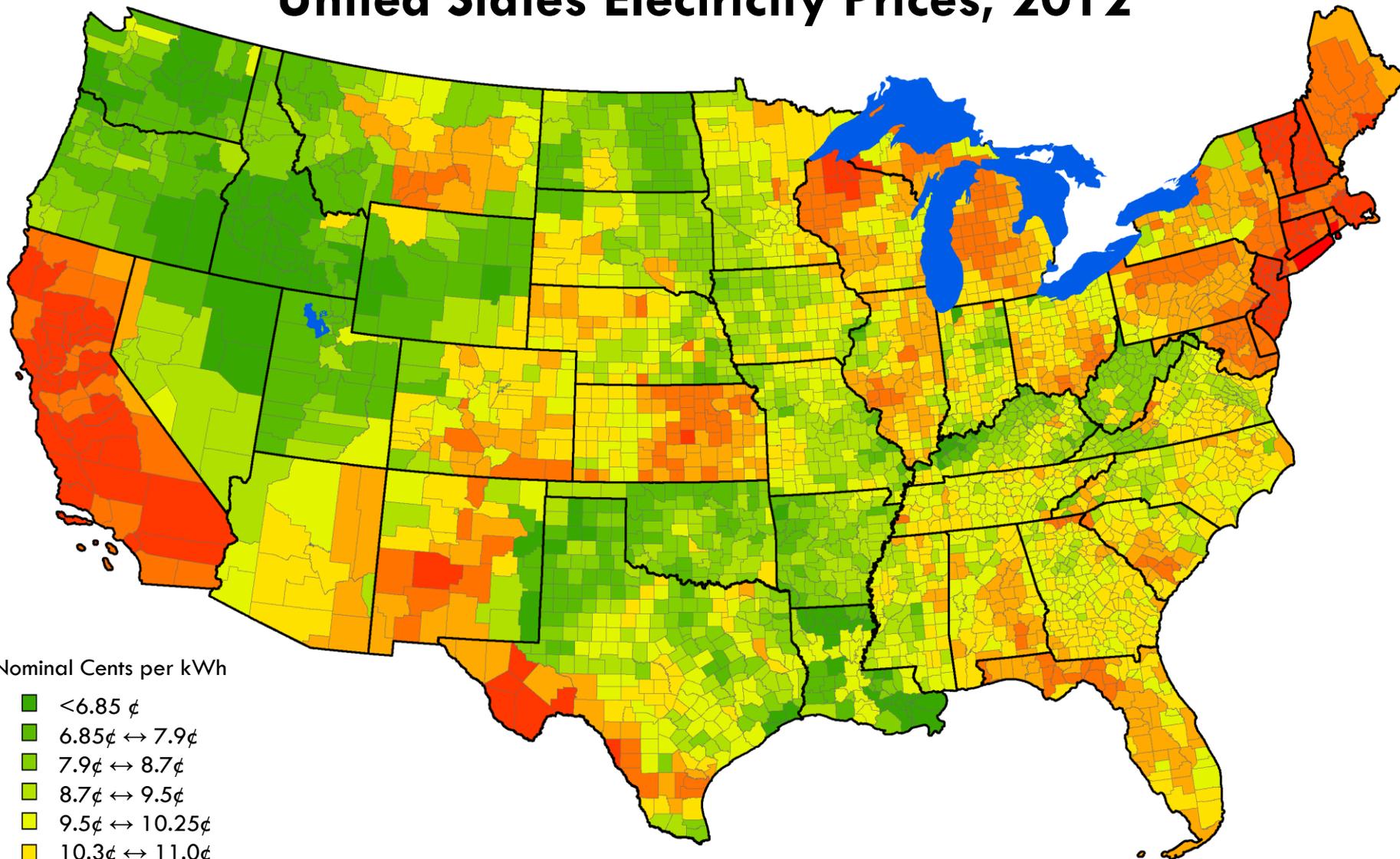
Purpose: This model estimates the implications of increasing electricity prices for economic growth, measured in terms of employment and value added by economic sector.

Findings: A hypothetical 10% increase in the real price of electricity nationally would be associated with a decrease of one million jobs and \$142 billion in Gross Domestic Product (GDP). However, impacts will vary substantially by industry, with electricity-intensive manufacturing experiencing the most-significant losses of productive capacity.

Implications: The United States Environmental Protection Agency (EPA) should incorporate economy-wide modeling of electricity price elasticity effects when evaluating the costs of proposed environmental regulations.

Statistical Modeling Details: We estimated separate multiple regression of panel data models using fixed effects by state for employment and value added for 12 specific economic sectors for a total of 24 models. Models were estimated using public data.

