CENTRO STUDI LUCA D'AGLIANO

WWW.DAGLIANO.UNIMI.IT

CENTRO STUDI LUCA D'AGLIANO
DEVELOPMENT STUDIES WORKING PAPERS

N. 414

January 2017

Energy Intensity: Prices, Policy, or Composition in US States

*Arik Levinson**

* Georgetown University and NBER

ISSN 2282-5452

Energy Intensity:
Prices, Policy, or Composition in US States

Arik Levinson
Georgetown University and NBER
arik.levinson@georgetown.edu

December, 2015

Abstract

This project uses the historical experience of US states to ask why energy intensity has declined in some places more than in others, and whether that difference can help provide guidance for other states and countries to pursue less energy-intensive (and therefore less pollution-intensive) economic growth. There are several advantages to studying US states. The variation in energy intensity across states has been similar to the changes across countries, and some states – notably California – have been held up as models for the rest of the world by international organizations such as the World Bank. More importantly, the industrial composition of US states can be studied at a highly disaggregated level. The 473 six-digit NAICS codes in the manufacturing sector are measured comparably across states, ameliorating concerns about industry definition or aggregation bias. And finally, if California, Texas, New York and Florida were independent countries, they would rank among the world's top twenty largest economies. What happens in individual US states matters not just for local and US national policy but for the climate across the globe.

I show that US energy intensity fell by 40 percent between 1982 and 2007; that much of that decline was in the industrial sector; but that the decline is not explained by the decreasing industrial share of the US economy or the changing composition of the industrial sector. Across US states, prices and policies are correlated with the decreasing share and composition of manufacturing, but not with the technique of production, which appears to be the most important source of US energy intensity gains.

Acknowledgments

This paper was prepared as part of the "Value Added in Motion (VAM)" project funded by the Enel Foundation. I am grateful to the Foundation for financial support, to Asif Islam for help with state expenditures data, to Jonah Birnberg and Julia Kieserman for research assistance, and to Claire Brunel for helpful discussions.

Energy Intensity: Prices, Policy, or Composition in US States

Energy consumption per dollar of GDP – energy intensity – has declined worldwide by 35 percent in the past 30 years. But that global average masks tremendous heterogeneity. In more than one fifth of the world's countries, energy intensity *increased*. If global greenhouse gas emissions are to be reduced without reversing economic growth, we must understand how some jurisdictions have been able to reduce their economies' energy intensities. Likely explanations include regulations, energy prices, and industrial composition. And each explanation comes with a different set of policy implications. If regulations explain the reduction, that suggests energy policies have worked as intended, without sacrificing economic growth relative to jurisdictions that have become more energy intensive. If prices explain the reduction, that supports market-based policies such as taxes on energy-intensive industries commensurate with the external costs those industries generate. And if industrial composition explains the reductions in energy intensity, that raises the concern that the differences may involve no more than simply shifting energy around from one jurisdiction to another, without necessarily reducing overall energy use or pollution.

Figure 1 plots energy intensity for various parts of the world, indexed so that 1980 equals 100. Global energy per dollar of GDP fell by 25 percent, but as noted that masks enormous diversity. Energy intensity grew by 86 percent in the Middle East, and fell by 76 percent in China. Intensity fell 37 percent in the EU, and 47 percent in the U.S.. Figure 2 plots the same concept across US states, revealing a similar diversity. Energy intensity grew by 46 percent in Alaska and fell by 69 percent in Oregon.

What accounts for this heterogeneity, and have government policies had any effect? To address these questions I study the historical experience of US states during the 25-year period from 1982 to 2007.[1] There are several advantages to studying states. US energy intensity has fallen even faster than that for the world, the changes in energy intensity across states have been similar to the changes across countries, and some states – notably California – have been held up

[1] I focus on the 25-year period from 1982 to 2007 because the US Census of Manufactures is conducted every five years, in years ending in two and seven.

as models for the rest of the world by international organizations such as the World Bank. More importantly, in the US industry composition can be studied at a highly disaggregated level. The 473 six-digit NAICS codes in the manufacturing sector are measured comparably across US states, ameliorating concerns about industry definition or aggregation bias. And finally, some states are comparable in size to the world's largest countries. If California, Texas, New York, and Florida were independent countries, they would rank among the world's top 20 largest economies. What happens in US states matters not just for local and US national policy but for the climate across the globe.

The rest of the paper is divided into three parts. First, I explore as a potential explanation for the decline in energy intensity the fact that manufacturing and other industrial sectors are playing a diminishing role in the US economy over time.[2] I show that while that is true, it only explains a small part of the decline in US energy intensity. Most of the decline has occurred within sectors, and manufacturing deserves special focus as a large, energy-intensive, and geographically mobile sector. So in the second part of the paper, I look within the manufacturing sector and ask how much of manufacturing's declining energy intensity is explained by the changing composition of manufacturing – i.e. I ask whether the US is producing relatively more goods whose production is less energy intensive. I show that composition changes do not account for the declining energy intensity of US manufacturing. Most of the decline then must be due to technique – changes in production processes that allow narrowly-defined industries to produce more output with less energy.

Finally, in the third part of the paper I examine how these explanations (declining manufacturing, changing composition, technique) differ across US states, and look to see whether those differences are correlated systematically with changes over time in states' energy prices and environmental policies. First, it's important to acknowledge just a few of the many papers that have already touched on these issues, and to note how this analysis differs from what has been done before.

[2] The industrial sector includes manufacturing, agriculture, mining, and construction.

Prior evidence: Decompositions, Convergence, and Regressions

Versions of the questions posed here have been asked in many different ways. Most studies fall into one of four rough categories. They focus on either comparisons across countries or US states. And they use either decomposition or convergence analyses. Decomposition analyses explain the change in energy use as a function of underlying trends – population, income growth, industry composition, etc. Convergence analyses ask whether differences across countries in their energy use are growing or shrinking – "converging". Table 1 summarizes select studies, listing the data and methodologies used, main findings, and key figures or tables in those papers. Below I outline some highlights relevant to this project.

International Analyses

Mulder and de Groot (2012) examine energy intensity – energy use per dollar of GDP – for 18 OECD countries and 50 sectors. They show that the standard deviation of the log of energy intensity across countries has been falling from 1980 to 2005. So OECD countries' energy intensities are converging. Moreover, most of that convergence is explained by the decline in the standard deviation of energy intensities of the countries' manufacturing sectors. That finding, and others like it, are the reason that in this paper I focus attention on manufacturing.

Marrero and Ramos-Real (2013) study 15 EU countries using an approach similar to what I do here and arrive at a similar conclusion. Most of the decline in energy intensity comes within broad sectors (manufacturing, services) rather than across sectors. Like Mulder and de Groot, however, Marrero and Ramos-Real use only 50 sectors. Some within-sector composition changes may be misclassified as efficiency gains. An advantage I have in studying US states is that the manufacturing sector alone can be divided into almost 500 different activities.

Some of the studies contradict one another, although it's difficult to tell whether the conflicts arise from using different time periods, countries, sectors, or methodologies. Jakob et al. (2012) examine 15 countries and show that economic convergence – shrinking differences between rich and poor countries – has been accompanied by converging energy intensities. And Duro and Padilla (2011) expand the international analysis to 116 countries. Their results also support the conclusion that overall energy intensity differences across countries seem to be converging. By contrast, Kepplinger et al. (2013) focus on manufacturing and come to a slightly different conclusion. They note that countries with higher GDPs – industrialized countries – have industrial energy intensities that are both lower and falling faster than other countries. In other words, industrial energy intensity is diverging rather than converging.

In this project I focus on the energy intensity of US states, which enables me to study a far finer dissaggregation among sectors than is possible internationally. I also worry less about convergence or divergence, and simply describe the source of each state's manufacturing sector energy intensity changes, and how those sources might be related to state energy prices and policies.

US State Analyses

Metcalf's (2008) paper is closest in spirit to this project. He first documents that overall energy intensity in the US has declined steadily since 1970, and that only about one-fourth of this decline can be explained by shifting among the residential, commercial, industrial, and transportation sectors. Most of the decline comes from reductions in energy intensity within sectors, which Metcalf calls efficiency. But if, say, the manufacturing sector shifts from producing energy-intensive goods like cement to less intensive products like electronics, calling that within-sector shift "efficiency" may be a mischaracterization. In this project I study the manufacturing sector alone, and shifts in the scale and composition of manufacturing as determined by its 473 separate 6-digit NAICS codes. Metcalf then goes on to a state-by-state analysis to examine how much of the overall decline in energy intensity can be explained by state incomes or energy prices. I do the same, but add various measures of regulatory policy as well.

Huntington (2010) presents an intermediate step between Metcalf's paper and this one. He disaggregates US economic activity into 65 different industries, spread across the commercial, industrial, and transport sectors. Huntington finds that almost 40 percent of the decline in energy intensity in the US can be attributed to shifts among these sectors – 54 percent if we eliminate transportation.

Instead of studying energy efficiency itself, Bhole and Surana (2009) take the interesting strategy of examining state expenditures on energy efficiency. They find that state electricity prices are positively correlated with state expenditures, suggesting that high prices may induce state governments to invest in efficiency. There could be other explanations: perhaps states with constituents inclined towards energy efficiency enact regulations that raise energy prices. But the question is very much in the spirit and style of what I ask here: what state policies are associated with energy intensity declines in US states?

