Energy Conservation in the United States: Understanding its Role in Climate Policy

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Abstract

Efforts to reduce carbon emissions significantly will require considerable improvements in energy intensity, the ratio of energy consumption to economic activity. Improvements in energy intensity over the past thirty years suggest great possibilities for energy conservation: current annual energy consumption avoided due to declines in energy intensity since 1970 substantially exceed current annual domestic energy supply.

I analyze a data set on energy intensity in the United States at the state level between 1970 and 2001 to disentangle the key elements of energy efficiency and economic activity that drive changes in energy intensity. Rising per capita income plays an important role in lowering energy intensity. Higher energy prices also are important. Price and income predominantly influence intensity through changes in energy efficiency rather than through changes in economic activity.

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I. Introduction

The objective of any policy to address global warming is to reduce greenhouse gas emissions in general and carbon emissions in particular. Since energy consumption is associated with over 98 percent of carbon emissions (Energy Information Administration (2006b), Table 5), any carbon policy must focus on energy use. Two channels exist by which energy related carbon emissions can be reduced: 1) shifting from high to low carbon-content fuel (fuel switching); and 2) reducing energy intensity, defined as the amount of energy consumed per dollar of GDP.[1]

Energy intensity can be reduced by one of two means. First, energy users can become more efficient at using energy whether in production or consumption. Second, the U.S. economy can shift away from more to less energy-intensive production and consumption activities. The goal of this paper is to analyze in greater detail the sources of and potential for improvements in energy intensity in the United States. I do this using state-level data on energy consumption between 1970 and 2001. As part of my empirical analysis, I isolate the two determinants of changes in energy intensity – efficiency improvements and changes in economic activity – to see which determinant has been more important in driving improvements in energy intensity in the past thirty years. I will refer to these as *efficiency* and *activity* determinants. Efficiency refers to the reduced energy use per unit of economic activity within a particular sector (e.g. industrial sector) while activity refers to the changing mix of economic activity (shift from energy intensive economic activity towards non-energy intensive economic activity) holding efficiency constant.

[1] A third channel is to reduce economic activity. This is not viewed as a desirable policy option.

It is well recognized that significant reductions in carbon emissions will require considerable improvements in energy efficiency. A recent study by the National Commission on Energy Policy and the Pew Center on Global Climate Change (2004) emphasized the need for improvements in energy efficiency as an important short-term strategy for reducing carbon emissions while waiting for more capital-intensive responses to come on-line in the longer-term. Pacala and Socolow (2004) present "stabilization wedges," activities that reduce carbon emissions so as to achieve stabilization of atmospheric carbon concentrations at 500 ppm. Each wedge has the potential to reduce 1 GtC/year after fifty years and seven wedges are required for stabilization, according to the authors. They present fifteen wedge options, four of which involve energy efficiency improvements and conservation. In fact, the authors argue that "[i]mprovements in efficiency and conservation probably offer the greatest potential to provide wedges." (p. 969) Energy efficiency improvements also factor into the Bush Administration's replacement of carbon emission targets with carbon intensity targets (carbon emissions relative to GDP). In 2002, the administration called for an eighteen percent reduction in carbon intensity (carbon emissions per dollar of GDP) over this decade. In a similar vein, the National Commission on Energy Policy (2004) recommended greenhouse gas emission reductions through the use of carbon emission intensity caps. In their proposal, the Commission recommends a gradual reduction in carbon intensity of 2.4 percent per year beginning in 2010. One of the key recommendations to contribute to this goal is enhanced energy efficiency. The NCEP recommendations form the basis for the plan proposed by Senator Jeff Bingaman (D-NM) to reduce carbon emissions.[2] Pizer (2005) makes an economic and political economy case for intensity targets for carbon emissions.

[2] Senator Bingaman's current proposal along with other carbon cap and trade proposals is described in

To appreciate the importance of improvements in energy intensity as a contributor towards reducing reliance on fossil fuels, consider the following thought experiment. Imagine that the United States had the same energy intensity in 2003 that it had in 1970. At that energy intensity, the United States would have consumed 186.8 quadrillion BTUs of energy (or quads) in 2003. In actuality, the United States consumed 98.2 quads of energy in that year. This thought experiment suggests that we "conserved" 88.6 quads of energy in 2003 through reductions in energy intensity. Table 1 compares these energy savings with domestic energy production in that year.

Table 1. Domestic Energy Supply in 2003

Source	Amount (quads)	Percentage of Total Supply
Fossil Fuels	56.4	35.4
Nuclear	8.0	5.0
Renewables	6.2	3.9
Improvement in Energy Intensity Since 1970	88.6	55.7
Total	159.2	100.0

Source: Energy Information Administration and author's calculations. See text for details.

Treating energy efficiency as a supply substitute, Table 1 points out that it has held the 2003 United States's requirement for fossil, nuclear, and other supplies to less than half the amount had these economic changes not occurred. Of course, one cannot attribute all of the reductions in energy intensity to conservation and efficiency activities. Some of the reductions in energy intensity have come about due to shifts in economic activity (shifts from manufacturing, for example, to services) that have nothing to do with energy considerations. The share of industrial energy use in total energy consumption has fallen from 44 percent in 1970 to 33 percent in 2003 (Energy Information Administration

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Paltsev, Reilly, Jacoby et al. (2007).

(2006a)). But the experiment is suggestive of the importance of energy conservation as a strategy for reducing energy consumption in general and carbon emissions in particular.

In the next section, I decompose changes in energy intensity into efficiency and activity components. I find that improvements in energy efficiency are responsible for between 2/3 and 3/4 of the decline in energy intensity since 1970 at the national level. In the following section, I undertake an econometric analysis of the drivers of changes in energy intensity, efficiency, and activity. I find that rising per capita income and higher energy prices contribute to declines in energy intensity, primarily through improvements in energy efficiency. The regressions imply a short-run price elasticity of energy demand of -0.11 and a long-run elasticity of -0.30.

II. Decomposing Energy Intensity Into Structural and Efficiency Effects

Energy intensity (e_t) is a function of energy efficiency and economic activity. Specifically,

$$e_t \equiv \frac{E_t}{Y_t} = \sum_i \left(\frac{E_{it}}{Y_{it}} \right) \left(\frac{Y_{it}}{Y_t} \right) \equiv \sum e_{it} s_{it} \tag{1}$$

where E_t is aggregate energy consumption in year t, E_{it}, energy consumption in sector i in year t, Y_t is GDP in year t, and Y_{it} is a measure of economic activity in sector i in year t. Note that energy consumption in the sectors must sum to aggregate energy consumption but the measures of economic activity need not sum to GDP (indeed, they need not be in the same units). Equation 1 simply states that aggregate energy intensity is a function of sector specific energy efficiency (e_{it}) and sectoral activity (s_{it}). This emphasis on decomposing changes in intensity into efficiency and activity components is analogous to the decomposition employed by Antweiler, Copeland and Taylor (2001) in their analysis

of the impact of free trade on the environment. They distinguish between scale, technique, and composition effects. My efficiency and activity measures correspond to the technique and composition effects in the Antweiler et al. paper.

Decomposing changes in energy intensity into components based on improvements in energy efficiency and changes in economic activity became a major research topic beginning in the mid-1970s.[3] Ang and Zhang (2000) note that early researchers calculated the importance of changes in economic activity by computing energy intensity in a given year holding sectoral energy intensities constant. Differences between this hypothetical energy intensity and measured energy intensity were attributed to changing economic activity. Boyd, McDonald, Ross et al. (1987) were the first to use index number theory to provide a theoretically based decomposition. They used a Divisia Index number methodology and like earlier methodologies (which were essentially based on a Laspeyres Index), these decompositions had residual terms which could account for a considerable degree of the variability in the underlying index of energy intensity change.[4] Research in this area has increased sharply with Ang and Zhang noting that their 2000 survey found 124 studies, up from 51 in their 1995 survey.

Index number theory has a long history in economics with Irving Fisher being a key contributor to the literature. Fisher (1921) identified two properties that he argued an index number should satisfy. First, "[t]he formula should *work both ways* as to the two factors, prices and quantities." And second, it "should *work both ways* as to time." (p. 534, italics in original) The first property (known as factor reversal) is equivalent to

[3] Ang and Zhang (2000) provide a survey of this literature. My discussion of this literature draws on their survey.