United States Electricity Prices, 2012



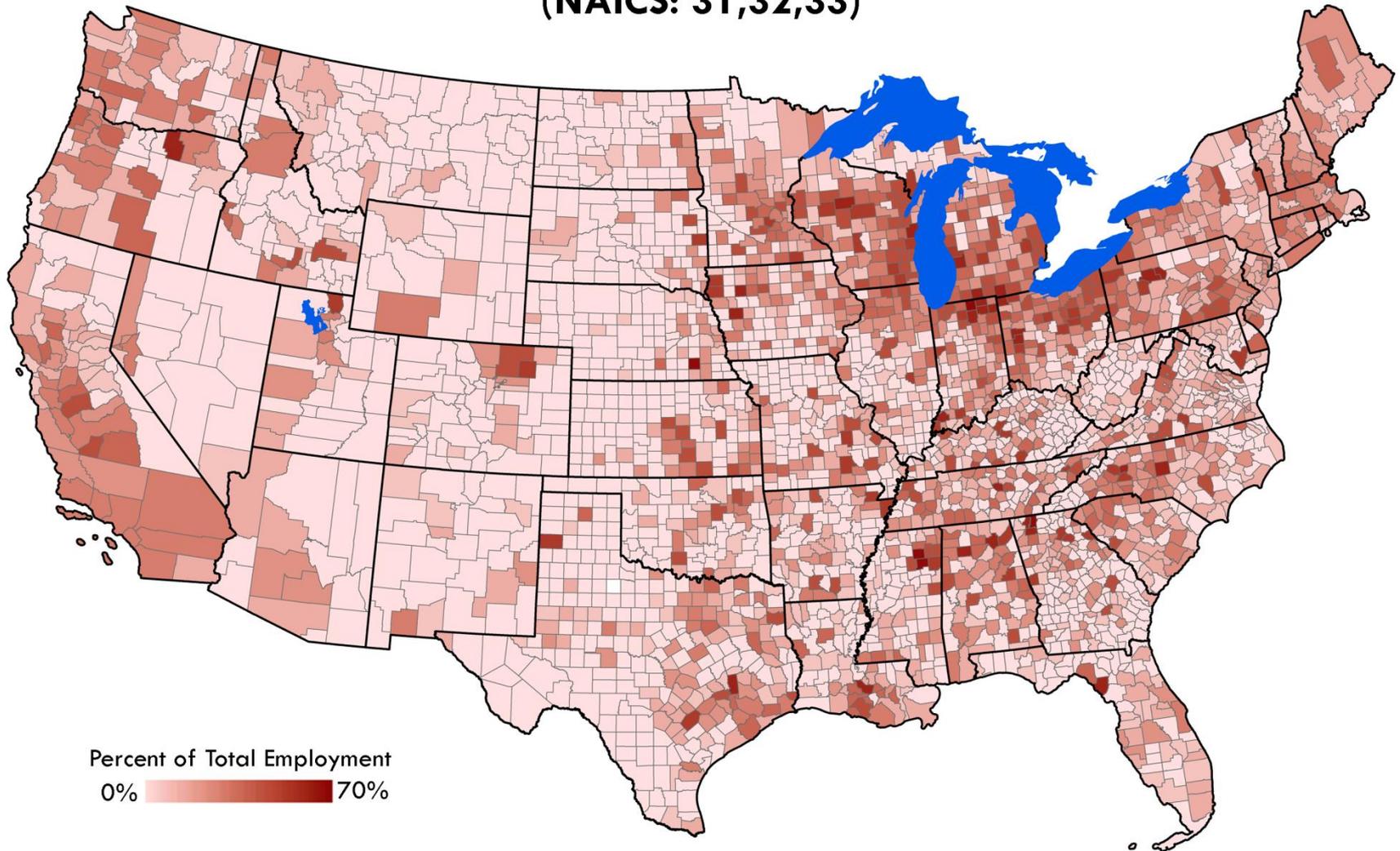
Nominal Cents per kWh

- <6.85 ¢
- 6.85¢ ↔ 7.9¢
- 7.9¢ ↔ 8.7¢
- 8.7¢ ↔ 9.5¢
- 9.5¢ ↔ 10.25¢
- 10.3¢ ↔ 11.0¢
- 11.0¢ ↔ 12.0¢
- 12.0¢ ↔ 14.0¢
- 14.0¢ ↔ 25.0¢
- 25.0¢ ↔ 55.0¢

Animated versions of these maps are online at:

<https://www.youtube.com/watch?v=QExe0zRFzFE>

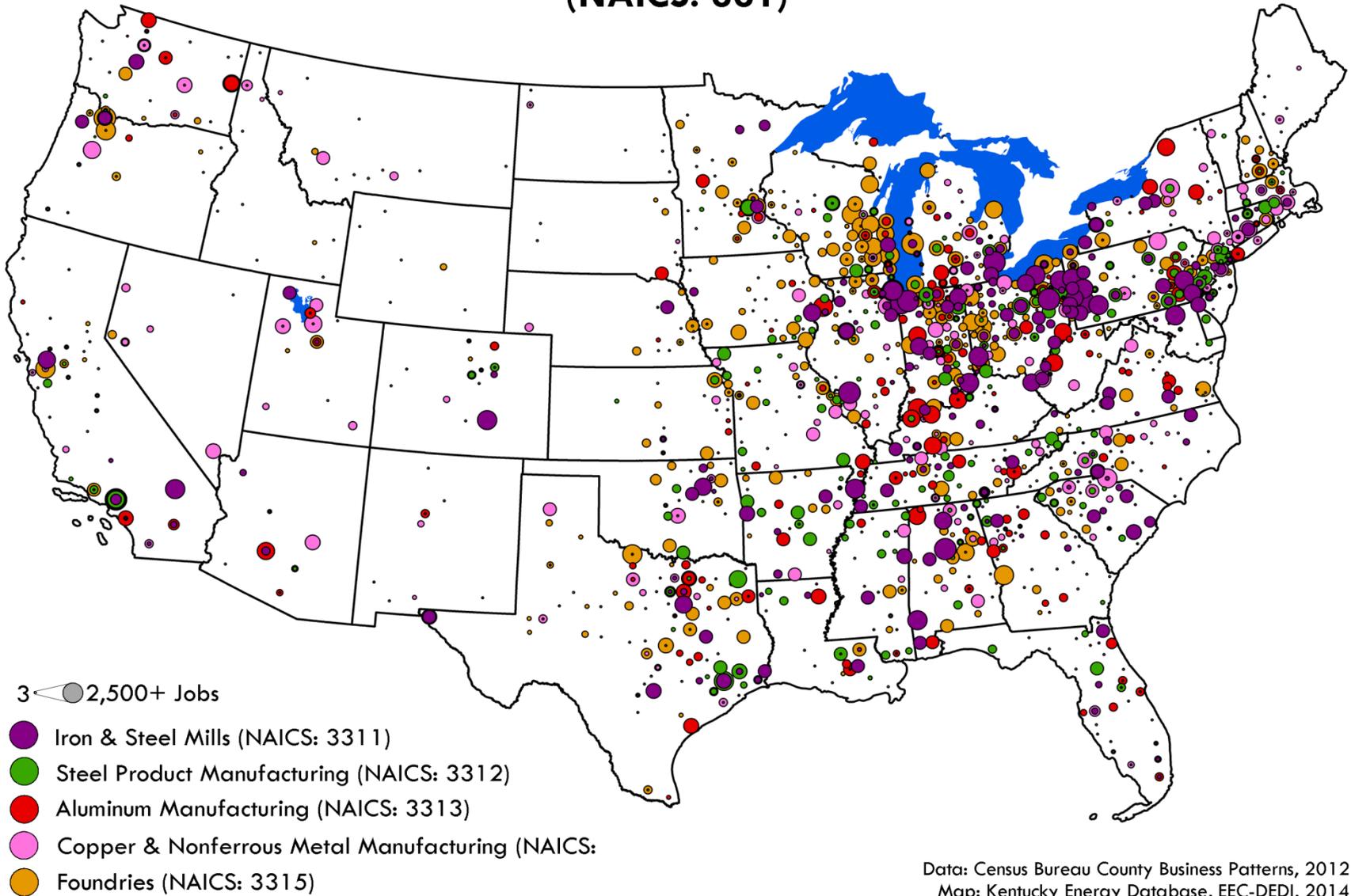
United States Manufacturing Employment as a Percent of Total, 2012 (NAICS: 31,32,33)