The simplest way to ask that question is to calculate

$$\hat{E}_{jt} = \sum_{i} \left(\frac{E_{ij,1982}}{V_{ij,1982}} V_{ijt} \right) \quad \textbf{(1)}$$

This is the predicted total energy use ($\hat{E}_{jt}$) in jurisdiction *j* in year *t*, where the prediction is calculated as the current value of output (V_{ijt}) times the sum, across sectors *i*, of the energy intensity in jurisdiction *j* in the baseline year 1982 $\left(\frac{E_{ij,1982}}{V_{ij,1982}}\right)$. This prediction ($\hat{E}_{jt}$) is an estimate of what energy consumption would be in jurisdiction *j* in year *t* if each industry had its 1982 energy intensity – in other words holding within-sector energy intensities fixed. The prediction allows the scale and composition of industries to change over time, but not the technology, or "technique."

Using equation **(**1) it is then possible to parse the changes in energy intensities in each state that are due to *composition* – the cross-industry changes in the relative shares of output coming from industries with different initial-year energy intensities – and *technique* – the within-industry changes in energy intensity. The first of these, composition, is just the difference between the prediction in **(**1) and what would have happened to total energy use if it had increased proportionally with output:

$$composition = \Delta\%V_{jt} - \Delta\%\hat{E}_{jt} \quad \textbf{(2)}$$

where $\Delta\%V_{jt}$ and $\Delta\%\hat{E}_{jt}$ are the percentage changes in output and energy, respectively, indexed so that 1982=100. The second of these, technique, is just the difference between this prediction and what actually happened to energy use

$$technique = \Delta\%\hat{E}_{jt} - \Delta\%E_{jt} \quad \textbf{(3)}$$

again indexed so that 1982=100.

None of the calculations in equations **(**1) **- (**3) are complicated. The only difficulty involves obtaining data with a fine enough degree of disaggregation to separate the composition and technique effects. If the sectoral disaggregation of the economy is too course, some broad categories may have composition changes within them that get mislabeled as technique changes. For example, the manufacturing sector has some industries that are energy intensive and others that are not. If we treat all of manufacturing as one sector in equation in **(**1), we may then call some within-manufacturing reallocation of industries "technique" rather than "composition." In fact, I believe that this has been a feature of much of the prior research on this topic.

To study this composition-technique distinction carefully, I parse it into two parts. In the next section I examine the composition change between the industrial sector and the other uses of energy in the economy: transport, commercial, and residential. And in the following sector I focus on the manufacturing sector, disaggregated into 473 separate industries.

The Declining Share of Industry in the US Economy

At first glance, it appears that the declining share of the industrial sector in the overall US economy, both in terms of energy use and output, might explain the declining US energy intensity. Figure 3 plots the shares of overall energy use of each the four sectors: industry, residential, commercial, and transport. Industry is the only sector that shrank.

Figure 4 contrasts changes in energy use by each sector with changes in overall output, measured differently for each sector. The first pair of darkly-shaded columns plot the total energy used by industry in 1982 and 2007, which rose from 28 quadrillion BTUs ("quads") to 32. But superimposed on the second of those columns is the (unshaded) projected 2007 industrial energy use, calculated by multiplying the 1982 energy use by the percentage change in industrial output, measured in inflation-adjusted dollars. Had industrial energy grown as fast as output, 2007 energy use would have been 52 quads rather than 32. The difference, represented by the unshaded gap, is the declining energy intensity of US industry.

The second pair of columns in Figure 4 does the same thing for commercial buildings. In this case I don't have a good measure of the change in scale of output, and so I use the square footage of commercial buildings. Energy use grew more, from 11 to 18, and energy intensity measured this way declined less. The third pair of columns does the same for residential buildings, where the scale effect is based on population growth. And finally, the last pair of columns scales the transport sector's energy use by vehicle miles traveled. This last case does appear to rival industry in terms of its contribution to declining US energy intensity. But transport is non-tradable. We cannot import our commutes to work, shifting the resulting pollution from the US to other countries. And so there's less concern for transport energy use about the composition-technique distinctions.

Figure 5 plots the scale, composition, and technique changes to US energy use, where the sectors are defined broadly as either "industrial" or "other." So the composition effect here is really "deindustrialization." The bottom line, labeled "Energy", plots the total energy used in the US, indexed so 1982=100. Energy use grew by 39 percent. The top line, labeled "Scale" is just the real value of GDP, which grew by 125 percent. The middle line, labeled "Scale and Deindustrialization," is the estimate of $\hat{E}_{jt}$ from equation **(**1**)**, indexed so 1982=100, using only the two broad sectors "industrial" and "other". The top two lines are quite close, suggesting that most of the decline in energy intensity has come from within the industrial sector, not between the industrial and other sectors – i.e. not deindustrialization.

Figure 6 presents that same information in a slightly different way, dividing by scale so that contributions to energy intensity can be seen more directly. The bottom line depicts the overall energy intensity of the US, which fell by 38 percent to 62 (indexed to 1982=100). And the top line depicts the decline in overall energy intensity explained by the declining share of industry in overall output. That line falls much less, by only 8 percent. Again, most of the decline in energy intensity must be within the industrial sector.

Finally, that same pattern holds across US states. Figure 7 plots that middle line – the decline in energy intensity due to the changing industrial share of GDP – for each US state. For most states the industrial share is less than 10 percent. For some, where industrial output grew as a share of gross state product, it is even positive.

These analyses all suggest that the biggest contributor to declining energy intensity in the US has come within the manufacturing sector. That sector also raises the largest concerns about whether declining energy intensity has been the result of changes in the mix of goods manufactured (composition) or reductions in the amount of energy required to produce each good (technique).

Manufacturing Changes: Composition or Technique

US States exhibit heterogeneity in the 25-year change in energy intensity within the industrial sector, just as much as they do overall. Figure 8 presents a version of Figure 2 using only industrial energy use – output per dollar of value added without transportation, commercial or residential energy. Although the individual state lines exhibit more year-to-year noise, the basic trends are nearly identical. Industrial energy intensity fell by 67 percent on average for the US, but rose by 20 percent in Alaska and fell by 90 percent in Oregon.

Figure 9 plots indexes of energy use in the US. The bottom line, labeled "Energy", is simply the total energy used by the US manufacturing sector, indexed so 1982=100.[3] The top line, labeled "Scale and Composition", is the estimate of $\hat{E}_{jt}$ from equation **(**1**)**. This is calculated using the 473 six-digit NAICS codes that comprise the manufacturing sector. And the middle line, labeled "Scale" is just the real value of total manufacturing sales, indexed to 1982.

As Figure 9 shows, manufacturing output grew 121 percent over 25 years, but manufacturing energy use grew only 22 percent. This difference represents a huge decline in energy intensity. Does it come from composition changes across industries, or efficiency/technique changes within six-digit industries? In fact, for the US, the composition effect works against the trend. If every industry continued using its 1982 energy intensity, the changing scale and composition of US manufacturing would have led to a 330 percent increase in total energy use. So in aggregate, for the US manufacturing sector, the composition effect *increased* energy consumption by 209 percentage points, and the technique effect reduced energy consumption by 308 percentage points.

To be clear, nothing about Figure 9 suggests a causal relationship. A number of papers have documented evidence of a "pollution-haven" effect. Jurisdictions with strict environmental regulations, or where environmental regulations have become stricter, have seen a modest but

[3] Source: NBER-CES Manufacturing Industry Database (www.nber.org/nberces).

statistically significant shift in their industrial compositions towards less pollution-intensive and energy-intensive industries, *all else equal.*[4] The key phrase being those last three words. The fact that US manufacturing has shifted towards energy-intensive industries should not be surprising. Energy costs are low in the US, relative to other countries,[5] and labor costs are high. So the fact that the US manufacturing sector composition is energy intensive, or has become more energy intensive over time, should not be surprising. What would be surprising, however, would be if rising prices or stricter environmental policies did not cause a shift towards less energy intensive composition, relative to what that composition would have been absent those prices and policies.

Do prices or polices affect the shift in composition? We cannot answer that question with just one observation, the entire US. And so the next step is to calculate equations **(**1) - **(**3) on a state-by-state basis, and examine whether the differences across states are associated with differences in state energy prices or policies.

State-specific estimates

To calculate state specific changes in manufacturing-sector energy composition, I combine annual state energy data from the US Energy Information Administration (EIA) with the 1982 and 2007 Censuses of Manufactures.[6] I then calculate versions of equation **(**1**)** for those two years for each state.[7]

Figure 10 plots a version of Figure 9 for California alone. If California's manufacturing sector energy use had grown proportionately with its output, energy use would have grown 86 percent ("Scale"). The predicted energy growth $\widehat{E}_{jt}$ grew by 64 percent. The difference between those two represents the composition changes that, in this case, reduced the state's manufacturing energy use. So California industry shifted towards less energy-intensive industries, unlike the nation as a whole. The state's industrial energy use grew 36 percent; and

[4] See Kahn and Mansur (2013), Mulatu et al. (2010), or Levinson and Taylor (2008).
[5] www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices
[6] The EIA data are called the State Energy Data System (SEDS). www.eia.gov/state/seds/seds-data-complete.cfm.
[7] State-specific manufacturing output data are not available by six-digit NAICS code for the years in between the five-year Censuses.

the difference between that relatively low growth rate and the predicted 64 percent growth rate represents within-industry "technique". So the explanation for California's declining energy intensity can be divided fairly evenly between composition and technique, with technique accounting for a little more than half of the gains.

