An Empirical Analysis of Energy Intensity and Its Determinants at the State Level

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Aggregate energy intensity in the United States has been declining steadily since the mid-1970s and the first oil shock. Energy intensity can be reduced by improving efficiency in the use of energy or by moving away from energy-intensive activities. At the national level, I show that roughly three-quarters of the improvements in U.S. energy intensity since 1970 results from efficiency improvements. This should reduce concerns that the United States is off-shoring its carbon emissions.

A state-level analysis shows that rising per capita income and higher energy prices have played an important part in lowering energy intensity. Price and income predominantly influence intensity through changes in energy efficiency rather than through changes in economic activity. In addition, the empirical analysis suggests that little policy intervention will be needed to achieve the Bush Administration goal of an 18 percent reduction in carbon intensity by the end of this decade.

1. INTRODUCTION

Energy intensity – the ratio of energy consumption to GDP – has long been of interest to energy researchers. Understanding the drivers of energy consumption and energy intensity has been a major focus of research activity for the past thirty years and one approach commonly used is a decomposition methodology that allows one to separate out structural shifts in the economy from more fundamental improvements in our use of energy. This decomposition has contrib-

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uted to our understanding of the extent to which changes in manufacturing and other economic activities have reduced the demand for energy as opposed to improvements in our use of energy. While these indexes are useful for understanding trends in energy consumption as well as trends in economic activity that influence energy demand, we have limited understanding of the economic forces that drive changes in these indexes over time.

This paper contributes to our understanding of this literature by undertaking an econometric analysis of an intensity index constructed at the state level as well as indexes constructed from a decomposition of the intensity index that disentangles changes in energy use within a sector and changes in sectoral activity over time. As part of my analysis, I isolate two key 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.

My goal in this paper is to identify the key economic forces driving changes n the efficiency and activity components of energy intensity. As a secondary goal, I relate the parameters estimated in my econometric analysis to underlying price and income elasticities of demand. Finally, I draw insights from the econometric analysis on policy issues relating to energy demand and climate change.

To carry out this analysis, I analyze a data set on energy consumption at the state-level data between 1970 and 2001. I undertake an econometric analysis of the drivers of changes in energy intensity, efficiency, and activity at the state level. 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. The regressions also have implications for current climate policy as I discuss in the conclusion.

2. DECOMPOSING ENERGY INTENSITY INTO EFFICIENCY AND ACTIVITY EFFECTS

Energy intensity (e_t) can be written as a function of energy efficiency and economic activity components. Specifically,

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

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.

Ang and Zhang (2000) provide an extensive survey of the energy decomposition literature. They 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 and Hanson (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. Research using some sort of index decomposition methodology 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) proposed what has become known as the Fisher Ideal index. The Fisher Ideal Index is the geometric mean of the Laspeyres and Paasche indexes and has the desirable property that it effects an exact decomposition. In Fisher's case, this was a decomposition of an expenditure index into price and quantity 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 apply this decomposition at both the national and 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.[1]

1. 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. An analysis, however, of their index series with mine show a high correlation at the national level (personal communication with Sue Wing, August, 2007). That our two papers come to different conclusions about the relative importance of activity versus efficiency changes in driving changes in intensity is a puzzle yet to be solved.

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 (F_t^{eff}) and activity (F_t^{act}) indexes with no residual:[2]

$$\frac{e_t}{e^0} \equiv I_t = F_t^{eff} F_t^{act}. \tag{2}$$

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.[3]

This decomposition suggests a way to attribute changes in energy consumption arising from improvements in energy intensity. Define energy savings (ΔE_t) due to changes in energy intensity as

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

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

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

Equation 4 allows me to attribute energy savings to improvements in efficiency and changes in economic activity. I present estimates of this attribution for the United States in the next section.