[4] Greening, Davis, Schipper et al. (1997) compare six different decomposition methodologies on the basis of their residuals.

perfect decomposition (i.e. no residual). The second property means that an index computed between, say 1970 and 2000 should be the inverse of the same index computed between 2000 and 1970. Fisher proposed what has become known as the Fisher Ideal index which satisfies both these properties. This index is the geometric mean of the Laspeyres and Paasche indexes. Boyd and Roop (2004) first used a Fisher Ideal index as the basis for an exact decomposition of changes in energy intensity into changes in energy efficiency and economic activity. I use this approach at both the national level and at the state-level in this study. My analysis builds on Boyd and Roop's work in several ways. First, I focus on total energy consumption rather than consumption in the manufacturing sector alone. Second, I construct and analyze indexes at the state level and over a much longer time period. Third, unlike previous work in this area I use regression analysis to measure the impact of changes in economic and climate variables on the components of changes in energy intensity.[5]

Denoting e_0 as the aggregate energy intensity for a base year, I construct an energy intensity index as e_t/e_0. As noted above, Fisher (1921) showed that his ideal index satisfied perfect decomposition of an expenditure index into a price and quantity index. In my context, a Fisher ideal index provides a perfect decomposition of an aggregate energy intensity index into economic efficiency $\left(F_t^{eff}\right)$and activity $\left(F_t^{act}\right)$ indexes with no residual:[6]

$$\frac{e_t}{e_0} \equiv I_t = F_t^{eff} F_t^{act} \quad . \tag{2}$$

[5] Sue Wing and Eckaus (2004) decompose energy intensity at the national level for 35 industries and analyze the drivers of efficiency and economic activity using results from estimating a quasi-fixed input cost model. While based on a structural underlying production model, their decomposition is not exact and, more important, some of the impact of changes in efficiency show up in their structural term making it difficult to determine through which avenues energy prices affect energy intensity.

[6] See appendix for details of index constructions.

This is a very attractive property for an energy intensity index since other intensity indexes have residual terms that make difficult an interpretation of the relative importance of compositional effects and efficiency effects.

This decomposition suggests a way to attribute changes in energy consumption arising from improvements in energy intensity. Recall that my thought experiment in the Introduction suggested energy savings of 88.6 quads of energy in 2003 given the improvements in energy intensity between 1970 and 2003. Using my notation from this section, this change in energy (ΔE_t) is

$$\Delta E_t = E_t - \hat{E}_t \tag{3}$$

where $\hat{E}_t$ is the level of energy consumption that would have occurred had energy intensity remained at 1970. I attribute the change in energy between efficiency and activity as follows:

$$\Delta E_t = \Delta E_t\left(\frac{\ln(F_t^{act})}{\ln(I_t)}\right) + \Delta E_t\left(\frac{\ln(F_t^{eff})}{\ln(I_t)}\right) \equiv \Delta E_t^{act} + \Delta E_t^{eff} \tag{4}$$

II A. Analysis at the National Level

I first provide an example of the Fisher decomposition at the national level using data from 1970 through 2003. I partition aggregate energy use into residential, commercial, industrial, and transportation sectors and use economic activity measures appropriate for each energy sector as discussed in the next two sub-sections.[7] Table 2 shows my sectors and summary statistics for the measures of economic activity in that

[7] The Energy Information Administration attributes electricity consumption to these four sectors based on usage. The degree of disaggregation affects the relative importance of efficiency and economic activity changes. This disaggregation, for example, obscures shifts from energy intensive manufacturing to non-energy intensive manufacturing. Such shifts will show up here as efficiency improvements. I discuss this further below.

sector that I use for the decomposition as well as summary statistics on sectoral energy efficiency.

Table 2. Sectors for Decomposition Analysis at National Level

	Economic Activity			Sectoral Energy Efficiency		
Sector	**Measure**	**Mean**	**Standard Deviation**	**Measure**	**Mean**	**Standard Deviation**
Residential	Aggregate Personal Consumption Expenditures ($2000 in billions)	4,448	1,440	BTUs per dollar ($2000)	4,090	861
Commercial	Value Added in Commercial Sector ($2000 in billions)	4,663	1,754	BTUs per dollar ($2000)	2,847	440
Industrial	Value Added in Industrial Sector ($2000 in billions)	1,883	276	BTUs per dollar ($2000)	17,156	2328
Transportation	Vehicle Miles Traveled (billions of miles)	1,953	550	BTUs per VMT	11,512	1,787
Total	GDP ($2000 in billions)	6,597	2,003	BTUs per dollar ($2000)	13,333	2,717

Data from 1970 to 2003. The industrial sector includes manufacturing, agriculture, forestry, fishing, mining, and construction. The commercial sector includes transportation, communication, wholesale and retail trade, finance, services, and government.
Source: Energy consumption data from the Energy Information Agency. Economic data from Bureau of Economic Analysis. Transportation data from Federal Highway Administration.

Figure 2 shows the results of this decomposition analysis for the United States taking 1970 as the base year for the analysis.[8] Aggregate energy intensity in 2003 was 53 percent of its intensity level in 1970. The activity index was 86 percent of its level in 1970 while the efficiency index was 61 percent of its 1970 level. In other words, had the composition of economic activity not changed between 1970 and 2003, energy intensity would have been 61 percent of its 1970 level. The forty percent improvement in energy intensity was due to improvements in energy efficiency. Similarly, had energy efficiency

[8] See Appendix Table A1 for the index numbers at the national level.

been fixed at its 1970 levels for all sectors, changes in economic activity would have led to a 14 percent reduction in energy intensity.

Using equation (4), I can allocate the change in energy use (relative to the amount that would have been consumed had energy intensity remained at its 1970 level) between efficiency and economic activity. Based on this approach, roughly one-quarter of the 88.6 quads of energy reduction arising from improvements in energy intensity can be attributed to changes in the composition of economic activity and the remaining three-quarters to improvements in energy efficiency.[9] Figure 3 shows the contributions of improvements in energy efficiency and compositional changes on energy savings between 1970 and 2003. Initial reductions in energy consumption can be attributed almost entirely to improvements in efficiency.[10] By 1990 changes in economic activity were beginning to contribute substantially to energy savings with major increases in the activity component around 1997.

II B. Analysis at the State Level

To further investigate the forces contributing to changes in energy intensity, I next turn to an analysis at the state-level.[11] This allows me to take advantage of variation across states as well as across time. I will also use the state-level index data for an

[9] This is conditional on the particular choice of sectors in this analysis. To see whether finer disaggregation within the industrial sector affects the results, I constructed Fisher efficiency and activity indexes for the manufacturing sector disaggregating at the two-digit SIC level between 1974 and 1997 (data available from Energy Information Administration at http://www.eia.doe.gov/emeu/mecs/). Energy intensity (energy consumption per dollar of real value added in manufacturing) fell by the same percentage in manufacturing as it did in the economy as a whole between 1974 and 1997. Based on my Fisher indexes for this disaggregation, improvements in efficiency were responsible for 82 percent of the improvement in energy intensity and changes in economic activity for 18 percent as of 1997. Thus it does not appear that I am imparting significant bias by failing to disaggregate the industrial sector further.

[10] In fact, in some early years, changes in economic activity led to increases in energy consumption.

[11] An additional reason for a state-level analysis is provided by Auffhammer and Steinhauser (2005). They find that carbon emission predictions are more accurate when built up from state-level predictions than when constructed at the national level.

econometric analysis in the next section. Table 3 shows my sectors and measures of economic activity that I use to construct the indexes.