Percent of Total Employment
0%  70%

Data: Census Bureau County Business Patterns, 2012
Map: Kentucky Energy Database, EEC-DEDI, 2014

United States Primary Metal Manufacturing Employment, 2012 (NAICS: 331)



Data: Census Bureau County Business Patterns, 2012
Map: Kentucky Energy Database, EEC-DEDI, 2014



CENTURY ALUMINUM SEBREE LLC

SPLR ID
SPLR ASG (130) 174717525

LOT #
SERIAL # (S) 413-159-000837

ALLOY #

DIMENSIONS (INCHES)

STORAGE TAG

SEB

PRODUCED IN
KENTUCKY, USA

Century Aluminum in Sebree, Kentucky in 2015



Century Aluminum in Sebree, Kentucky in 2015



Embodied Electricity

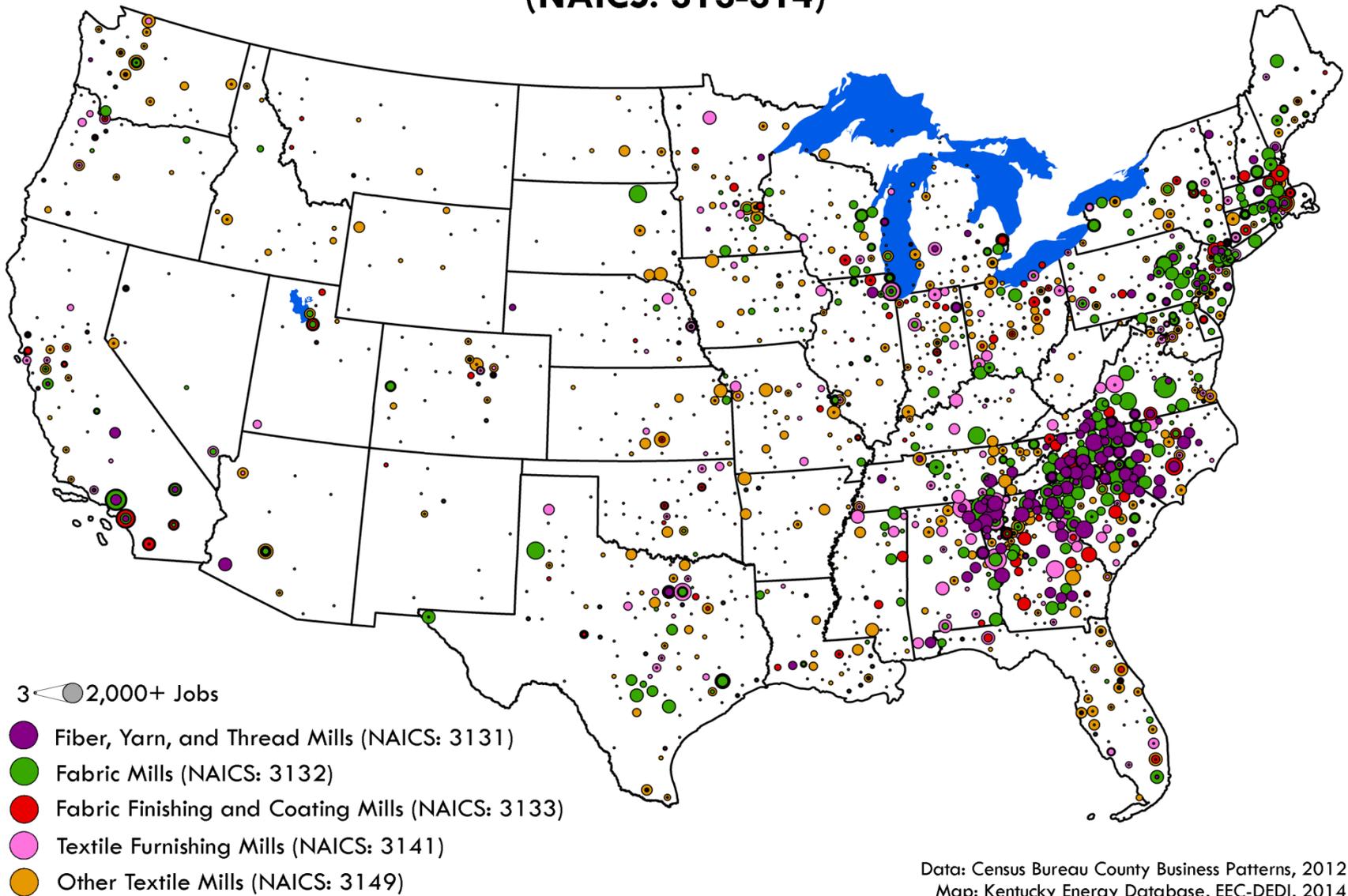
Intensity Rank	Manufacturing Sector	Kilowatt-hours per \$ of Product	Electricity Cost per \$ of Product	Percentage of Production Costs	United States Workers
1	Primary Aluminum Production	12.9	\$0.573	57.3%	8,652
2	Iron & Steel Mills	1.65	\$0.086	8.6%	100,719
5	Glass Manufacturing	0.81	\$0.055	5.5%	82,661
24	Motor Vehicle Parts	0.29	\$0.021	2.1%	101,715
52	Motor Vehicle Assembly	0.12	\$0.008	0.8%	166,937

Increasing the costs of the embodied energy of a product—the energy required to convert the raw materials into a usable product—has multiplier effects throughout the economy. Whenever the production cost of primary material inputs increases, for whatever reason, the production cost of higher value products further down the commodity chain will increase as well.