3. ANALYSIS AT THE NATIONAL LEVEL

Before turning to an analysis of state-level data, I 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 appendix.[4]

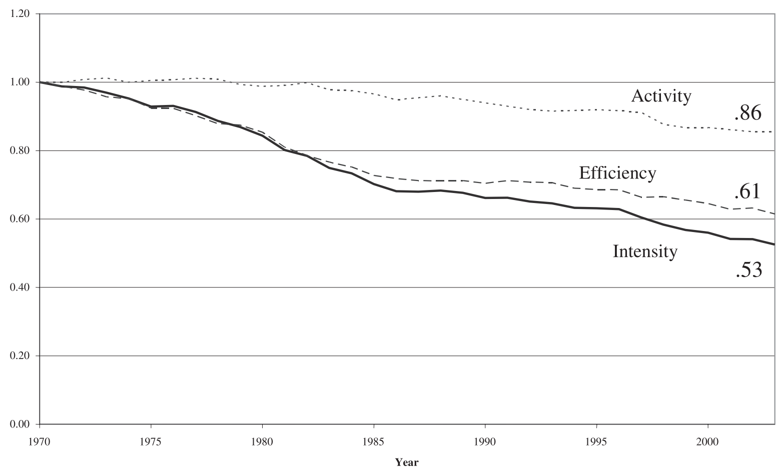
2. See appendix for details of index construction.

3. Greening, Davis, Schipper and Khrushch (1997) compare six different decomposition methodologies on the basis of their residuals.

4. 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.

Figure 1 shows the results of this decomposition analysis for the United States taking 1970 as the base year for the analysis.[5] 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 been fixed at its 1970 levels for all sectors, changes in economic activity would have led to a 14 percent reduction in energy intensity.

Figure 1. U.S. Energy Indexes



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. Figure 2 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. By 1990 the effects of the changing mix of economic activity began to have an impact though the influence of this channel is always dominated by gains in efficiency.

5. See Appendix for the index numbers at the national level as well as representative years at the state level.

Figure 2. Energy Savings Relative to 1970 Intensity

This decomposition 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.[6] 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.

4. STATE LEVEL ANALYSIS OF CHANGES IN INDEX VALUES

I next turn to my main analysis of determinants of changes in the intensity, efficiency, and activity indexes at the state-level. This allows me to take advantage of variation across states as well as across time. I maintain the same sectors (residential, commercial, industrial, and transportation) that I used at the federal level 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

6. Data are available from Energy Information Administration at http://www.eia.doe.gov/emeu/mecs/.

income.[7] Second, I use earnings by place of work in the commercial (industrial) sector as my measure of economic activity in the commercial (industrial) sector.

Table 1 provides summary statistics on the three indexes for the 48 continental states for various years between 1970 and 2001. Each row provides statistics across the states for a given year for one of the three indexes.

Table 1. State-Level Energy Indexes

Year	Mean	S.D.	Min	Max	Average Annual Change (Cumulative)	Average Annual Change (Decade)
Intensity						
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%
Efficiency						
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%
Activity						
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. Indexes are normalized to one in 1960.

The top panel of the table shows trends over time and variation across states for the intensity index. Several facts are noteworthy. First, 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).

7. I would prefer to use gross domestic product (GDP) at the state level but GDP 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. Despite this caution, I ran regressions using indexes constructed using the GDP data rather than the income and earnings based data and find little change in the regression results. 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 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. The second panel in Table 1 provides summary information on the energy efficiency index. Energy efficiency worsened between 1960 and 1970. Holding economic activity constant, changes 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 0.9 percent.[8]

The third panel of the table provides information on the economic activity index. 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.

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 2 reports summary statistics on the shares for the states in 2001.

Table 2. 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. ND and WY excluded. Full data in appendix table A2.

On average 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.[9]

8. 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.

9. 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.

As Table 1 suggests, there is considerable variation in all three of these indexes both across time and across states. 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.[10] 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.[11] 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 variables, 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) on this point).[12] Second, I include a variable measuring population growth in the state. Fast growing states may be adding infrastructure that is more energy efficient than slow growing states. On the other hand fast-growing states may be less efficient in their use of energy if their capital investment does not keep pace with growth (e.g. traffic congestion).