Table 3. Sectors for Decomposition Analysis at State Level

	Economic Activity			Sectoral Energy Efficiency		
Sector	**Measure**	**Mean**	**Standard Deviation**	**Measure**	**Mean**	**Standard Deviation**
Residential	personal income ($2000 in billions)	105.4	131.9	BTUs per dollar ($2000)	3,018	832
Commercial	earnings by place of work in commercial sector ($2000 in billions)	53.0	72.8	BTUs per dollar ($2000)	4,227	961
Industrial	earnings by place of work in industrial sector ($2000 in billions)	26.0	28.9	BTUs per dollar ($2000)	23,014	18,355
Transportation	Vehicle Miles Traveled (billions of miles)	34.2	38.0	BTUs per VMT	11,576	2,906
Total	personal income ($2000 in billions)	105.4	131.9	BTUs per dollar ($2000)	14,721	6,812

Data from 1960 to 2001 for the 48 continental states. The industrial sector includes manufacturing, agriculture, forestry, fishing, mining, and construction. The commercial sector includes transportation, communication, wholesale and retail trade, finance, services, and government. Sectoral energy efficiency summary statistics weighted by personal income.
Source: See Table 2.

I maintain the same sectors (residential, commercial, industrial, and transportation) but adapt the methodology for a state-level analysis in two ways. First, my measure of energy intensity is the ratio of total energy consumption to personal income. I would prefer to use gross state product (GSP) but GSP only go back to 1977 and the series has a structural break in 1997 resulting from the shift from SIC to NAICS in that year. BEA specifically advises against piecing together the pre and post-1997 data into a single time-series.[12] Second, I use earnings by place of work in the commercial (industrial) sector as my measure of economic activity in the commercial (industrial) sector.

[12] One result of this change in definition is that a measure of national energy intensity built up from state-level data differs somewhat from the intensity measures reported earlier in the paper. Aggregating from the

Table 4 provides summary statistics on the energy intensity index for the 48 continental states for various years between 1960 and 2001.

Table 4. State-Level Energy Intensity						
Year	**Mean**	**S.D.**	**Min**	**Max**	**Annual Change (Cumulative)**	**Annual Change (Decade)**
1960	1.000	0.0	1.000	1.000	-	-
1970	0.977	0.098	0.774	1.390	-0.23%	-0.23%
1980	0.835	0.091	0.584	1.002	-0.90%	-2.02%
1990	0.713	0.129	0.474	1.178	-1.12%	-1.57%
2001	0.615	0.127	0.433	1.098	-1.18%	-1.34%
Author's calculations.						

Several facts emerge from this table. First, (unweighted) average energy intensity has been declining at a 1.2 percent annual rate between 1960 and 2001. Not surprisingly, the decrease was more rapid in the '70s and '80s given the oil price shocks of 1973 and 1979. Second, the variation in intensity across states is rising. The coefficient of variation, for example, doubles between 1970 and 2001. Third, while some states have reduced their energy intensity dramatically (Rhode Island's intensity fell by nearly 57 percent between 1960 and 2001), other states have failed to reduce their energy intensity at all (North Dakota's intensity increased by nearly 10 percent over this period). Figure 4 shows the changes in energy intensity for the eight states with the largest and smallest declines in energy intensity across this period. Not only are the trends different, but the patterns of change are different. Explaining this variation across states is a major focus of the econometric analysis below.

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state-level, energy intensity in 2001 is 62 percent of its 1970 value, as compared to 53 percent using national data. Trends, however, are unaffected by the change and the correlation between the two time series between 1970 and 2001 is 0.99.

Next I disaggregate these trends into efficiency and activity components. Table 5 provides summary information on the energy efficiency index. Energy efficiency worsened between 1960 and 1970. Holding economic activity constant, changes

Table 5. State-Level Energy Efficiency Index

Year	Mean	S.D.	Min	Max	Annual Change (Cumulative)	Annual Change (Decade)
1960	1.000	0.0	1.000	1.000	-	-
1970	1.019	0.108	0.826	1.535	0.19%	0.19%
1980	0.909	0.117	0.621	1.253	-0.48%	-1.14%
1990	0.819	0.164	0.535	1.417	-0.66%	-1.04%
2001	0.736	0.163	0.506	1.442	-0.74%	-0.97%

Author's calculations.

in efficiency led to a 0.2 percent per year on average increase in energy consumption relative to economic activity in the states. This trend was reversed in the 1970s which saw a 1.1 percent per year improvement in efficiency. Efficiency continued to improve though at a declining rate in the 1980s and 1990s. As with overall energy intensity, the variation in efficiency improvements increasingly varied across states over time with the coefficient of variation more than doubling between 1970 and 2001. Finally, a number of states experienced declines in energy efficiency (holding economic activity constant). North Dakota's index, on the other hand, rose by 44 percent between 1960 and 2001, an annual increase of .9 percent.[13] Figure 5 shows the changes in the efficiency index for the states with the largest and smallest declines in their index.

Table 6 provides information on the economic activity index.

[13] The Fisher efficiency index for North Dakota suddenly starts rising in 1984 and is explained by a sharp increase in industrial energy use, most of which is coal. This coincides with the opening of the Great Plains Synfuels plant in Beulah, ND. The plant consumes over 6 million tons of coal – about 90 percent of the industrial coal consumed in the state – to produce 54 billion cubic feet of syngas annually. If this plant were not operating, North Dakota's efficiency index would have been 0.86 in 2001 rather than 1.44.

Table 6. State-Level Energy Activity Index						
Year	**Mean**	**S.D.**	**Min**	**Max**	**Annual Change (Cumulative)**	**Annual Change (Decade)**
1960	1.000	0.0	1.000	1.000	-	-
1970	0.960	0.034	0.861	1.023	-0.41%	-0.41%
1980	0.922	0.052	0.712	1.008	-0.41%	-0.40%
1990	0.874	0.055	0.750	0.992	-0.45%	-0.53%
2001	0.840	0.060	0.692	1.092	-0.42%	-0.36%
Author's calculations.						

There is much less variation over time in the reduction in energy intensity due to changes in economic activity relative to the variation in energy intensity or in the energy efficiency index. There is also less variation across the states at any point in time. While the coefficient of variation doubles between 1970 and 2001, it is roughly one-third the coefficient of variation in any given year for the energy efficiency index. Figure 6 shows the change over time in the activity index for the four states with the largest and smallest changes in the index respectively.

As with the national data, we can measure the relative contributions of improved energy efficiency and structural change to improved energy intensity and consider the variation across the states. Table 7 reports summary statistics on the shares for the states in 2001.

Table 7. Efficiency and Activity Contributions to Changes in Intensity				
Share Due to:	Mean	Std. Dev.	Min	Max
Efficiency	64%	17%	28%	106%
Activity	36%	17%	-6%	72%
Author's calculations for 2001. These are unweighted averages. ND and WY excluded. Full data in appendix table A2.				

Efficiency contributes to the roughly two-thirds of the decline in intensity between 1960 and 2001. I excluded North Dakota and Wyoming from the table as they are significant outliers.[14]

Before turning to a regression analysis of variation in state-level energy intensity, I briefly discuss the only other study of which I am aware that addresses state-level changes in energy intensity. Bernstein, Fonkych, Loeb et al. (2003) run fixed effects regressions at the state-level between 1977 and 1999 of energy intensity (in log form) on various variables (gross state product, energy prices, climate data, etc.) and compute a measure of "residual energy intensity," the difference between observed log energy intensity and predicted intensity (including observed variables and year effects but not fixed effects). Residual energy intensity in their view "may contain useful information about the role of policy in lowering energy intensity." (p. 21) My dataset improves on the Bernstein et al. dataset in several ways. First, it is a more comprehensive dataset running from 1960 to 2001 (1970 to 2001 for regressions below using energy prices). Second, their study uses gross state product as a measure of economic activity despite a structural break in GSP occurring in 1997. Third, their residential and transportation energy intensity measures are energy use per capita rather than consumption relative to a measure of economic activity. Fourth, their study's weather data are at the census region rather than state level (as in my dataset).[15] Fifth, I use the Fisher ideal index decomposition to separate out efficiency and activity effects explicitly. The advantage of

[14] As noted above, North Dakota's energy intensity is skewed by a very large synfuels plant. Wyoming's intensity is also skewed – though to a lesser extent – by the coal mining operations in that state. Wyoming produces roughly 40 percent of the nation's coal. Because Wyoming's efficiency index is greater than 1, the state's efficiency contribution is negative. Including these two states does not change the average share contributions appreciably. It does drive up the standard deviation sharply.