Complete List of Manufacturing Sectors on Page of 4 of the White Paper *The Vulnerability of Kentucky's Manufacturing Economy to Increasing Electricity Prices*:

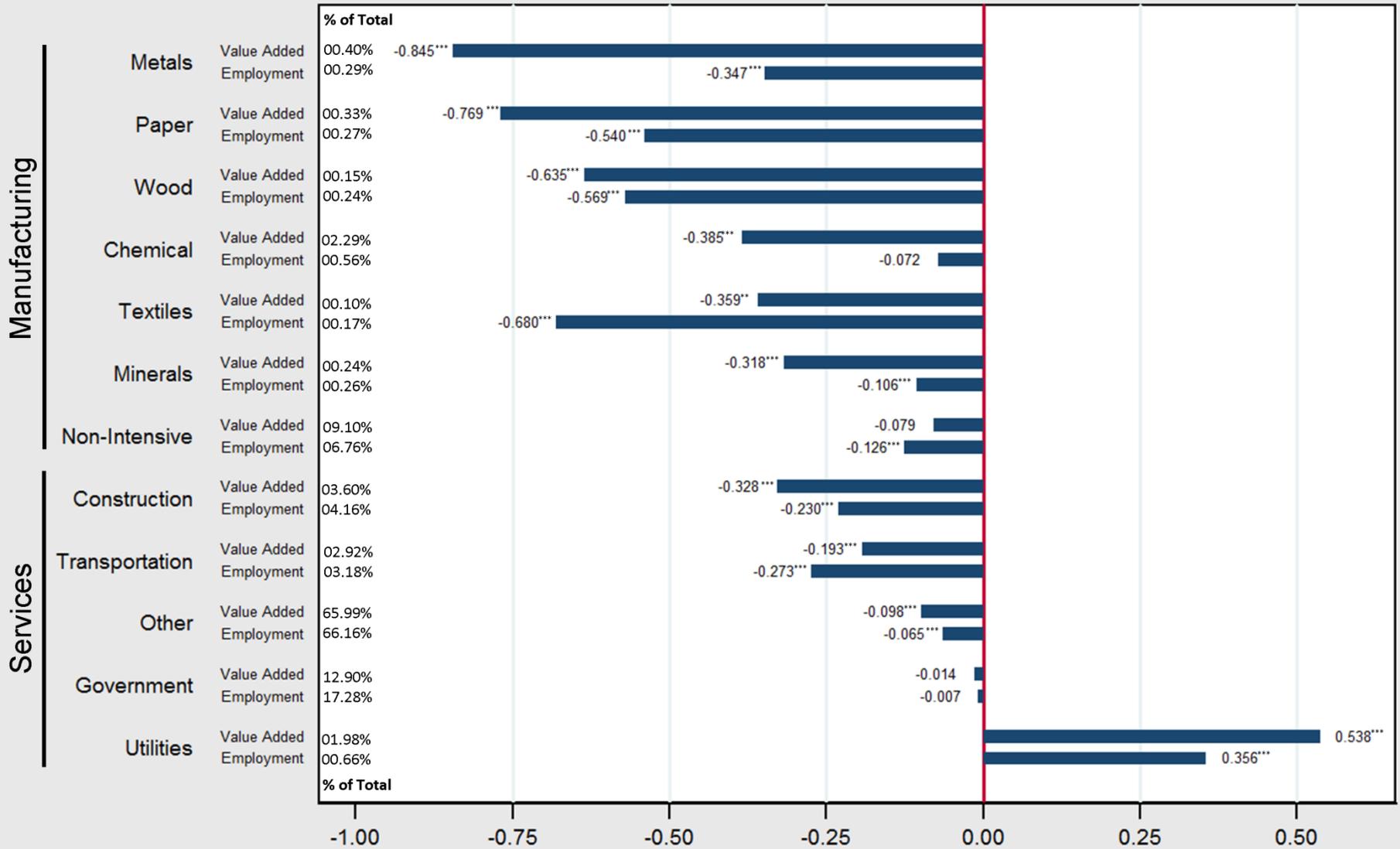
<http://energy.ky.gov/Programs/Documents/Vulnerability%20of%20Kentucky's%20Manufacturing%20Economy.pdf>

United States Textile Manufacturing Employment, 2012 (NAICS: 313-314)



Data: Census Bureau County Business Patterns, 2012
Map: Kentucky Energy Database, EEC-DEDI, 2014