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. In an effort to measure the vintaging effect, I include the log of investment relative to 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 3.

10. Bernstein, Fonkych, Loeb and Loughran (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). They do not carry out a decomposition analysis of the sort done in this paper.

11. 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.

12. 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). Thompson and Taylor (1995) present estimates of the Morishima elasticity of substitution that suggest capital and energy are substitutes in the short and long run.

Table 3. Summary Statistics

		Std. Dev.				
Variable	**Mean**	**Overall**	**Between**	**Within**	**Min**	**Max**
Intensity	0.762	0.140	0.084	0.113	0.433	1.166
Efficiency	0.846	0.133	0.093	0.096	0.505	1.182
Activity	0.899	0.064	0.040	0.050	0.692	1.131
Real energy price ($1982-84/million BTUs)	6.41	1.57	0.90	1.29	2.45	12.53
Real income per capita ($1982-84)	13100	2703	1828	2008	6758	24235
Heating degree days (HDD) (1000)	5.22	2.00	1.98	0.38	0.48	9.92
Cooling degree days (CDD) (1000)	1.09	0.77	0.77	0.14	0.07	3.85
ln(income per capita)	9.46	0.20	0.14	0.15	8.82	10.10
ln(income per capita)2	89.50	3.84	2.60	2.85	77.80	101.90
ln(heating degree days)	1.55	0.51	0.50	0.08	-0.74	2.30
ln(cooling degree days)	-0.18	0.75	0.74	0.17	-2.62	1.35
ln(energy price)	1.83	0.24	0.14	0.20	0.90	2.53
ln(capital labor ratio)	11.04	0.17	0.14	0.09	10.62	11.64
ln(capital labor ratio) 2	121.99	3.72	3.17	1.99	112.82	135.55
Population growth rate	0.0117	0.0124	0.0094	0.0082	-0.0257	0.1150
ln(investment capital ratio)	-2.89	0.73	0.23	0.69	-12.28	-1.89

Source: See Table A1. 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/ .

I report three measures of the standard deviation to indicate the sort of variation in the data. The overall standard deviation measures variation in the pooled cross-section, time-series data. The between standard deviation measures the variation in the average state-level data across the 46 states while the within standard deviation measures the variation in the data from state-specific means. Looking at the heating and cooling degree data, for example, we see that the between standard deviation is much larger than the within standard deviation. This is not surprising since weather variation across time is much less than variation across states. The within standard deviations overall suggest that there is sufficient variation across time within states to obtain meaningful estimates of the coefficient estimates in the fixed effects regressions that I report below. Fixed state effects allow me to control for unobserved state-specific forces that affect energy consumption as well as tastes for energy conservation or types of economic activity that might be correlated with price and income variables. Not controlling for these forces would lead to biased coefficient estimates in the regressions if the unobserved state-specific fixed effects are correlated with the explanatory variables.

Table 4 presents results for the first set of regressions. The first two columns present results from a regression of the intensity index on price, income, along with other variables. All regressions control for individual fixed state effects.[13] A ten percent rise in energy prices is associated with a 1.1 percentage point