[15] I am indebted to Maximilian Auffhammer for providing me with his state-level data on heating and cooling degree days. Auffhammer obtained these data directly from the National Oceanic and Atmospheric Administration. See Auffhammer and Steinhauser (2005) for more information on these data.

the approach I propose is that changes in economic activity may be driven in part by energy price changes. I can test for this indirect effect of energy prices on improved energy intensity by regressing the activity index on prices (along with other variables) to measure the impact. I turn to the econometric analysis now.

III. State-Level Empirical Results

I've shown how changes in energy intensity can be decomposed into efficiency and activity components. What drives changes in these variables? To help answer this question, I present results from various regressions of the different indexes on economic and weather related variables. Regression variables include energy prices and per capita income, both in log form. For my energy price variable I use the average weighted price of energy in the state based on fuel uses as computed by EIA. This price includes excise taxes. Under the assumption that states are price takers in energy markets, I interpret the regressions as energy demand-style regressions.[16] In the spirit of the environmental Kuznets curve literature, I include the log of income and the log squared to account for possible non-linearities in the response of energy use to income.

In addition to price and income, I include climate data to account for different demands for heating and cooling in homes and businesses. I include a number of other socioeconomic variables that could account for differences in energy intensity. First, I include the log of the capital-labor ratio and the squared log capital-labor ratio to allow for differences in capital intensity to affect energy intensity. This reflects a finding that capital and energy are likely substitutes in production (see Thompson and Taylor (1995)

[16] I constructed a Hausman test for energy price exogeneity by running a two-stage least squares regression using a synthetic energy price as instrument for the energy price. The instrument is the average of state energy prices of those states adjacent to a given state in each year. Regression results are not appreciably changed by the use of this instrument and I fail to reject price exogeneity at the 95 percent level.

on this point).[17] Second, I include variables measuring population growth in the state. In particular, I construct two dummy variables that measure whether a state is in the top or bottom quartile of states for population growth in a given year.[18] Fast growing states may be adding infrastructure that is more energy efficient than slow growing states. On the other hand fast-growing states may experience more dislocation from growth (e.g. traffic congestion) that increases energy intensity. I also indirectly allow for different vintaging of the capital stock. Slower turn over of the capital stock means that a state is likely to have less energy-efficient capital on average. Conversely, fast growing states may have a newer, more energy-efficient capital stock and so lower energy intensity. I include two dummy variables that measure whether a state is in the top or bottom quartile of states for investment relative to their capital stock in a given year Finally, I allow for a quadratic trend to account for secular changes in energy intensity over time. Summary statistics for the regression data are in Table 8.

[17] Antweiler, et al. (2001) include the capital-labor ratio in their pollution regressions under the assumption that capital and pollution are complements (their composition effect). Here, capital and energy consumption are more likely substitutes in the medium to long run.

[18] The two variables are inversely correlated as expected but not perfectly collinear with a correlation coefficient of -0.33.

Table 8. Summary Statistics				
Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Intensity	0.762	0.140	0.433	1.166
Efficiency	0.846	0.133	0.505	1.182
Activity	0.899	0.064	0.692	1.131
Real energy price ($1982-84/million BTUs)	6.414	1.568	2.454	12.532
Real income per capita ($1982-84)	13100	2703	6758	24235
Heating degree days (HDD) (1000)	5.215	1.995	0.476	9.921
Cooling degree days (CDD) (1000)	1.087	0.769	0.073	3.845
ln(income per capita)	9.460	0.203	8.818	10.096
ln(income per capita)^2	89.5	3.8	77.8	101.9
ln(heating degree days)	1.550	0.505	-0.742	2.295
ln(cooling degree days)	-0.175	0.753	-2.617	1.347
ln(energy price)	1.829	0.244	0.898	2.528
ln(capital labor ratio)	11.043	0.168	10.622	11.643
ln(capital labor ratio)^2	121.986	3.715	112.817	135.552

Source: See Table 2. Summary statistics on 46 continental states excluding ND and WY between 1970 and 2001 (1,472 observations). State-level capital stocks are constructed by S. Yamarik as described in Garofalo and Yamarik (2002) and available on his website: http://www.csulb.edu/~syamarik/ .

Table 9 presents results for the first set of regressions. The first three columns present results from a regression of the intensity index on price, income, and (possibly) other variables. The first regression includes only price and income variables along with a quadratic in trend. A ten percent rise in energy prices is associated with a 1.2 percentage point drop in energy intensity. In addition, energy intensity is falling with respect to income given the range of income in the data set.

Table 9. Index Regressions									
	Intensity			**Efficiency**			**Activity**		
ln(price)	-0.115 (0.012)	-0.100 (0.012)	-0.108 (0.008)	-0.144 (0.014)	-0.134 (0.014)	-0.126 (0.010)	0.021 (0.007)	0.028 (0.007)	0.009 (0.006)
ln(per capita income)	4.861 (0.813)	4.101 (0.898)	1.873 (0.545)	5.111 (0.937)	4.235 (1.026)	4.091 (0.693)	0.741 (0.471)	0.896 (0.521)	-1.533 (0.399)
ln(per capita income)^2	-0.264 (0.056)	-0.224 (0.047)	-0.113 (0.029)	-0.278 (0.049)	-0.231 (0.054)	-0.241 (0.037)	-0.039 (0.025)	-0.048 (0.028)	0.091 (0.021)
ln(HDD)	--	-0.019 (0.007)	0.089 (0.013)	--	-0.027 (0.008)	0.077 (0.017)	--	0.006 (0.004)	0.022 (0.010)
ln(CDD)	--	-0.004 (0.005)	-0.014 (0.006)	--	-0.007 (0.005)	-0.012 (0.008)	--	0.001 (0.003)	-0.005 (0.004)
ln(K/L)	--	6.182 (1.317)	2.150 (0.813)	--	4.159 (1.504)	4.217 (1.034)	--	2.403 (0.763)	-2.747 (0.595)
ln(K/L)^2	--	-0.277 (0.059)	-0.099 (0.037)	--	-0.186 (0.068)	-0.188 (0.047)	--	-0.108 (0.034)	0.119 (0.027)
pop grwth: high	--	-0.037 (0.006)	0.004 (0.004)	--	-0.036 (0.007)	0.005 (0.005)	--	-0.005 (0.003)	-0.010 (0.002)
pop grwth: low	--	-0.002 (0.006)	0.004 (0.003)	--	0.021 (0.006)	0.016 (0.004)	--	-0.024 (0.003)	-0.014 (0.002)
inv: high	--	-0.017 (0.006)	-0.005 (0.003)	--	-0.027 (0.006)	-0.013 (0.003)	--	0.009 (0.003)	0.009 (0.002)
inv: low	--	0.007 (0.006)	0.002 (0.003)	--	0.013 (0.006)	0.005 (0.003)	--	-0.006 (0.003)	-0.003 (0.002)
trend	-0.013 (0.001)	-0.015 (0.001)	-0.010 (0.001)	-0.006 (0.001)	-0.007 (0.001)	-0.003 (0.001)	-0.008 (0.0007)	-0.009 (0.001)	-.008 (.0006)
trend^2	0.0001 (0.00004)	0.0002 (0.0056)	0.0001 (0.00002)	-0.0000 (0.00005)	0.00002 (0.00005)	0.00005 (0.00003)	0.0001 (0.00002)	.0002 (.00002)	.00006 (.00002)
Fixed Effects	no	no	yes	no	no	yes	no	no	yes
Adj. R^2	0.620	0.643	0.885	0.440	0.482	0.740	0.386	0.421	0.680
Regressions are on the forty-six continental states excluding ND and WY. All regressions include an intercept. Standard errors are reported in parentheses.									

In column 2, I add additional variables to control for other factors affecting energy intensity. The first thing to note is that the price and income variables are not affected by the inclusion of these variables. These additional variables are important, however, in helping to explain the variation in the intensity index. Somewhat counter intuitively, energy intensity is lower in colder climates and also lower in warmer climates though the coefficient on cooling degree days is not statistically significant in this regression. Intensity is first increasing and then decreasing with higher capital-labor ratios in this regression. At the mean value for ln(K/L) in the sample, intensity is rising with K/L.