Electricity Price Elasticity Coefficients by Sector

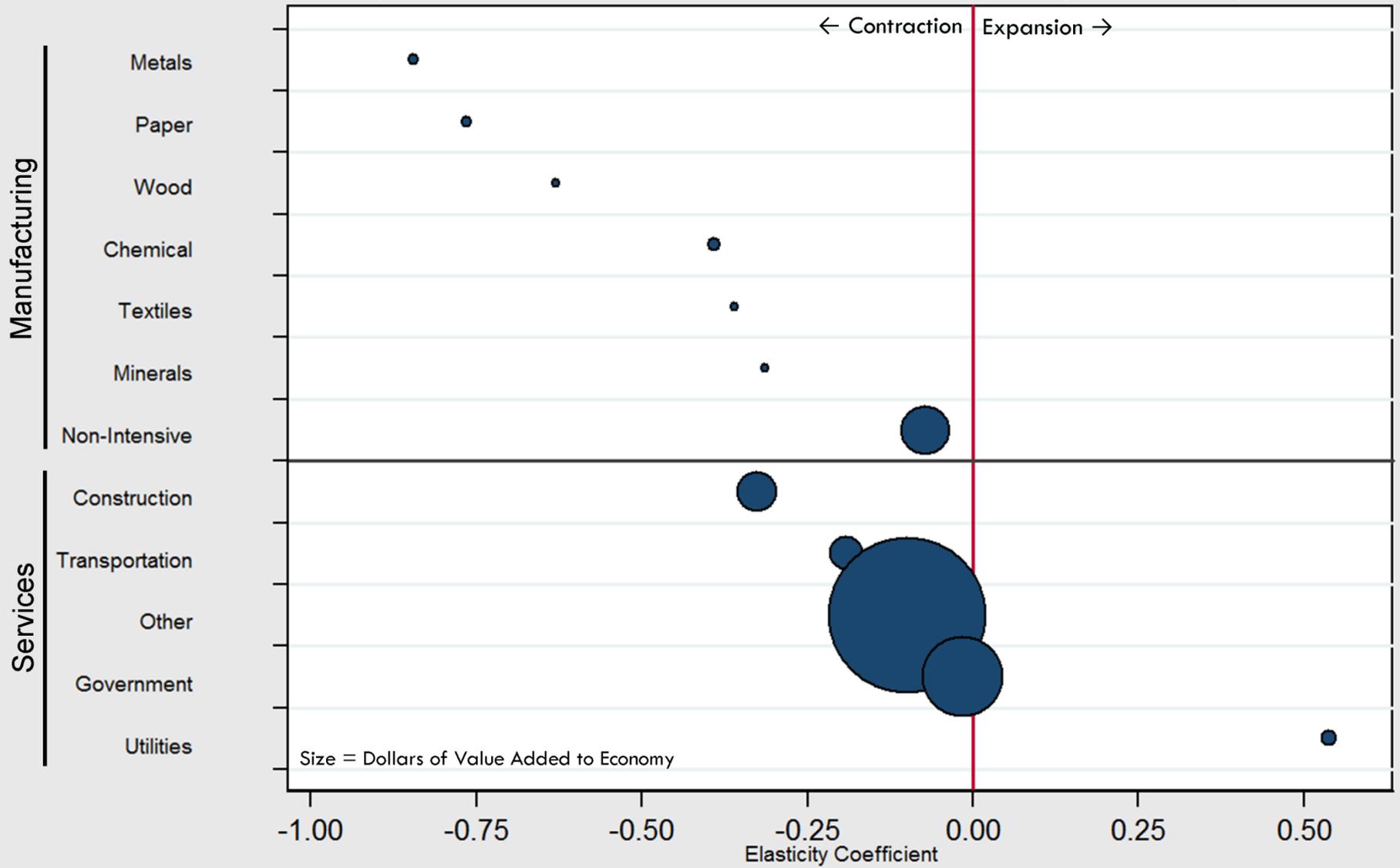


Kentucky Energy Database, EEC-DEDI, 2014

Elasticity Coefficient

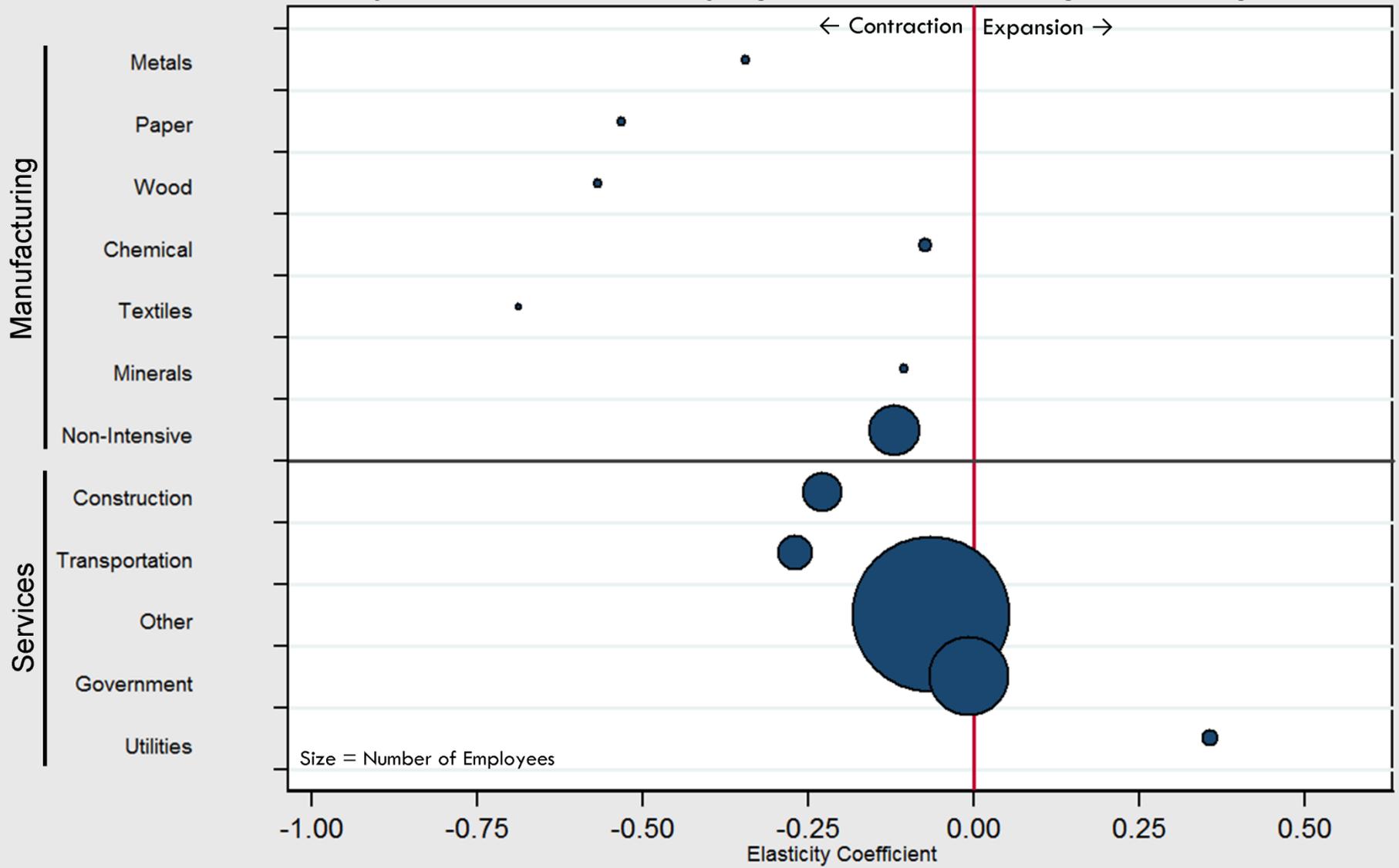
Asterisk Denotes Statistical Significance at the Following Levels: * $P > |t| < 0.05$, ** $P > |t| < 0.01$, *** $P > |t| < 0.001$

Responsiveness of Value Added to Electricity Prices by Sector



Kentucky Energy Database, EEC-DEDI, 2014

Responsiveness of Employment to Electricity Prices by Sector



Kentucky Energy Database, EEC-DEDI, 2014

Analytical Methodology

A multiple regression of panel data model using fixed effects was estimated for employment and value added by economic sector for a total of 24 models. Fixed effects were used to control for the numerous factors inherently affecting sector-specific employment as well as electricity prices from state to state that have not been accounted for in the independent variables included in this study.

The multiple regression of panel data model with fixed effects can be generally given by,

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Where i and t index states and years, such that y_{it} is the dependent variable of interest, employment by industry, in state i in year t , β_0 is the constant y intercept across all states, X is a k by 1 vector of explanatory variables, $\beta_j X_{jit}$ is the product of the observation for each independent variable j through k for state i in year t and the coefficient of X , k is the total number of included independent variables, α_i is the time-invariant fixed effect for state i , and ε_{it} are the residuals, and where $\varepsilon_{it} \sim N(0, \sigma^2)$, or are approximately normally distributed with a mean of zero.