Contrast that with Texas, depicted in Figure 11. Texas's pattern looks more like the national case. A proportional increase in Texas's manufacturing output would have increased manufacturing energy use by 122 percent. Composition and scale together ($\widehat{E}_{jt}$) would have increased energy use by 180 percent. So while California's manufacturing sector shifted towards less energy-intensive goods; Texas's shifted in the opposite direction, towards industries that use more energy.

What accounts for the difference between California and Texas, and for all the other differences across states? Why did California's industrial composition shift towards less energy-intensive industries while Texas's shifted towards more energy-intensive industries? And why was Texas's technique effect – the within-industry energy-intensity decline – larger than California's. Could it be energy prices or some other regulatory policy differences between the states? The next section attempts to answer those questions.

State Prices and Polices

Appendix Table A1 reports the data for two measures of changes in states' energy intensities. The first two columns examine the share of the economy-wide decline in energy intensity that is due to a drop in the industrial sector's importance to the overall economy. The discussion above suggests that in general, declining industry does not explain the US energy intensity decline. But for some individual states the share is larger, and it remains of interest how much that decline may be correlated with state prices and policies.

Columns (3) through (5) of Appendix Table A1 turn to the manufacturing sector, and examine separately each of the components of declining energy intensity. Column (3) is an index of total manufacturing energy use (1982=100), which ranges from 53 in Maryland – a 47 percent decline in manufacturing energy use – to 297 in North Dakota – a 197 percent increase. Column (4) contains an estimate of the composition change and its contribution to the state's decline in manufacturing energy intensity, from equation **(**2**)**. The state where composition shifted the most towards energy-using industries is Delaware. If every industry in Delaware retained its 1982 energy intensity, that state's 2007 manufacturing energy use would have been 197 percentage points larger. The state where composition shifted the most towards industries using less energy is Nevada. Column (5) presents the technique effect from equation **(**3**)**, which ranges from -27 percent in New Mexico to +650 percent in Nevada.

To what extent are variations in these measures of state energy intensity associated with states' prices or policies? Appendix Table A2 contains some measures of those state characteristics, and Table 2 reports their correlations with the measures of energy intensity, starting with prices.

Columns (1) and (2) of Table A2 report the percentage change in the price of electricity, 1982-2007, and the average absolute price over that time period, respectively. Table 2 reports the correlations between these measures of state energy prices and the five measures of state energy intensity reported in Appendix Table A1. States with high prices (row 1) or steeply rising prices (row 2) had higher-than-average declines in overall energy intensity. And for states with high prices, a larger-than-average share of that decline came from industry's declining share of gross state product (GSP). That declining industry share is also reflected in column (3), the scale effect of manufacturing. We cannot make too much of these correlations, of course. They are, after all, not demonstrations of causation. States with growing manufacturing sectors may put upward pressure on energy prices. But it does seem that states with the highest and fastest growing energy prices saw the steepest declines in the industrial sector as a share of GSP and in the scale of the manufacturing portion of the industrial sector. That said, the earlier discussion demonstrates that the shrinking role of manufacturing accounts for only a small part of states' declining energy intensities.

Column (3) of Appendix Table A2 contains the year the state first implemented energy efficiency standards for building codes, from Aroonruengsawat et al. (2012). This is intended as an indicator for broader concerns about energy efficiency. Table 2 reports the correlations between the year of building code establishment and the five measures of energy intensity. There seems to be no correlation.

Columns (4) and (5) of Appendix Table A2 explore environmental policies. There are numerous approaches to measuring the stringency of those policies. Galeotti et al. (2015) discuss various measures of environmental and energy policy stringency and develop their own cross-country measure based on Brunel and Levinson (2015). Here we use that same approach but for US states, from an index developed in Keller and Levinson (2002). The index is based on the US Pollution Abatement Costs and Expenditures (PACE) survey, conducted annually by the US Census Bureau from 1973 until 1994. The Census Bureau published the average annual abatement expenditures by industry and by state. Keller and Levinson use those published data to calculate the total costs per dollar of manufacturing value added: $S_{st} = P_{st}/Y_{st}$, where P_{st} is the pollution abatement cost in state *s* in year *t*, and Y_{st} is the manufacturing sector's value added state *s* in year *t*. They compare that to the *predicted* abatement costs, $\hat{S}_{st}$, a weighted average of the national pollution abatement costs for each of 20 industries, where the weights are the industries' shares of output in state *s*, Y_{sit}/Y_{it}. Keller and Levinson's measure of stringency is just the ratio of actual over predicted costs, $S_{st}/\hat{S}_{st}$. When this ratio is greater than one, pollution abatement costs are larger than would be expected given the state's industrial composition, and Keller and Levinson infer that the state's regulations are relatively stringent.

Column (4) of Appendix Table A2 contains the average PACE index from 1973 to 1994, and column (5) contains the change. As reported in Table 2, neither is particularly strongly correlated with the states' change in total manufacturing energy use, composition, or technique. Although states with high average PACE indices do seem to have a larger share of their energy intensity declines explained by shrinking industrial sectors.

Columns (6) and (7) of Appendix Table A2 contain the shares of state government spending on "parks, libraries, arts and humanities" in column (6) and "infrastructure and communication" in column (7) from Islam (2013). Back in Table 2, spending on parks appears negatively correlated with the industrial decline's share of energy intensity decline, positively correlated with manufacturing energy growth, and positively correlated with composition change towards less energy-intensive industries. I suspect that what's really happening is that states with the fastest economic growth spend more on parks – a luxury public good – and that those states have a large increase in manufacturing energy use but an even larger increase in manufacturing output, offset by energy reductions due to composition and technique.

Column (8) of Appendix Table A2 presents another measure of environmental policy: the share of the state's population living in counties declared to be out of attainment with federal ambient air quality standards. These have been used as a measure of stringency by Henderson (1996), Becker and Henderson (2000), and others. Counties that have poor air quality and do not meet federal standards are required by the US Clean Air Act to impose tough regulations to try to come into compliance, and so that distinction has been interpreted as an exogenously imposed environmental standard. As reported in Table 2, states with higher shares of their populations living in non-attainment counties saw larger drops in industry's share of GSP, a larger drop in overall energy use, and a bigger within-industry (technique) decline in energy intensity.

Columns (9) and (10) of Appendix Table A2 contain indexes of regulatory policy. The American Council for an Energy Efficient Economy (ACEEE) publishes an annual "scorecard" designed to assess "the progress of state policies and programs that save energy while also benefiting the environment and promoting economic growth."[8] Column (9) contains the ACEEE scorecard for 2006, the first year they published it. In Table 2 this index is correlated with the decline in industry's share of GSP and the slower growth of the manufacturing sector, but not with the composition or technique effects. The League of Conservation Voters (LCV) publishes a different index – also called a "scorecard" – based on the pro-environmental voting record of states' congressional delegations. Like the ACEEE scorecard the LCV scorecard is negatively correlated with overall manufacturing energy growth, but not with the composition or technique effects.[9]

Finally, the last column of Appendix Table 2 contains the growth in real gross state product per capita, from 1982 to 2007. At the bottom of Table 2, GSP growth is correlated with declines in industry's share of states' economies, but negatively correlated with that decline's contribution to declining energy intensity, and uncorrelated with the scale, composition, or

[8] www.aceee.org

[9] Table 2 also shows the correlations with three other indexes: (1) 24/7 Wall Street 2010 ranking of US states based on the environmental problems in each state and how effectively these problems are addressed; (2) Greenopia 2011 State Sustainability Index based on air quality, water quality, recycling rate, number of LEED buildings, green business density, per capita water consumption, per capita energy consumption, per capita emissions, per capita waste generation, and several renewable energy statistics; (3) Forbes 2007 America's Greenest States ranking based on six equally weighted categories: carbon footprint, air quality, water quality, hazardous waste management, policy initiatives and energy consumption.

technique of the manufacturing sector. It does not appear to be the case that energy intensity changes are correlated with economic growth.

Conclusions

The results here may raise more questions than they answer. In the first section of the paper I demonstrate that while the US as a whole has experienced a large decline in energy intensity over the past 25 years, individual states exhibit considerable heterogeneity, with some state intensities decreasing much more than the national average and some increasing their energy per dollar of output. Moreover, I show that deindustrialization has not played a significant role in declining energy intensity, either for the nation as a whole or on a state-by-state basis. Much of the declining energy intensity has been due to changes within the manufacturing sector.

In part 2 of the paper, I correlate those cross-sector and within-sector changes with measures of state energy prices and policies. While those prices and policies do seem to be associated with deindustrialization, they are not correlated with the within-manufacturing technique changes that explain the bulk of energy intensity declines in the US. In other words, the prices and policies appear correlated with changes to states economies that are the least important determinants of energy intensity.

References

Aroonruengsawat, Anin, Maximilian Auffhammer and Alan H. Sanstad. 2012. "The Impacts of State Level Building Codes on Residential Electricity Consumption" *Energy Journal* 33(1): 31-52

Baldwin, James G. and Ian Sue Wing. 2013. The Spatiotemporal Evolution of U.S. Carbon Dioxide Emissions: Stylized Facts And Implications For Climate Policy Spatiotemporal Evolution Of U.S. Carbon Dioxide Emissions, *Journal of Regional Science,* 53(4):672-689.

Becker, R.A. and J.V. Henderson (2000), "Effects of Air Quality Regulations on Polluting Industries," *Journal of Political Economy*, 108, pp.379-421.

Bhole, Bharat. 2011. Electricity prices and state commitment to energy efficiency in the U.S., *Energy Efficiency,* 4(1), 9 - 16.