The population growth variables suggest that fast-growing states have below-average energy intensity. States in the top quartile for population growth in a given year have an intensity index 3.7 percentage points lower than other states. It appears that the infrastructure investment associated with fast growth offsets any dislocations arising from that growth. The investment dummies enter as expected. High investment states have an intensity index 1.7 percentage points lower than states in the middle of the investment distribution while low investment states have a slightly higher index (0.7 percentage points).

Finally, the energy intensity index is trending down at an annual rate of 1.5 percentage points though the trend rate is slowing. By 2001, the trend had slowed to 0.4 percentage points.

Adding state fixed effects (column 3) changes the story a bit. The price coefficient is essentially unchanged but the income coefficients are much smaller. The marginal impact at the mean, however, is nearly twice as large in this regression (-0.265

as opposed to -0.137). Energy intensity continues to fall with income across the range of income in the dataset. The coefficients on the capital-labor ratio are also considerably smaller but again the turning point is not appreciably affected. The heating degree day variable now has the expected sign and is quite large. A one standard deviation increase in this variable raises the intensity index by 4.5 percentage points. Cooler states have lower energy intensity but the magnitude of the effect is smaller than for heating degree days. Energy intensity continues to first increase and then decrease with the capital labor ratio with the turning point unchanged from the second regression.

The sign on the high population growth dummy is now positive but not statistically significant. It continues to be the case that high investment states have lower energy intensity than low investment states though the size of the effect is muted with the inclusion of state fixed effects. Energy intensity continues to trend down initially at a rate of roughly 1 percentage point per year but declining to roughly one-quarter of a percentage point per year by the end of the sample.

As noted above, energy intensity changes in part from improvements in energy efficiency and in part from changes in economic activity. I now turn to an analysis of the forces affecting each of these components of energy intensity. The next three regressions focus on the efficiency index. Recall that this index measures the change in energy intensity holding constant the mix of economic activity in each state over time. The first regression includes just price and income variables along with a quadratic trend. Comparing this regression to the comparable intensity regression (column 1), it appears that price plays most of its role in reducing energy intensity through the efficiency channel. In fact, the semi-elasticity is larger in the efficiency index regression than in the

intensity index regression. That price drives intensity changes through the efficiency channel is robust to the model specification. Adding other explanatory variables in the OLS regression does not change matters. Coefficient estimates in the fifth column also are quite similar to the estimates from the intensity index regression in the second column.

Adding state fixed effects (column 6) has a similar impact as in the intensity index regression. The heating degree day variable now has a positive coefficient and is statistically significant. The effect continues to be large. Energy intensity through the efficiency channel first rises and then falls as states become more capital intensive. The turning point occurs at a value of ln(K/L) of 11.18, just above the mean value in the dataset of 11.06. This turning point corresponds to a capital-labor ratio of $71,690 per worker, just above the 75^{th} percentile in the dataset.

The fast growing states appear to have higher energy intensity through the efficiency channel though the coefficient is not statistically significant. Slow growing states have higher efficiency indexes by 1.6 percentage points. High investment states continue to have lower efficiency indexes than low investment states with the difference between the top and bottom quartile coefficients equal to 1.8 percentage points. Finally, adding fixed effects continues to dampen the downward trend in the index (as it did for the intensity regression).

The last three columns report results from the activity index regressions. Energy prices have little impact on the activity index and in fact have a counterintuitive sign. Once state fixed effects are added, the coefficient on price is no longer statistically significant. It appears that energy prices influence energy intensity primarily through the

efficiency channel. In the regression with state fixed effects, the activity index first falls and then rises with income with a turning point at 8.42. Again this is well below the range of income in the sample indicating that the activity index rises with income. This may be a manifestation of a sunbelt effect where income and manufacturing activity are both migrating to the sunbelt states.

Fast growing states appear to have lower energy intensity through the activity channel than the average state. But slow growing states also have lower energy intensity. Two forces may be at work that could also be viewed as a sunbelt effect. Energy intensive manufacturing activity has exited from northern, previously industrialized sections of the country to faster-growing regions in the south and southwest. This exodus would manifest as a negative coefficient on the low growth states. But as industry moves into the south and southwest, it installs more energy efficient capital leading to the negative coefficient on the high growth states.

The capital labor coefficients indicate that the activity index is first falling and then rising with the capital-labor ratio once fixed effects are included in the regression. The turning point occurs at 11.54 in the regression with a trend. This is just above the mean of ln(K/L) in the dataset. The investment variables are not surprising as energy intensive economic activity also tends to be capital intensive. Finally, the downward trend in this index is substantial ranging from roughly one percent per year at the beginning of the sample period to 0.6 percent per year by 2000. This is perhaps not surprising given the trend away from manufacturing in the U.S. economy over this period.[19]

[19] The share of manufacturing income in private industry income has fallen from 31 percent in 1970 to 19 percent in 2000.

One difficulty with the specification in Table 9 is that energy intensity is assumed to respond immediately to changes in economic variables. More realistically, energy prices likely affect energy intensity with some lag. The next set of regressions provide results from a partial adjustment model. Let y_{it}^* be the desired energy intensity in state *i* in year *t*. I assume that the desired intensity is a function of the variables included in previous regressions now subsumed in the vector x_{it}. The relationship then is

(5) $$y_{it}^* = x_{it}'\beta + \varepsilon_{it}$$

where $\varepsilon_{it} = \alpha_i + \nu_{it}$ includes a state fixed effect. The adjustment process related actual energy intensity y_{it} to desired intensity as follows:

(6) $$y_{it} - y_{i,t-1} = (1-\lambda)(y_{it}^* - y_{i,t-1})$$

where λ is a measure of the adjustment process in moving from desired to actual energy intensity.

Combining equations (x) and (x) yields the following estimating equation:

(7) $$y_{it} = x_{it}'\tilde{\beta} + \lambda y_{i,t-1} + \tilde{\varepsilon}_{it}$$

where $\tilde{\beta} = (1-\lambda)\beta$ is the short-run impact of changes in *x* on *y* and $\frac{\tilde{\beta}}{1-\lambda}$ measure the long-run impacts. The error term is $\tilde{\varepsilon} = (1-\lambda)\varepsilon$. Because of the lagged dependent variable, fixed effect regressions will produce biased estimates. I report estimates using the Arellano-Bond estimator for the three energy indexes in Table 10.

I report results for the reduced form specification (price and income variables only) as well as the full model. The price coefficients are robust to the exclusion of the additional variables. Income, however, is affected by their exclusion. The first two regressions suggest that the short-run semi-elasticity of intensity with respect to price is

-0.06. The long-run estimate (-0.18 in the full specification) is nearly double the estimate from Table 9 suggesting that the price coefficient in that regression is a mixture of a short run and long run effect. While the income coefficients differ across the two regressions, energy intensity continues to fall with income throughout the sample. In the first regression the turning point is well below the minimum value in the dataset while it is above the maximum value in the second regression. The slope of the intensity index with respect to income at the mean value of income is also similar in the two regressions (-0.186 in the first regression and -0.176 in the second).

The other variables in the second regression have similar effects as in the Table 9 regressions. One difference is that the turning point for the capital labor ratio is now below the minimum value in the sample so that energy intensity is falling with respect to K/L for all states in all years, consistent with the view that capita and energy are substitutes.

The efficiency and activity index regressions continue to tell a similar story as in Table 9. Most of the impact of changing prices on intensity works through the efficiency channel. While energy intensity is everywhere falling with K/L in the full specification, it is first rising and then falling in the efficiency regression (column 4) and falling and then rising in the activity regression (column 6).

While the population growth dummies have little impact, the high investment states continue to have lower energy intensity both overall and through the efficiency channel. The opposite is true, however, in the activity regression. High investment states have higher energy intensity working through the economic activity channel than do low

investment states. As noted above, this may simply reflect the fact that energy intensive industries are also capital intensive.