Analytical Methodology

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The multiple regression of panel data model with fixed effects can be generally given by,

Predicted Employment by Industry in State (i) and Time (t)

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Stochastic Error Term ($\sim N(0, \sigma^2)$)

Constant Intercept Across States

Sum of the product of the observation for each independent variable j through k for state i in year t and the coefficient of X_j

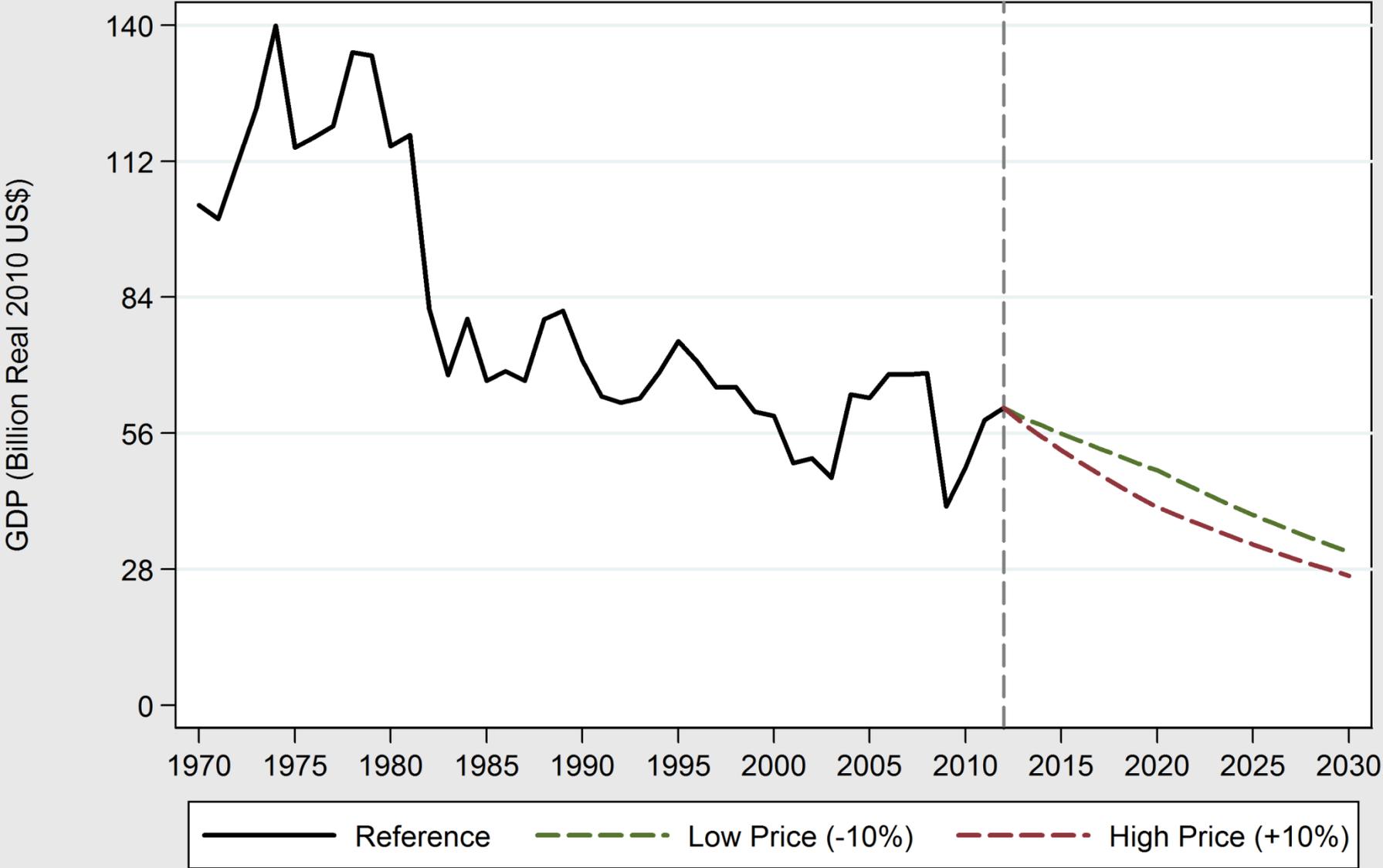
Fixed Effect for State (i)

Where i and t index states and years, such that y_{it} is the dependent variable of interest, employment by industry, in state i in year t , β_0 is the constant y intercept across all states, X is a k by 1 vector of explanatory variables, $\beta_j X_{jit}$ is the product of the observation for each independent variable j through k for state i in year t and the coefficient of X , k is the total number of included independent variables, α_i is the time-invariant fixed effect for state i , and ε_{it} are the residuals, and where $\varepsilon_{it} \sim N(0, \sigma^2)$, or are approximately normally distributed with a mean of zero.