Brunel, Claire and Arik Levinson. 2015. "Measuring Environmental Regulatory Stringency" *Review of Environmental Economics and Policy*, forthcoming.

Caron, Justin, Gilbert Metcalf, John Reilly. 2014. "The CO_2 Content of Consumption across US Regions: A Multi-Regional Input-Output (MRIO) Approach" Working Paper.

Coccia, Mario. 2010. Energy metrics for driving competitiveness of countries: Energy weakness magnitude, GDP per barrel and barrels per capita, *Energy Policy*, 38(3), 1330 - 1339.

Duro, J. A. and E. Padilla. 2011. "Inequality across countries in energy intensities: An analysis of the role of energy transformation and final energy consumption", Energy Economics, 33, pp. 474-479.

Drummond, William J. 2010. Statehouse Versus Greenhouse Have State-Level Climate Action Planners and Policy Entrepreneurs Reduced Greenhouse Gas Emissions?, *Journal of the American Planning Association*, 76(4), 413 - 433.

Filippini, M. and L.C. Hunt. "Underlying Energy Efficiency" in the US" Center of Economic Research at ETH Zurich Working Paper 13/181 July 2013.

Galeotti, Marzio, Silvia Salini, and Elena Verdolini. 2015. "Measuring Environmental Policy Stringency: Approaches, Validity, and Impact on Energy Efficiency" working paper.

Gerlagh, Reyer, Nicole Mathys, Daniel Moran, Sylvain Weber. 2015. "CO2 Embedded in Trade: Trends and Drivers" working paper.

Hassett, Kevin A., Aparna Mathur and Gilbert E. Metcalf. 2009. "The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis." *The Energy Journal*, 30(2), pp. 157-79.

Henderson, V. (1996), “Effects of Air Quality Regulation,” *American Economic Review*, 86, pp.789-813.

Horowitz, Marvin J.. 2011. Measuring the savings from energy efficiency policies: a step beyond program evaluation, *Energy Efficiency*, 4(1), 43 - 56.

Huntington, Hillard G. 2010. Structural Change and US Energy Use: Recent Patterns, *Energy Journal*, 31(3), 25 - 39.

Islam, Asif M. 2013. “US Government Spending Allocation Database by State (SADS),” Working Papers 147368, University of Maryland, Department of Agricultural and Resource Economics.

Jakob, M., M. Haller, R.T. Marschinski. 2012. “Will history repeat itself? Economic convergence and convergence in energy use patterns” *Energy Economics* 34: 95-104.

Kahn, Matthew and Erin Mansur. 2013. “Do local energy prices and regulatio affect the geographic concentration of employment?” *Journal of Public Economics* 101: 105-114.

Keller, Wolfgang and Arik Levinson. 2002. “Pollution Abatement Costs and Foreign Direct Investment Inflows to U.S. States,” *The Review of Economics and Statistics* 84(4): 691-703.

Kepplinger, D. M. Templ, and S. Upadhyaya. 2013. “Analysis of energy intensity in manufacturing industry using mixed-effects models” *Energy* 59:754 - 763.

Levinson, Arik and M. Scott Taylor. 2008. “Unmasking the pollution haven effect” *International Economic Review* 49: 223–254.

Liddle, B. 2009. “Electricity Intensity Convergence in IEA/OECD Countries: Aggregate and Sectoral Analysis”, Energy Policy, 37, pp. 1470-1478.

Linares, Pedro. 2010. Energy Efficiency: Economics And Policy, *Journal Of Economic Surveys*, 24(3), 573 - 592.

Marrero, Gustavo. 2013. Activity Sectors and Energy Intensity: Decomposition Analysis and Policy Implications for European Countries (1991–2005),*Energies (Basel)*, 6(5), 2521 – 2540.

Marrero, Gustavo A. 2010. Greenhouse gases emissions, growth and the energy mix in Europe, *Energy Economics*, 32(6), 1356 - 1363.

Metcalf, Gilbert E. 2008. “An empirical analysis of energy intensity and its determinants at the state level” *Energy Journal*, 29(3), 1 - 26.

Mulatu, Abay, Reer Gerlagh, Dan Rigby, and Ada Wossing. 2010. “Environmental regulations and Industry Location in Europe” *Environmental and Resource Economics* 45:459-479.

Mulder, Peter and Henri L.F. de Groot. 2011. “Energy Productivity Performance Across 14 OECD Countries: The Role of Energy-Extensive Sectors”, in: R.J.G.M. Florax, H.L.F. de Groot and P. Mulder (eds), *Improving Energy Efficiency through Technology: Trends, Investment Behaviour and Policy Design*, Cheltenham: Edward Elgar, pp. 67-96.

Mulder, Peter and Henri L.F. de Groot. 2012. “Structural change and convergence of energy intensity across OECD countries,” 1970–2005, *Energy Economics*, 34(6), 1910 – 1921.

Sue Wing, I. 2008. Explaining the declining energy intensity of the US economy. Resource and Energy Economics 30: 21–49.

Tol, Richard S.J. 2009. Understanding Long-Term Energy Use and Carbon Dioxide Emissions in the USA, *Journal of Policy Modeling*, 31(3), 425 – 445.

Weber, Christopher L. 2009. Measuring structural change and energy use: Decomposition of the US economy from 1997 to 2002, *Energy Policy*, 37(4), 1561 - 1570.

Table 1. What Explains Energy Intensity Declines? US State and International Evidence

Paper	Data	Methodology	Main Finding	Key Cite
US States				
Metcalf (2008)	US States 1970-2001	Decomposition at state and national levels	Declines in energy intensity explained by “energy efficiency” broadly defined.	Table 3. pl10.
Weber (2009)	US Industries 1997-2002	I-O analysis, structural decomposition analysis.	Changes in the structure of the economy explain drop in total energy intensity more than increased energy efficiency.	Figure 4; Tables 2-3.
Tol (2009)	US 1850-2002	Decomposition at national level.	Energy intensity decline from technological and behavioral changes, structural change in economy, shift from coal to oil and gas.	Figure 8
Drummond (2009/10)	US 1990-2007	Regression analysis.	State-level climate actions have modest effect on GHG emissions.	
Huntington (2010)	5 sectors 1949-1996. 65 NAICS industries 1997-2006.	Decomposition	Structural changes in the economy account for much of the reduction in energy intensity	Table 1, Table 4
Bhole (2011)	state-level, non-contiguous years ranging from 1993-2004	Regression	Electricity prices have a significant positive effect on state energy efficiency expenditures	Table 4
Baldwin (2013)	1963-2008, US states	Index number decomposition	Carbon emissions among states are stochastically converging; 2010 EIA underestimates future carbon emissions	Figure 3
Sue Wing, I. (2008)	1958-2000, 35 economic sectors (2-digit level)	Decomposition, comparison among industries	Inter-industry structural change caused decrease in US energy intensity until 1973; intra-industry efficiency improvements had significant effect on energy intensity post-1980.	Table 5

International				
Coccia (2010)	Eurostat (32 European countries), 1996-2007	Energy metrics, decomposition	GDP per barrel of oil best indicates energy productivity. Barrels of oil per capita best indicate energy efficiency.	Figure 3
Mulder and de Groot (2012)	18 OECD countries, 50 sectors, 1970-2005	Decomposition, convergence analysis	Convergence patterns of energy intensity occur more within sectors than between; also, manufacturing sector experienced greatest decrease in energy intensity over time.	Figure 1
Marrero and Ramos-Real (2013)	EU 15 countries, 1991-2005	Decomposition	Efficiency, not structure explains variation between countries	Figure 5
Kepplinger et al. (2013)	UNIDO (1963-2009, 163 countries, 2-digit industrial codes for manufacturing industry); MVA (1990-2012, 200+ economies)		Countries with higher GDP have lower energy intensity; energy efficiency is achieved along with technological advancement	Figure 3, Figure 4
Duro and Padilla (2011)	IEA, 116 countries, 1971-2006.	Theil decomposition	Divergence in final energy consumption per GDP unit .	Table 4, Table 5
Jakob et al. (2012)	30 developing countries, 21 industrialized countries, 1971-2005	Convergence analysis	Developing countries have above-average energy intensities; industrialized countries have larger improvements in energy efficiency	Table 4
Liddle (2009).	22 developed countries, 1960-2006	Convergence analysis	Electricity intensity has converged less than aggregate energy intensity	
Mulder and de Groot (2011)	14 OECD countries, 13 sectors, 1970-1997	Comparison among countries by sector		

Table 2. Correlations: Energy Intensity, Composition, Prices, and Regulations in US States 1982-2007

	Economy-wide Energy Intensity		Industrial Energy Changes		
	Percentage Point Decline in Energy Intensity	Proportion due to declining share of industry in GDP	Scale	Composition	Technique
	(1)	(2)	(3)	(4)	(5)
Prices 1982-2007					
Average	**0.35***	**-0.34***	**-0.37***	0.05	-0.02
Change	**0.34***	0.21	**-0.26***	0.13	0.10
Year of first building code	0.13	0.06	-0.11	0.11	0.12
Pollution Abatement Cost Index					
Average	0.12	**0.50***	-0.09	-0.21	-0.05
Change	-0.17	0.14	-0.01	0.07	-0.17
Public spending shares					
Parks	0.04	**-0.27***	**0.39***	**0.38***	**0.30***
Infrastructure	-0.14	-0.03	**0.32***	0.04	0.23
Share of population in nonattainment counties	**0.36***	-0.18	**-0.30***	0.12	**0.33***
NGO Indexes					
ACEEE	**0.58***	-0.19	**-0.37***	0.09	-0.03
League of Conservation Voters	-0.09	0.15	**-0.28***	-0.13	-0.16
Economic growth per capita	**0.38***	**-0.45***	-0.06	-0.20	-0.21

*Statistically significantly different from zero at 5%.