Summing up, the long-run semi-elasticity of energy intensity with respect to price is -0.179 while the corresponding long-run responses for efficiency and activity are -0.133 and -0.046 respectively. Changes in energy price affect energy intensity through changes in efficiency more than changes in the mix of economic activity. Second, it appears that rising income contributes to declines in energy intensity, primarily through the efficiency channel.

Table 10. Partial Adjustment Model						
	Intensity		**Efficiency**		**Activity**	
ln(price)	-0.064 (0.005)	-0.063 (0.005)	-0.059 (0.006)	-0.062 (0.006)	-0.018 (0.003)	-0.014 (0.003)
ln(per capita income)	0.079 (0.529)	-1.614 (0.666)	-1.476 (0.614)	-1.720 (0.816)	2.122 (0.287)	1.488 (0.363)
ln(per capita income)^2	-0.014 (0.028)	0.076 (0.035)	0.058 (0.032)	0.072 (0.043)	-0.106 (0.015)	-0.071 (0.019)
ln(HDD)	--	0.059 (0.009)	--	0.042 (0.010)	--	0.024 (0.005)
ln(CDD)	--	0.001 (0.004)	--	0.004 (0.005)	--	-0.004 (0.002)
ln(K/L)	--	0.686 (0.887)	--	1.736 (1.111)	--	-2.534 (0.513)
ln(K/L)^2	--	-0.033 (0.040)	--	-0.078 (0.050)	--	0.112 (0.023)
population growth: high	--	-0.0002 (0.003)	--	-0.0003 (0.004)	--	-0.003 (0.002)
population growth: low	--	-0.0003 (0.002)	--	0.001 (0.003)	--	0.001 (0.001)
inv: high	--	-0.004 (0.002)	--	-0.008 (0.002)	--	0.003 (0.001)
inv: low	--	0.004 (0.002)	--	0.008 (0.002)	--	-0.003 (0.001)
trend	0.0006 (0.0008)	0.0005 (0.0007)	0.003 (0.001)	0.003 (0.001)	-0.004 (0.0004)	-0.004 (0.001)
trend^2	-0.00003 (0.00002)	-0.00004 (0.00002)	-0.00004 (0.00002)	-0.00004 (0.00002)	-0.00002 (0.00001)	0.00002 (0.00001)
adjustment parameter	0.677 (0.025)	0.648 (0.025)	0.534 (0.025)	0.531 (0.026)	0.730 (0.019)	0.694 (0.019)
Long Run Price Effect	-0.198 (0.021)	-0.179 (0.020)	-0.126 (0.014)	-0.133 (0.014)	-0.068 (0.012)	-0.046 (0.011)
Regressions are on the forty-eight continental states excluding ND and WY. All regressions assume state fixed effects. Arellano-Bond regressions are run and standard errors reported in parentheses.						

It is straightforward to show that the elasticity of demand for energy with respect to price equals the price coefficient from the intensity regression divided by the intensity index. Table 11 presents short and long-run price elasticities from the regressions with trend in Table 10 assuming the average state index level in 2001.

Table 11. Price Elasticities			
	Intensity	Efficiency	Activity
SR	-0.107	-0.087	-0.017
LR	-0.303	-0.187	-0.055
Elasticities based on estimated price coefficients from Table 10. Values of weighted average intensity, efficiency, and activity are .59, .71, and .84 respectively.			

Price elasticities from the intensity regressions are most comparable to estimates of price elasticities in the existing literature. Bjorner and Jensen (2002) cite estimates from a survey by Atkinson and Manning (1995) of median elasticity estimates of -0.5.

How important are the price effects from these regressions? To get a feel for this, we can do a back of the envelope calculation of the five-year consequences of a 50 percent permanent increase in energy prices. From the intensity regressions with trend in Table 10, the price coefficients suggest that a fifty percent increase in real energy prices would bring about a 7.3 percentage point decline in energy intensity on average relative to 2001. If $\Delta\left(\frac{E}{Y}\right)\frac{1}{e_0}$ = -0.073, then

$$\Delta\left(\frac{E}{Y}\right)\frac{1}{e_0} = -.073 = \left(\frac{\Delta E}{E} - \frac{\Delta Y}{Y}\right)\frac{E}{Ye_0}$$

or

$$\frac{\Delta E}{E} = \frac{-.073}{I} + \frac{\Delta Y}{Y}$$

The most recent *Annual Energy Outlook* (Energy Information Administration (2007)) assumes that personal income will grow at a 3.1 percent annual rate. Using this growth rate and the state average energy intensity of .59 for 2001 (weighted by energy consumption), energy consumption would be 4 percent higher than today at the end of five years. Had the energy intensity ratio stayed the same between the two periods

energy use would have grown by 16 percent, the rate that income grew. Obviously, this is a rough calculation but suggests the magnitude of energy efficiency improvements in response to price increases.

A second policy experiment we can consider is whether the Bush Administration reduction in carbon intensity is feasible without substantial policy intervention. The trend coefficients suggest that absent changes in price, income, or weather conditions, energy intensity will trend downward over this decade by a little over 6 percent. Absent changes in price or income, the Administration's goal will not likely be met. Growth in income, however, suggests we should observe a larger decline in energy (and thus carbon) intensity. In fact carbon intensity fell by 15 percent between 1990 and 2000 suggesting that little policy intervention may be required to achieve the Bush Administration's goal of an 18 percent reduction in carbon intensity.[20]

VI. Conclusion

This paper is a first cut at understanding the forces driving improvements in energy intensity in the United States since 1970. It builds on a large literature in energy decomposition analysis in two ways. First, it is the only analysis of changes in energy intensity at the state level using a perfect decomposition methodology. Second, this study uses econometric methods to identify the drivers of changes in efficiency and economic activity indexes.

I find that rising per capita income contributes to improvements in energy efficiency and intensity and that prices also play a key role. Neither price nor income has an appreciable impact on the mix of economic activities and – more importantly –

[20] As a (near) mid-decade check, carbon intensity has fallen by 6 percent between 2000 and 2004. See EIA (2006b).

changes in the mix of economic activity are considerably less important than improvements in efficiency over this time period to explain improvements in energy intensity.

Finally, it is not clear why higher income should lead to lower energy intensity since I'm controlling for the mix of economic activity in the efficiency regression. The reduction in energy intensity as income rises is not simply a shift away from manufacturing to services (or some other shift from energy using to energy saving technology) but rather something more intrinsic to activities within each of the four energy consumption sectors. Conducting the type of decomposition analysis that I've done in this study at a more disaggregated level is an important area for future research to explore this question more deeply. This study, however, at the minimum suggests that such an analysis is feasible and likely to be highly productive.

Appendix: Constructing the Fisher Indexes

Denoting e_0 as the aggregate energy intensity for a base year, I construct an energy intensity index as e_t/e_0. Following Diewert (2001), it can be shown that we can decompose the intensity index into efficiency and activity indexes if 1) we can construct sectors that account for all energy use in the economy without overlap (i.e. a partition); and 2) there exists a set of economic activity measures (Y_{it}) with which to construct a measure of energy intensity. Note that these economic activity measures do not need to form a partition.