Complete Model of Employment & Value Added by Sector

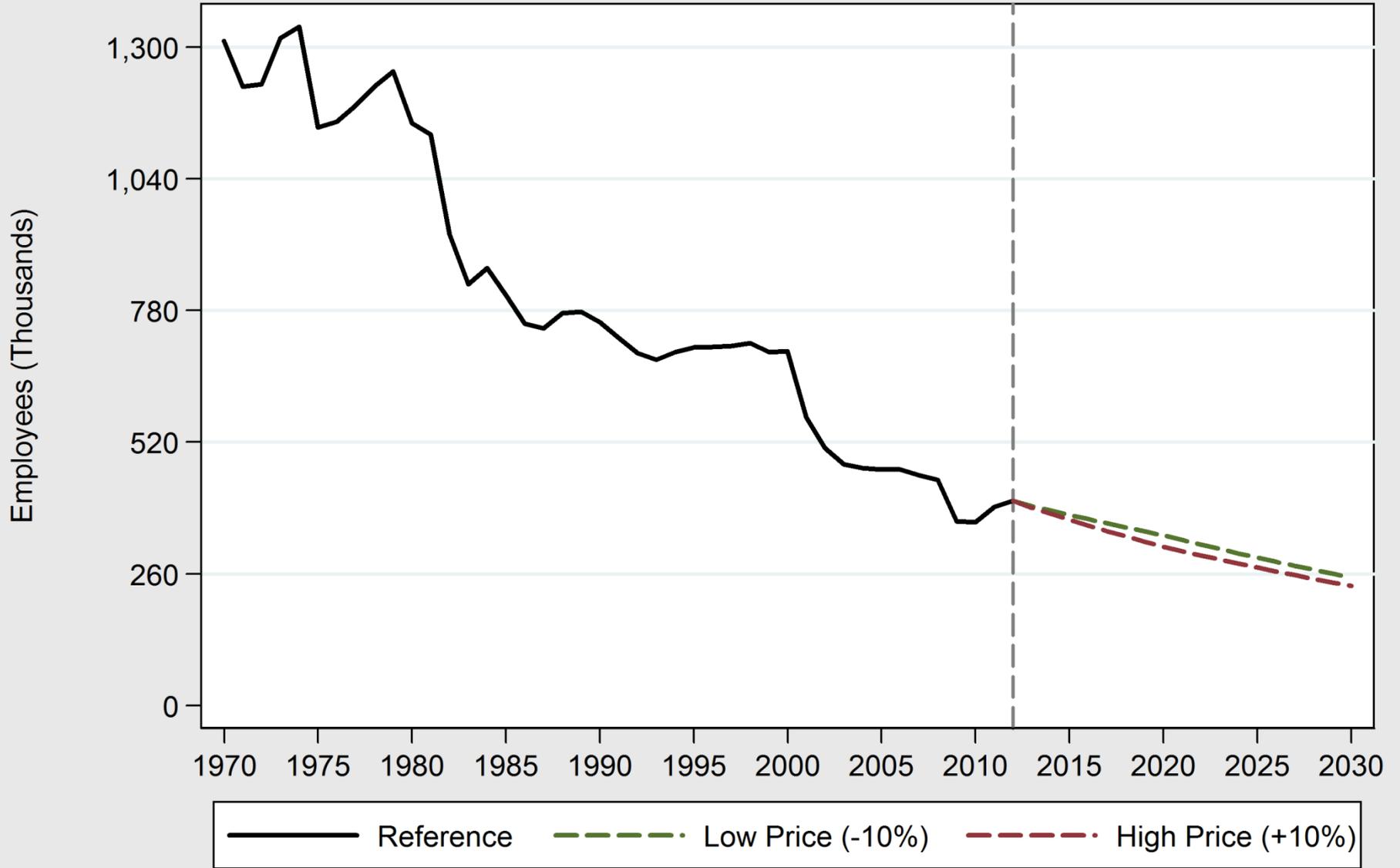
Logged Variables		Manufacturing														Services									
		Metals		Paper		Wood		Chemical		Textiles		Minerals		Non-Intense		Construct		Transport		Other		Government		Utilities	
		V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp
Electricity Price	β_1	-0.845	-0.347	-0.769	-0.540	-0.635	-0.569	-0.385	-0.072	-0.359	-0.680	-0.318	-0.106	-0.079	-0.126	-0.328	-0.230	-0.193	-0.273	-0.098	-0.065	-0.014	-0.007	0.538	0.356
	SE	0.089	0.064	0.091	0.064	0.059	0.041	0.062	0.051	0.124	0.114	0.039	0.031	0.045	0.034	0.025	0.023	0.022	0.020	0.015	0.008	0.010	0.008	0.028	0.022
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.004	0.000	0.000	0.001	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.159	0.330	0.000	0.000
Personal Income	β_2	0.427	-0.254	0.078	-1.160	0.042	-0.042	1.284	0.408	-0.870	-1.246	1.838	0.772	-0.058	-0.775	2.582	1.577	0.762	0.081	1.269	0.220	0.638	0.059	0.093	-0.004
	SE	0.219	0.157	0.223	0.157	0.146	0.100	0.152	0.124	0.305	0.280	0.096	0.076	0.110	0.084	0.060	0.057	0.054	0.050	0.037	0.019	0.024	0.019	0.069	0.053
	P> t	0.052	0.106	0.727	0.000	0.774	0.677	0.000	0.001	0.004	0.000	0.000	0.000	0.601	0.000	0.000	0.000	0.000	0.107	0.000	0.000	0.000	0.001	0.178	0.933
Education	β_3	1.589	0.839	2.586	1.459	3.392	2.449	0.238	0.646	-1.657	-0.413	0.199	0.305	0.504	1.077	-0.037	0.101	0.278	0.607	0.314	0.618	-0.174	0.147	0.756	0.411
	SE	0.195	0.140	0.198	0.140	0.130	0.089	0.136	0.111	0.271	0.250	0.085	0.068	0.098	0.075	0.054	0.051	0.048	0.045	0.033	0.017	0.022	0.017	0.061	0.047
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.000	0.000	0.098	0.019	0.000	0.000	0.000	0.496	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Population	β_4	0.863	0.763	2.136	2.190	0.704	0.301	0.509	0.696	1.417	2.003	1.511	1.403	1.687	1.444	1.387	1.290	1.159	1.235	1.118	0.940	0.650	0.665	0.989	0.820
	SE	0.115	0.082	0.117	0.083	0.077	0.053	0.080	0.065	0.160	0.147	0.050	0.040	0.058	0.044	0.032	0.030	0.029	0.026	0.019	0.010	0.013	0.010	0.036	0.028
	P> t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Petroleum Price	β_5	0.399	-0.101	-0.240	-0.223	-0.226	-0.192	0.104	-0.059	-0.368	-0.114	0.033	-0.045	-0.112	-0.191	0.105	-0.003	0.058	-0.098	0.061	-0.068	-0.019	-0.041	-0.248	-0.129
	SE	0.050	0.036	0.051	0.036	0.033	0.023	0.035	0.028	0.069	0.064	0.022	0.017	0.025	0.019	0.014	0.013	0.012	0.011	0.008	0.004	0.006	0.004	0.016	0.012
	P> t	0.000	0.005	0.000	0.000	0.000	0.000	0.003	0.037	0.000	0.074	0.124	0.009	0.000	0.000	0.000	0.825	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Year	β_6	-144.2	-81.3	-161.2	-85.3	-193.8	-134.9	-6.3	-48.9	87.4	13.0	-96.0	-78.1	-28.6	-60.9	-68.8	-46.7	-29.4	-24.2	-14.5	-3.7	22.6	0.3	-7.8	-12.0
	SE	10.76	7.69	10.92	7.70	7.16	4.91	7.47	6.10	14.95	13.74	4.70	3.72	5.41	4.12	2.96	2.81	2.67	2.47	1.81	0.93	1.20	0.91	3.38	2.61
	P> t	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.02	0.00
Constant (β_0)	β_0	1080	615	1192	633	1459	1024	34	364	-665	-105	694	572	201	458	484	330	206	174	90	24	-178	-1	49	86
	SE	79.6	56.9	80.9	57.0	53.0	36.3	55.3	45.1	110.6	101.7	34.8	27.5	40.0	30.5	21.9	20.8	19.8	18.2	13.4	6.9	8.9	6.7	25.0	19.3
	P> t	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.05	0.00
N		2192	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2192	2193	2193	2193	2193	2193
R ² Within		0.145	0.262	0.191	0.305	0.394	0.441	0.504	0.072	0.128	0.134	0.365	0.451	0.435	0.422	0.910	0.761	0.751	0.787	0.951	0.979	0.961	0.915	0.711	0.549
R ² Between		0.578	0.653	0.583	0.645	0.121	0.019	0.642	0.692	0.520	0.521	0.836	0.839	0.897	0.869	0.957	0.951	0.853	0.946	0.983	0.986	0.883	0.928	0.904	0.905
R ² Overall		0.540	0.621	0.550	0.626	0.140	0.034	0.556	0.669	0.472	0.481	0.812	0.824	0.866	0.852	0.932	0.930	0.845	0.934	0.976	0.986	0.881	0.926	0.887	0.891