Figure 1. Countries' Energy Use per Dollar of GDP

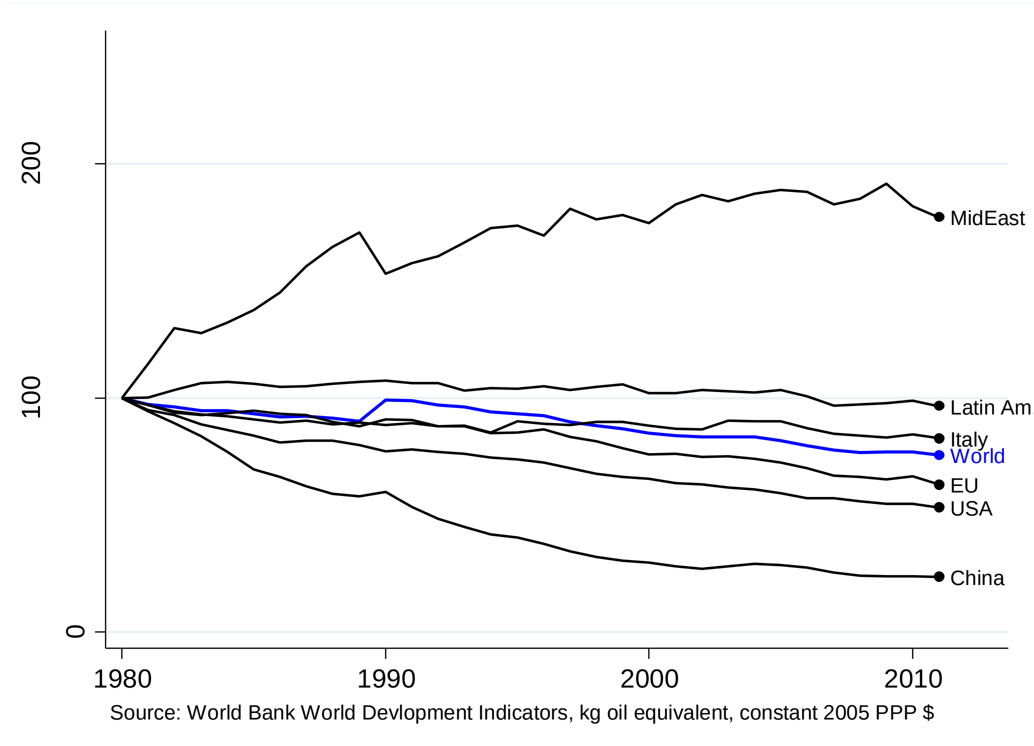


Figure 2. US States' Energy Use per Dollar of Gross State Product

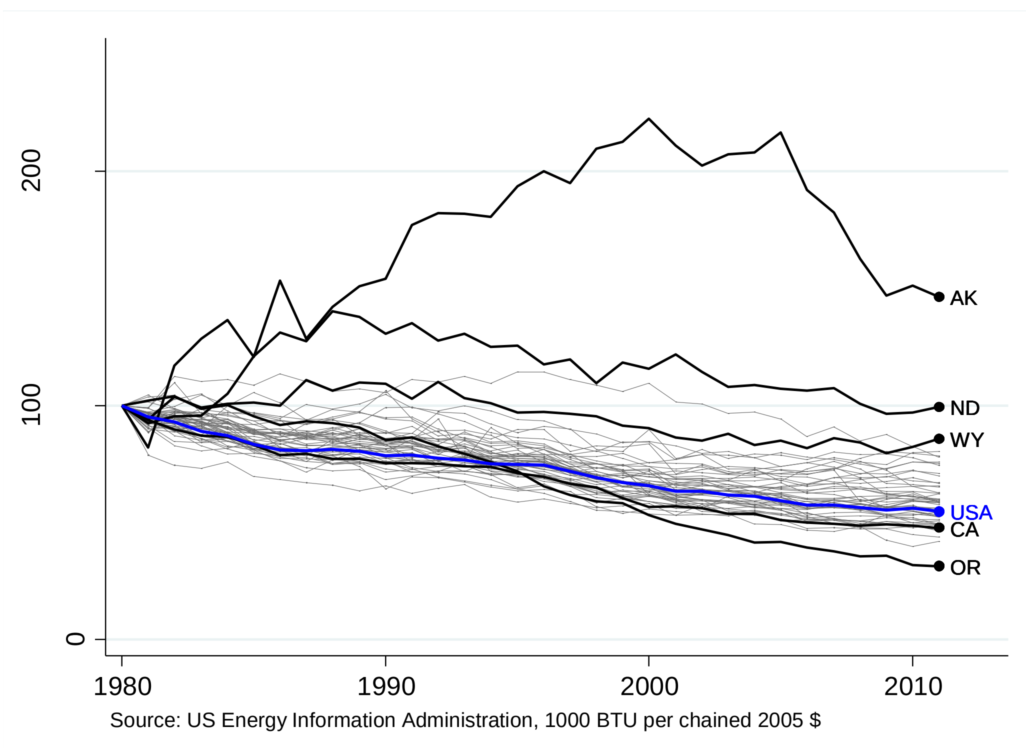


Figure 3. Sector Shares of US Energy Use

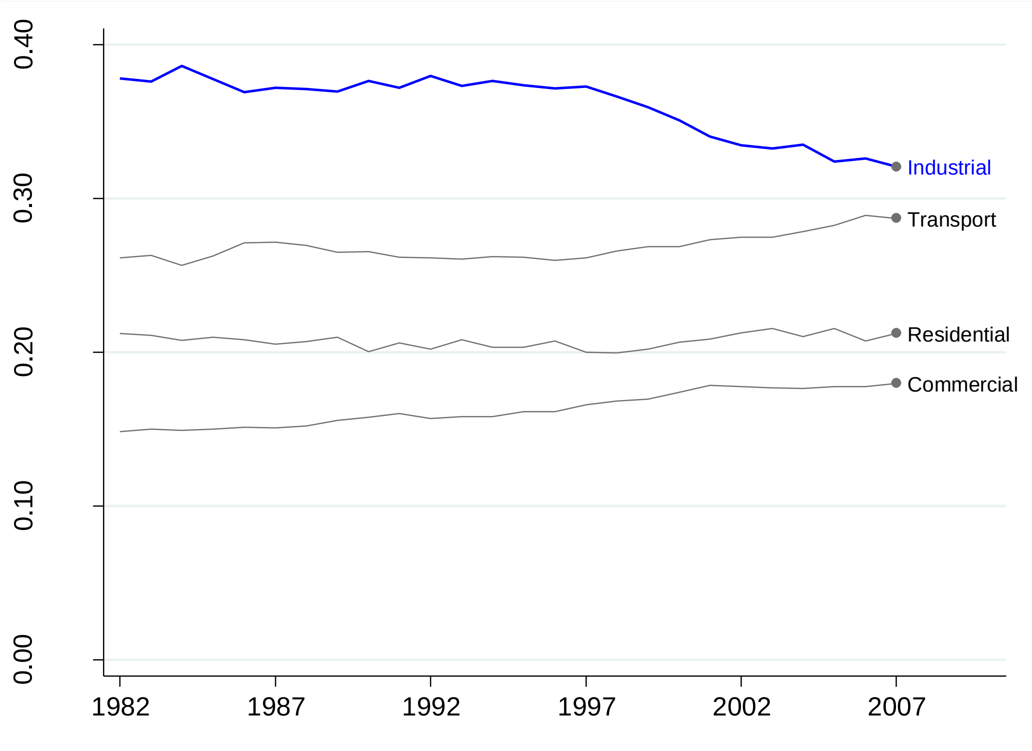


Figure 4. Total US Energy, Actual and Projected

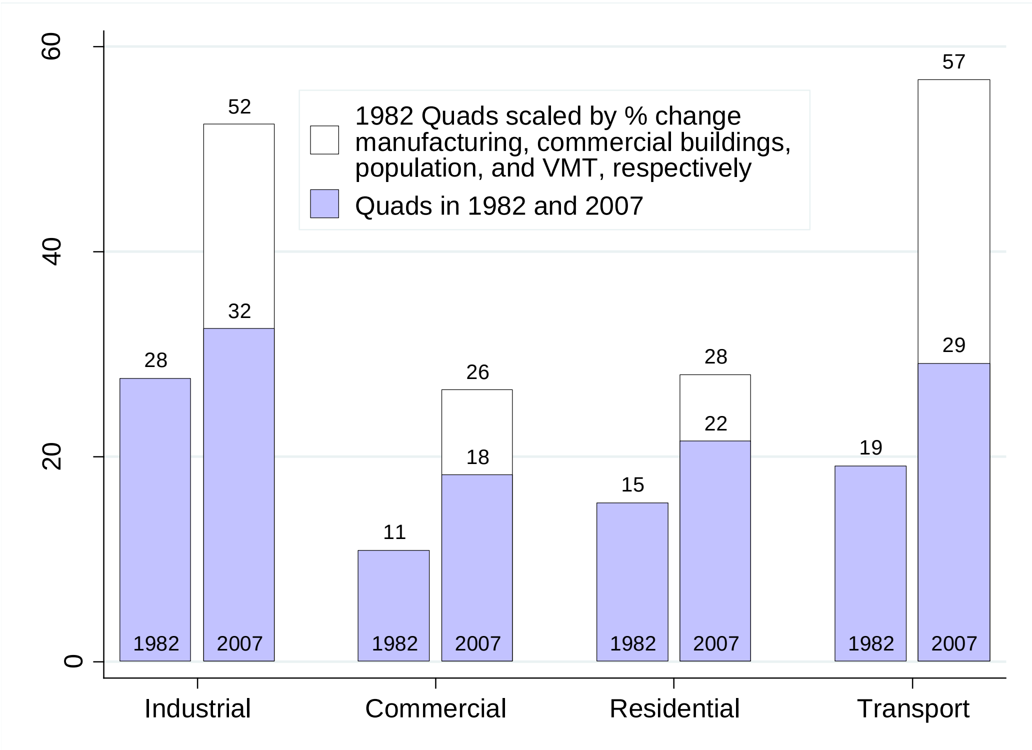


Figure 5. Scale and Deindustrialization Effects on Energy Intensity

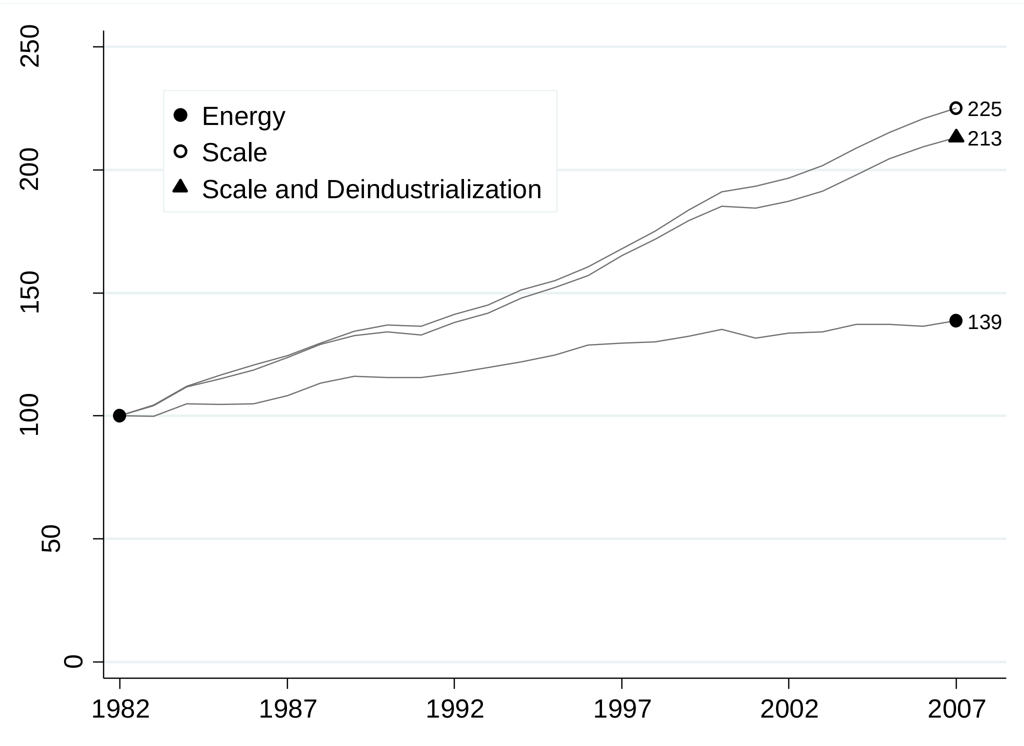


Figure 6. Deindustrialization Explain Little of the Decline in US Energy Intensity