To construct the Fisher Ideal index, I first construct Laspeyres and Paasche composition and efficiency indexes. The Laspeyres indexes are

$$L_t^{act} = \frac{\sum_i e_{i0} s_{it}}{\sum_i e_{i0} s_{i0}} \quad \text{(A1)}$$

$$L_t^{eff} = \frac{\sum_i e_{it} s_{i0}}{\sum_i e_{i0} s_{i0}} \quad \text{(A2)}$$

and the Paasche indexes are

$$P_t^{act} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{it} s_{i0}} \quad \text{(A3)}$$

$$P_t^{eff} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{i0} s_{it}}. \quad \text{(A4)}$$

The Laspeyres indexes use a base period fixed weight while the Paasche indexes use an end period. The Fisher Ideal indexes are then given by

$$F_t^{act} = \sqrt{L_t^{act} P_t^{act}} \quad \text{(A5)}$$

$$F_t^{eff} = \sqrt{L_t^{eff} P_t^{eff}}. \quad \text{(A6)}$$

As noted above, Fisher (1921) showed that his ideal index satisfied perfect decomposition of an expenditure index into a price and quantity index. In our context, a Fisher ideal index provides a perfect decomposition of an aggregate energy intensity index into economic activity and efficiency indexes with no residual:

(A7) $$\frac{e_t}{e_0} \equiv I_t = F_t^{act} F_t^{eff} \quad .$$

Table A1. U.S. Energy Intensity Indexes			
Year	**Intensity**	**Activity**	**Efficiency**
1970	1.00	1.00	1.00
1971	0.99	1.00	0.99
1972	0.98	1.01	0.98
1973	0.97	1.01	0.96
1974	0.95	1.00	0.95
1975	0.93	1.00	0.92
1976	0.93	1.01	0.92
1977	0.91	1.01	0.90
1978	0.89	1.01	0.88
1979	0.87	0.99	0.87
1980	0.84	0.99	0.85
1981	0.80	0.99	0.81
1982	0.78	1.00	0.79
1983	0.75	0.98	0.77
1984	0.73	0.98	0.75
1985	0.70	0.97	0.73
1986	0.68	0.95	0.72
1987	0.68	0.95	0.71
1988	0.68	0.96	0.71
1989	0.68	0.95	0.71
1990	0.66	0.94	0.70
1991	0.66	0.93	0.71
1992	0.65	0.92	0.71
1993	0.65	0.92	0.71
1994	0.63	0.92	0.69
1995	0.63	0.92	0.69
1996	0.63	0.92	0.69
1997	0.60	0.91	0.66
1998	0.58	0.88	0.67
1999	0.57	0.87	0.66
2000	0.56	0.87	0.65
2001	0.54	0.86	0.63
2002	0.54	0.86	0.63
2003	0.53	0.86	0.61
See text for construction			

Table A2. Efficiency and Activity Contributions to Changes in Intensity		
State	**Efficiency**	**Activity**
WY	-258%	358%
IA	28%	72%
ME	31%	69%
LA	33%	67%
WV	40%	60%
IN	43%	57%
NJ	43%	57%
SD	46%	54%
SC	48%	52%
NE	51%	49%
OK	54%	46%
GA	54%	46%
MS	55%	45%
MT	55%	45%
WI	56%	44%
AR	56%	44%
FL	57%	43%
PA	60%	40%
KY	60%	40%
AL	61%	39%
IL	61%	39%
OH	62%	38%
WA	65%	35%
ID	66%	34%
VA	67%	33%
NC	67%	33%
KS	67%	33%
NH	68%	32%
TX	68%	32%
MD	69%	31%
NV	71%	29%
TN	72%	28%
MN	72%	28%
NM	73%	27%
DE	74%	26%
CT	77%	23%
MI	78%	22%
OR	78%	22%
RI	80%	20%
NY	80%	20%
UT	81%	19%
CO	81%	19%
CA	82%	18%
MA	86%	14%
AZ	89%	11%
MO	94%	6%
VT	106%	-6%
ND	392%	-292%
Author's calculations. See text for details.		

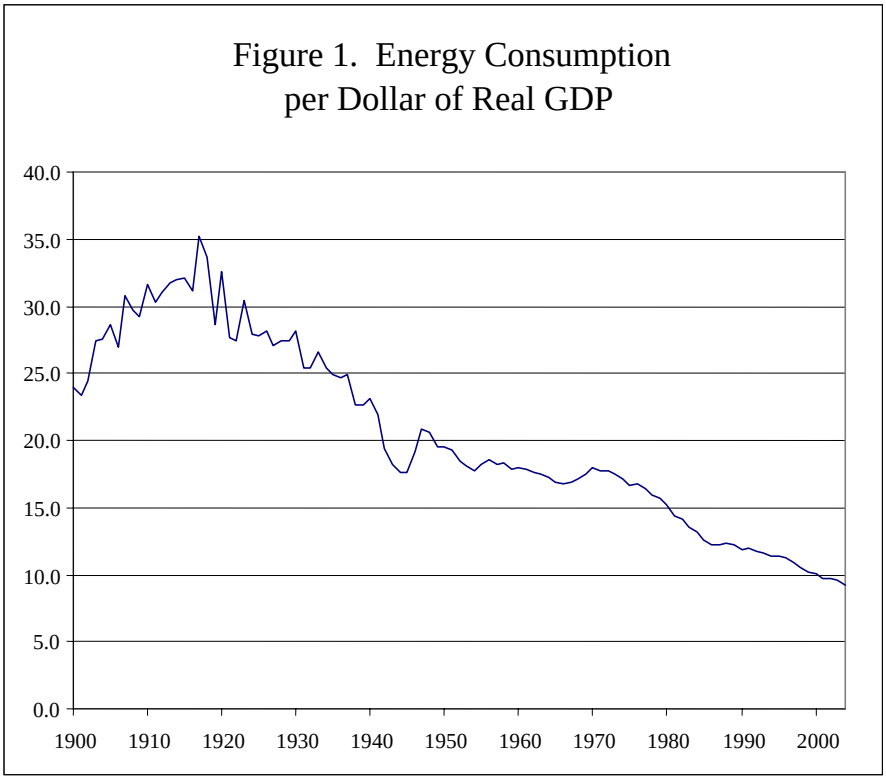

Figure 1. Energy Consumption
per Dollar of Real GDP
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