United States Metals Real GDP Forecast, 1970-2030



Kentucky Energy Database, EEC-DEDI, 2014

United States Metals Employment Forecast, 1970-2030



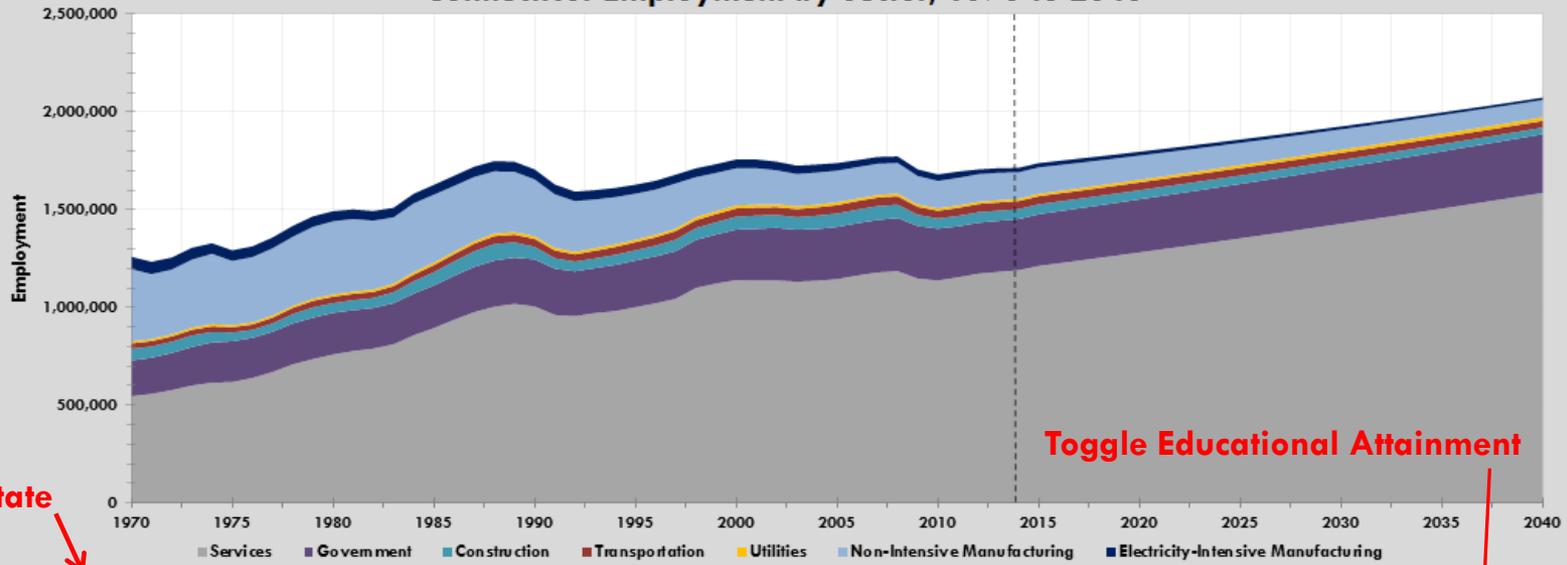
Kentucky Energy Database, EEC-DEDI, 2014

Interactive Excel Visual Basic Version

Download the Excel VBA interactive version of this model at:

<http://1.usa.gov/1G31BuN>

Connecticut Employment by Sector, 1970 to 2040



Select a State

Select a State
 Connecticut

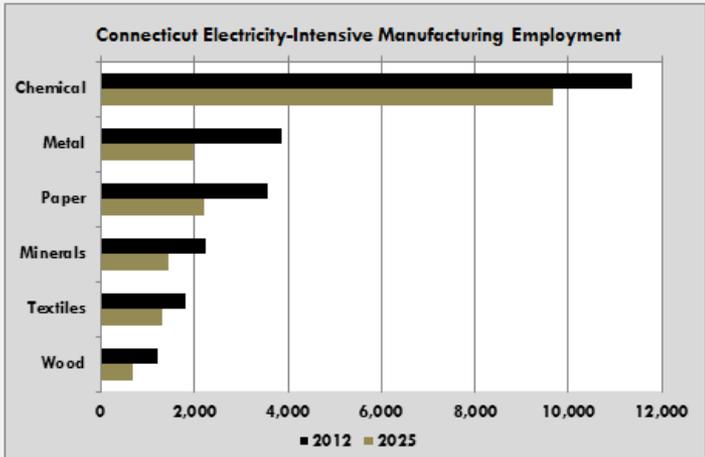
- Extrapolate
- Zero Growth
- Manual Entry

Model Input Assumption				
2025 Electricity Price (Real 2010 \$US per kWh)	2025 Petroleum Prices (Real 2010\$ per MMBTU)	2025 Connecticut Population	2025 Per Capita Personal Income (Real 2010 \$US)	2025 % of Population with Bachelor's Degree
\$0.2245	\$29.5184	3,811,502	\$61,016.74	43.96%
Electricity Price AGR	Petroleum Price AGR	Population AGR	Personal Income AGR	Educational Attainment AGR
3.357%	0.428%	0.428%	0.496%	1.50%

Explore component calculations...

- Instructions About Model
- Explore Model
- View & Edit Model Coefficients

Employment by Sector	2012	2025
Total Employment	1,706,622	1,859,805
Other Services	1,173,510	1,354,029
Government	260,741	278,762
Non-Intensive Manufacturing	141,388	113,843
Construction	53,356	43,006
Transportation	41,912	38,488
Utilities	11,684	14,413
Chemical Manufacturing	11,346	9,654
Metal Manufacturing	3,863	1,962
Paper Manufacturing	3,563	2,225
Minerals Manufacturing	2,240	1,444
Textiles Manufacturing	1,821	1,299
Wood Manufacturing	1,198	680



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