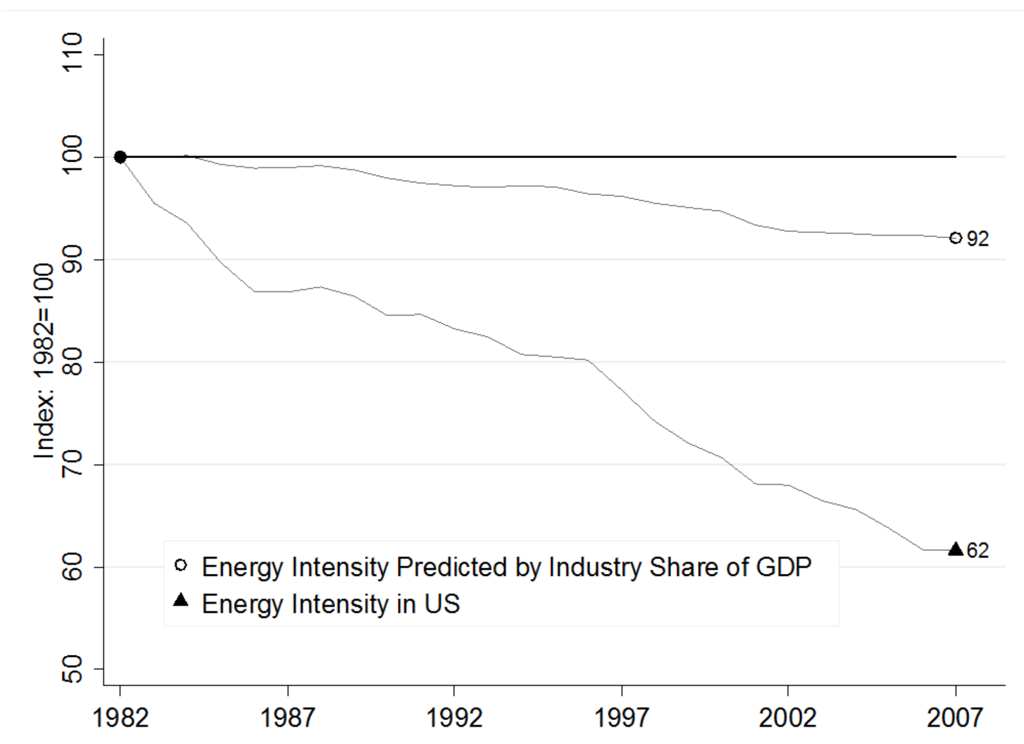


Figure 7. State by State, Changing Industry Shares and Energy Intensity

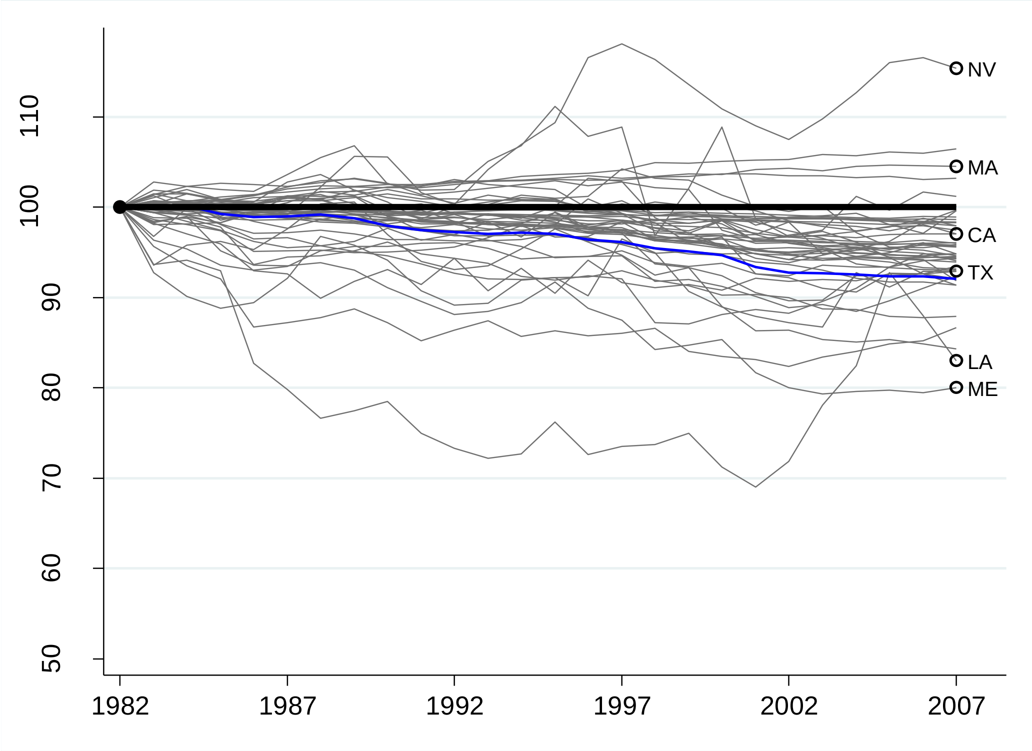


Figure 8. US States' Industrial Energy per Dollar of Output

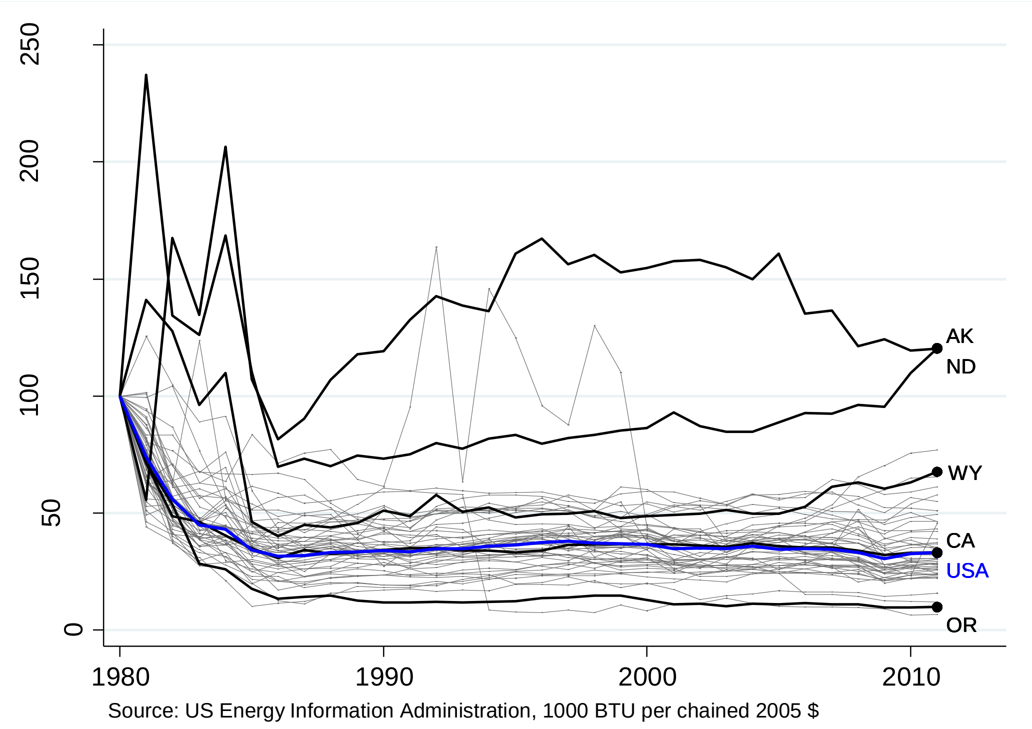