Figure 2. Aggregate Energy Intensity

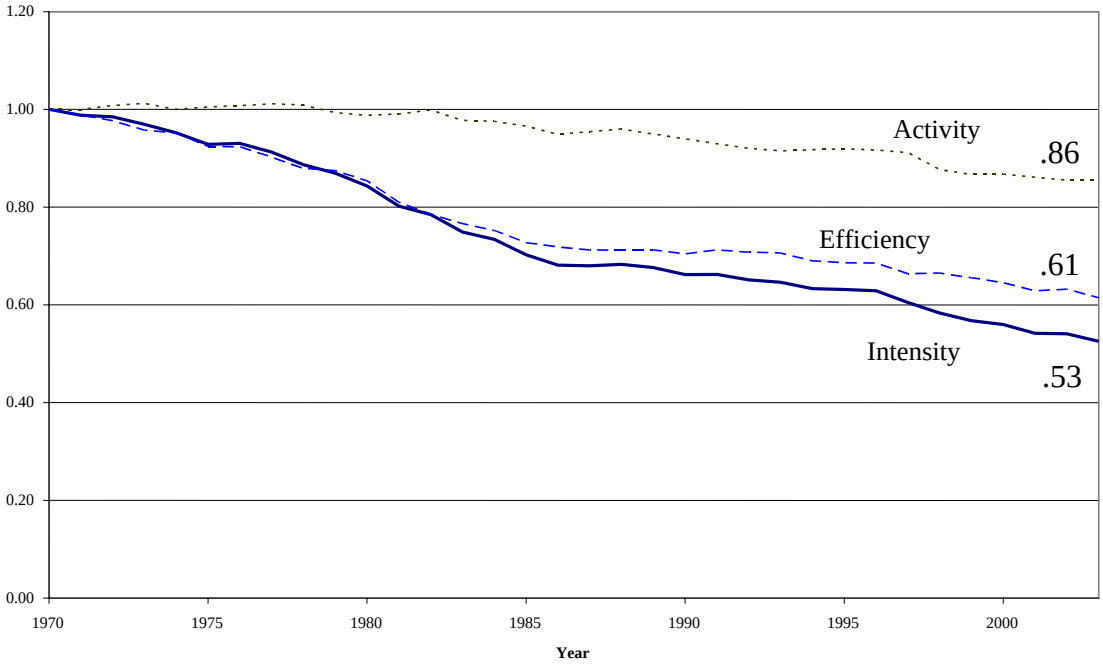


Figure 3. Energy Savings
Relative to 1970 Intensity

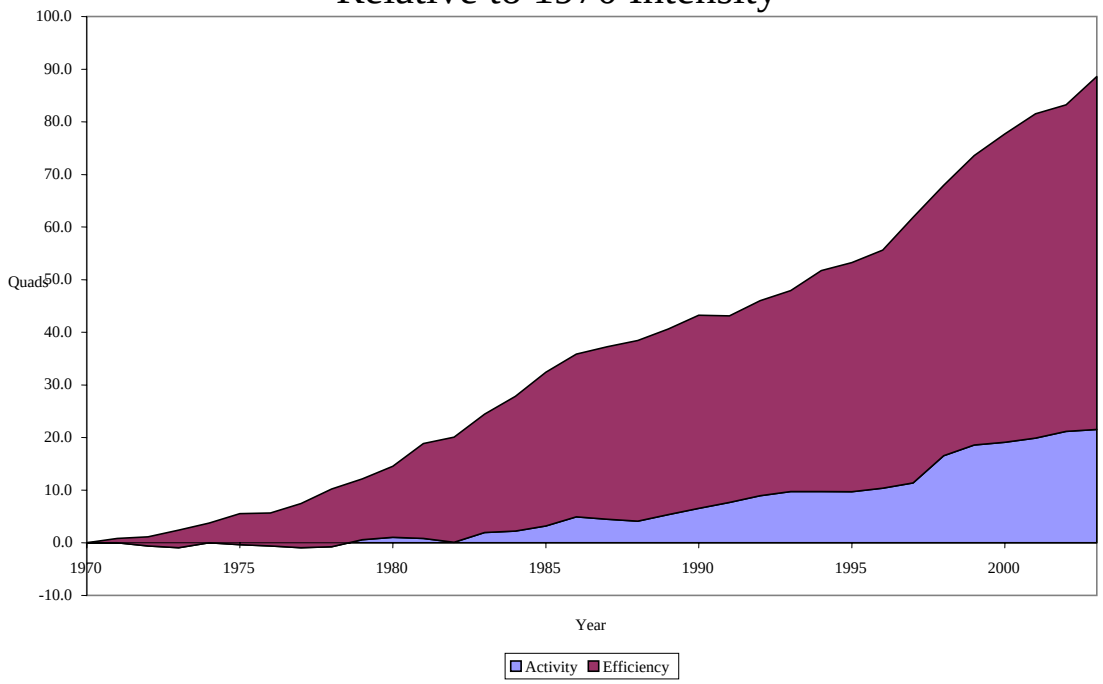


Figure 4. State Level Intensity Trends

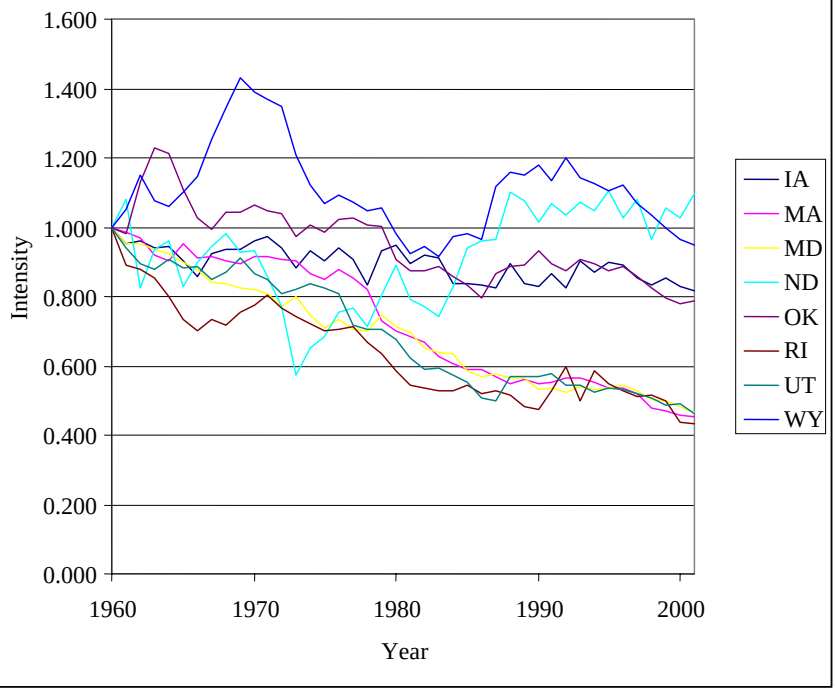


Figure 5. State Level Efficiency Trends

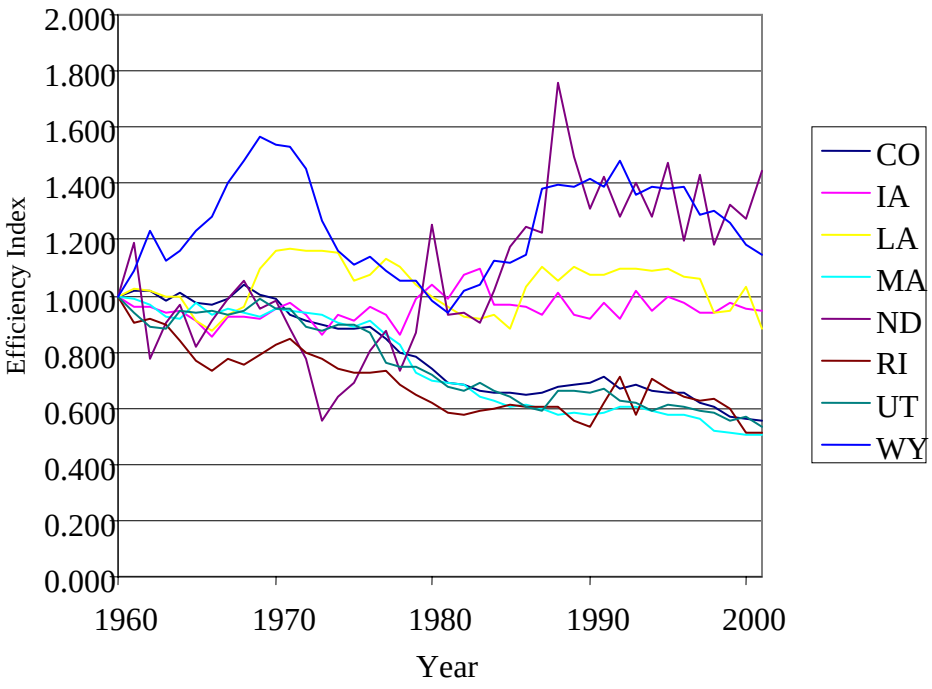
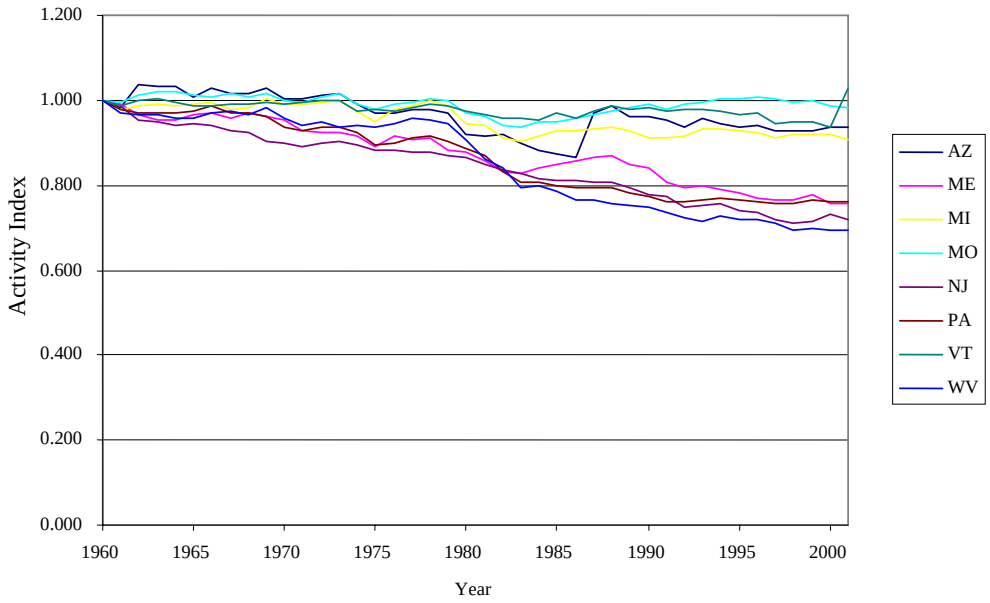


Figure 6. State Level Activity Trends



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