Figure 9. US States' Industrial Energy: Scale, Composition, Technique

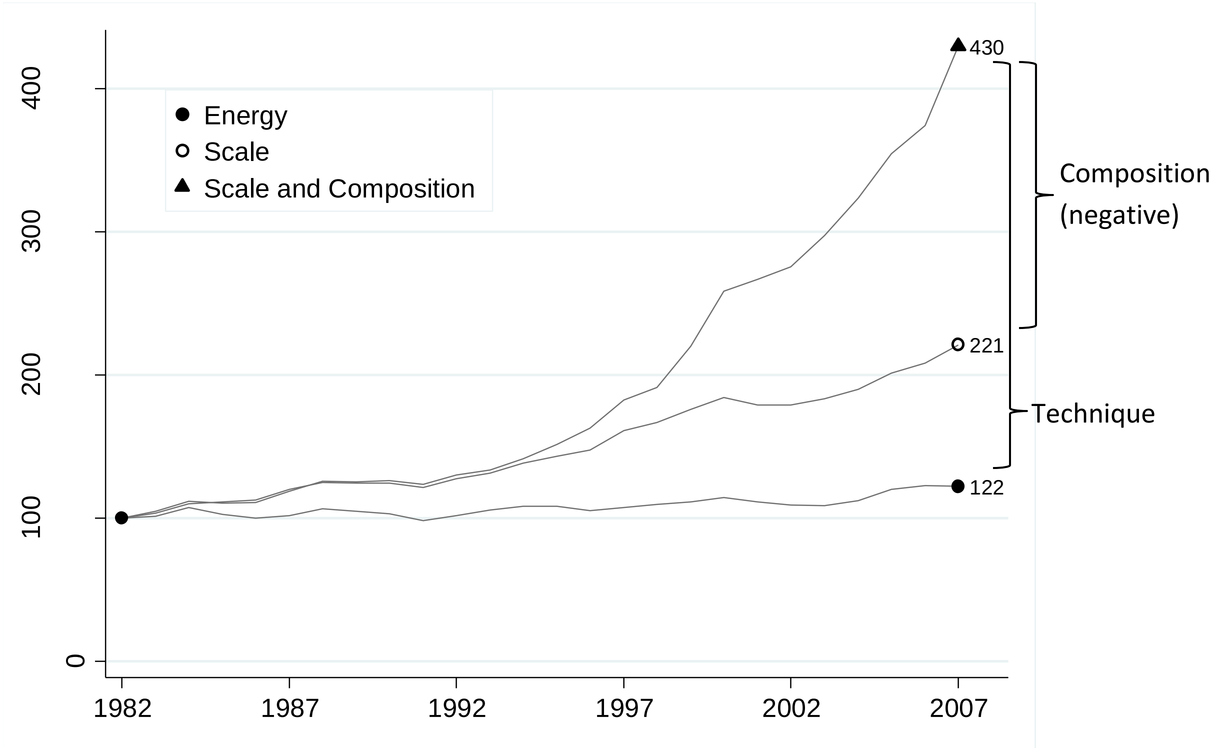


Figure 10. California Industrial Energy: Scale, Composition, Technique

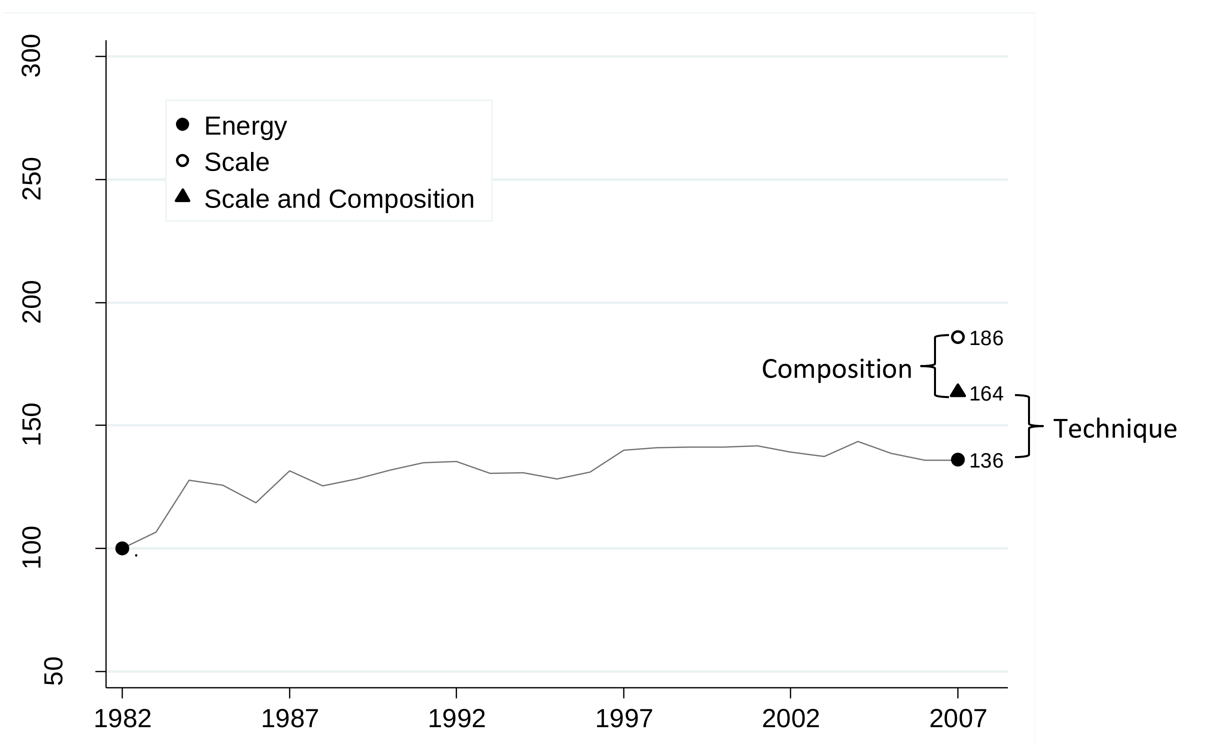
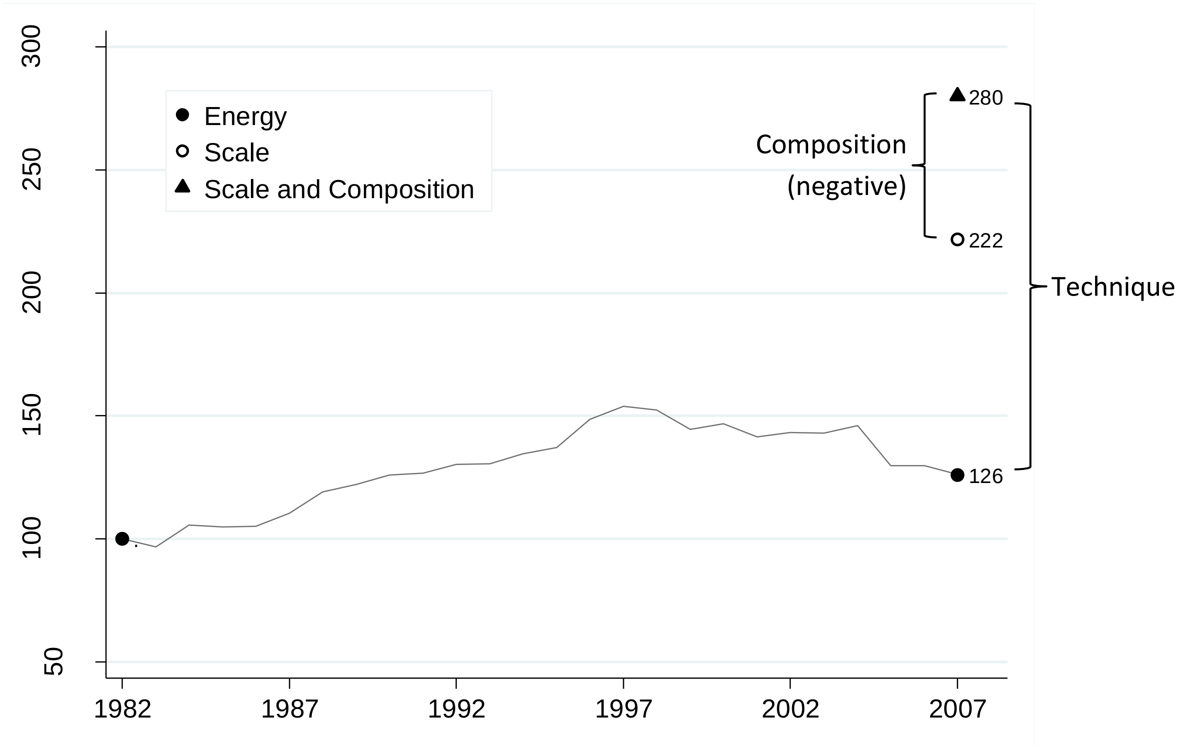


Figure 11. Texas Industrial Energy: Scale, Composition, Technique



Appendix Table A1. Industrial Energy Changes in US States 1982-2007

State (48 contiguous)	Economy-wide Energy Intensity: Pct Point Decline in Energy Intensity	Economy-wide Energy Intensity: Proportion due to declining share of industry in GDP	Manufacturing Energy Changes: Scale	Manufacturing Energy Changes: Composition	Manufacturing Energy Changes: Technique
	(1)	(2)	(3)	(4)	(5)
Alabama	32.6	0.26	111	63	2
Arizona	49.6	0.08	112	-127	556
Arkansas	35.0	0.23	115	92	10
California	45.0	0.07	136	22	28
Colorado	30.7	0.13	215	7	11
Connecticut	43.9	-0.07	69	-3	71
Delaware	38.2	0.14	125	-297	492
Florida	36.8	0.07	127	25	59
Georgia	36.6	0.19	150	54	73
Idaho	51.2	0.13	140	10	17
Illinois	38.1	0.15	100	3	51
Indiana	36.3	0.01	114	115	8
Iowa	28.9	0.10	171	24	-37
Kansas	34.3	0.01	113	8	39
Kentucky	14.0	0.37	161	31	125
Louisiana	19.2	0.88	121	34	-2
Maine	45.5	0.44	71	33	-54
Maryland	38.8	0.31	53	-28	160
Massachusetts	46.5	-0.10	79	49	47
Michigan	30.2	0.06	81	118	121
Minnesota	31.8	0.17	157	34	96
Mississippi	24.5	0.18	132	-70	117
Missouri	23.5	0.07	118	-13	42
Montana	12.3	1.09	161	-76	293
Nebraska	22.4	0.09	216	-41	-20
Nevada	41.8	-0.37	258	1055	750
New Hampshire	47.3	0.00	75	108	40
New Jersey	39.5	0.03	72	11	28
New Mexico	40.5	0.13	151	12	-127
New York	39.1	0.11	58	12	45
North Carolina	39.2	0.03	111	-7	49
North Dakota	-12.6	-0.63	297	-101	538
Ohio	36.4	0.17	78	13	72
Oklahoma	22.7	0.34	104	-9	69
Oregon	63.8	-0.02	85	148	78
Pennsylvania	35.4	0.24	89	16	28

Rhode Island	42.9	-0.15	62	2	62
South Carolina	29.8	0.23	144	-3	65
South Dakota	29.0	0.15	236	-57	-56
Tennessee	39.0	0.15	115	67	32
Texas	41.3	0.17	126	-58	154
Utah	42.4	0.13	112	57	131
Vermont	42.1	0.05	77	-16	102
Virginia	29.4	0.20	126	64	30
Washington	47.9	0.15	90	47	82
West Virginia	26.5	0.59	86	24	10
Wisconsin	35.3	0.11	99	18	112
Wyoming	17.0	0.30	131	-12	51

Sources: US Energy Information Administration, State Energy Data Systems (www.eia.gov/state/seds/seds-data-complete.cfm). US Census of Manufactures, 1982 and 2007.

Appendix Table A2. Prices and Regulations in US States 1982-2007

State	Prices 1982-2007 Δ	Prices 1982-2007 Avg	Year of first building code	PACE Index Avg	PACE Index Δ	Public Spending Shares Parks	Public Spending Shares Infrastruct	Share of pop in nonattainment counties	Indexes ACEEE	Indexes LCV	Economic Growth per Capita
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alabama	112	13	2005	1.19	-0.25	0.013	0.097	0.21	2.0	21.1	172
Arizona	116	16	2001	1.39	-1.72	0.022	0.120	0.88	11.5	32.8	178
Arkansas	132	13	1979	1.17	0.06	0.012	0.111	0.00	3.0	37.0	178
California	138	23	1978	0.90	0.03	0.018	0.092	0.94	33.0	76.5	168
Colorado	136	14	1978	1.01	-0.25	0.029	0.127	0.66	15.5	55.9	166
Connecticut	173	24	1999	0.67	0.32	0.015	0.104	1.00	33.0	81.6	200
Delaware	148	15	1979	1.30	-0.04	0.015	0.141	1.00	8.5	82.4	180
Florida	138	16	1979	1.21	-0.60	0.023	0.129	0.07	9.0	50.6	168
Georgia	119	13	1978	0.91	0.04	0.015	0.113	0.51	6.0	22.4	180
Idaho	171	9	2003	1.66	-0.05	0.015	0.133	0.10	10.5	38.1	193
Illinois	126	15	--	0.91	0.07	0.030	0.133	0.64	10.0	67.0	171
Indiana	102	13	1979	1.14	-0.16	0.018	0.102	0.45	5.0	29.9	176
Iowa	108	12	1978	0.96	0.05	0.018	0.135	0.00	16.5	54.2	188
Kansas	106	14	--	0.76	0.09	0.014	0.129	0.00	7.0	14.7	162
Kentucky	110	11	2005	0.99	0.13	0.014	0.117	0.29	6.5	24.6	161
Louisiana	151	14	1999	1.51	0.31	0.018	0.112	0.13	5.5	27.5	139
Maine	289	19	1980	1.55	0.41	0.010	0.119	0.00	15.5	58.8	168
Maryland	195	15	1981	1.17	-0.04	0.025	0.130	0.67	14.0	91.2	170
Massachusetts	184	25	1975	0.67	0.19	0.013	0.129	1.00	29.0	72.4	204
Michigan	115	16	1977	1.01	-0.11	0.014	0.093	0.48	7.5	74.1	149
Minnesota	118	13	1976	0.66	0.26	0.022	0.117	0.08	20.0	74.2	186
Mississippi	111	14	--	1.47	-0.33	0.010	0.109	0.00	1.0	35.3	173
Missouri	107	13	--	0.79	-0.02	0.018	0.126	0.29	2.0	30.4	160
Montana	233	10	1972	1.49	0.46	0.011	0.134	0.52	13.0	26.5	138

Nebraska	127	12	1980	0.83	0.09	0.013	0.104	0.00	6.5	11.8	181
Nevada	179	16	1978	0.63	0.03	0.032	0.142	0.88	14.5	60.5	140
New Hampshire	180	25	1977	0.75	-0.08	0.013	0.115	0.73	14.5	70.6	219
New Jersey	133	24	1977	0.82	-0.33	0.018	0.126	1.00	22.0	83.5	187
New Mexico	94	15	1978	1.64	-1.41	0.021	0.132	0.00	11.0	85.5	170
New York	155	18	1979	0.77	0.00	0.014	0.138	0.85	25.0	92.9	174
North Carolina	134	14	1973	0.82	-0.14	0.015	0.098	0.28	8.5	45.1	182
North Dakota	106	14	1977	0.77	-0.13	0.019	0.137	0.00	0.5	58.8	184
Ohio	129	13	1979	0.82	0.16	0.015	0.102	0.67	9.5	58.1	164
Oklahoma	130	12	1997	0.58	-0.18	0.017	0.110	0.00	3.5	18.2	141
Oregon	172	11	1974	1.22	-0.12	0.017	0.118	0.11	28.0	83.0	212
Pennsylvania	119	17	2004	0.91	-0.07	0.010	0.119	0.71	16.0	70.7	167
Rhode Island	156	25	1977	0.72	0.77	0.014	0.098	1.00	20.0	94.1	183
South Carolina	124	12	1979	0.99	-0.14	0.012	0.083	0.05	8.5	24.6	176
South Dakota	115	13	--	0.68	0.55	0.023	0.163	0.00	1.5	56.0	220
Tennessee	113	13	1978	1.10	-0.03	0.015	0.097	0.22	4.0	29.9	179
Texas	153	14	2000	1.39	0.22	0.014	0.118	0.51	17.5	19.4	153
Utah	102	12	1976	0.93	0.08	0.021	0.116	0.83	9.5	21.8	170
Vermont	166	21	1996	0.66	0.03	0.010	0.127	0.00	33.0	100.0	197
Virginia	108	12	1974	0.96	-0.03	0.019	0.139	0.21	6.0	60.4	179
Washington	238	9	1978	1.37	-0.19	0.020	0.122	0.12	27.0	80.1	157
West Virginia	101	11	1989	1.58	-0.27	0.012	0.123	0.40	6.5	58.1	155
Wisconsin	138	13	1978	0.89	0.06	0.019	0.123	0.33	17.0	70.1	173
Wyoming	129	10	1977	0.72	0.30	0.020	0.147	0.05	1.0	11.6	149