Table 4. State Level Regressions

	Intensity		Efficiency		Activity	
	(1)	(2)	(3)	(4)	(5)	(6)
ln(price)	-0.110 (0.008)	-0.063 (0.005)	-0.123 (0.010)	-0.060 (0.006)	0.004 (0.006)	-0.015 (0.003)
ln(per capita income)	2.276 (0.540)	-1.478 (0.667)	4.700 (0.694)	-1.490 (0.820)	-1.702 (0.392)	1.308 (0.363)
ln(per capita income)2	-0.136 (0.029)	0.069 (0.035)	-0.273 (0.037)	0.060 (0.043)	0.098 (0.021)	-0.062 (0.019)
ln(HDD)	0.088 (0.013)	0.057 (0.009)	0.075 (0.017)	0.039 (0.011)	0.021 (0.009)	0.026 (0.005)
ln(CDD)	-0.012 (0.006)	0.002 (0.004)	-0.011 (0.008)	0.005 (0.005)	-0.004 (0.004)	-0.004 (0.002)
ln(K/L)	2.293 (0.813)	0.610 (0.888)	4.211 (1.046)	1.567 (1.113)	-2.600 (0.590)	-2.333 (0.512)
ln(K/L)2	-0.105 (0.037)	-0.030 (0.040)	-0.188 (0.047)	-0.070 (0.050)	0.113 (0.027)	0.103 (0.023)
pop growth rate	0.286 (0.138)	0.077 (0.102)	-0.155 (0.177)	0.085 (0.123)	0.500 (0.100)	-0.072 (0.055)
ln(I/K)	0.001 (0.002)	-0.002 (0.001)	-0.006 (0.002)	-0.005 (0.001)	0.007 (0.001)	0.002 (0.001)
trend	-0.010 (0.001)	0.0005 (0.0008)	-0.003 (0.001)	0.003 (0.001)	-0.006 (.0006)	-0.003 (0.0004)
trend2	0.0001 (0.00002)	-0.00004 (0.00002)	0.00008 (0.00003)	-0.00003 (0.00002)	.00002 (.00002)	0.00002 (0.00001)
adjustment parameter	—	0.648 (0.025)	—	0.537 (0.026)	—	0.694 (0.019)
Long Run Price Effect	—	-0.178 (0.020)	—	-0.130 (0.015)	—	-0.048 (0.011)

Regressions are on the forty-six continental states excluding ND and WY. All regressions include fixed effects. Regressions with lagged dependent variable are run using Arellano-Bond estimator. Standard errors are reported in parentheses.

13. A Hausman test for correlated fixed effects rejects exogeneity and so I report fixed effects rather than random effects regressions throughout.

drop in energy intensity. The coefficient is precisely estimated and statistically significant at the 1 percent level. Energy intensity exhibits a quadratic response to income, first rising and then falling. The turning point is well below the minimum level of per capita income in the dataset and so intensity falls with income at every level of income in the dataset. A one standard deviation change in the log of per capita income is associated with a 6 percentage point decrease in the intensity index at the mean of log-per capita income. The price and income effects are substantial. Below I discuss whether price and income work disproportionately through either the efficiency or activity channel.

Energy intensity is higher in states in years with higher heating degree days as expected. A one standard deviation increase in this variable raises the intensity index by 4.5 percentage points. In years that states have warmer temperatures (more cooling degree days), energy intensity is lower but the magnitude of the effect is smaller than for heating degree days. Energy intensity first increases and then decreases with the capital labor ratio with the turning point just below the mean log capital labor ratio in the sample. The coefficient on the population growth variable is positive and statistically significant. Faster growing states have higher energy intensity. Whether this occurs because faster growing states suffer from congestion induced energy costs or whether faster growing states attract energy intensive activities will be explored below. The investment variable has little impact in the intensity regression. Energy intensity trends 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.

One difficulty with the regression in the first column of Table 4 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 regression provides 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

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

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

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

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

Combining equations (5) and (6) yields the following estimating equation:

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

where $\tilde{\beta} = (1 - \lambda)\beta$ is the short-run impact of changes in x on y and $\tilde{\beta} / (1 - \lambda)$ measures the long-run impacts. The error term is $\tilde{\varepsilon} = (1 - \lambda)\varepsilon$. Because of the lagged dependent variable, standard fixed effect regression procedures will produce biased estimates. I report estimates for the intensity index regression using the Arellano and Bond (1991) estimator in the next column.

The regression in column (2) provides results from this partial adjustment model and suggests that the short-run semi-elasticity of intensity with respect to price is -0.06. The long-run estimate (-0.18) is nearly fifty percent larger than the estimate from the regression in column (1) suggesting that the price coefficient in that regression is a mixture of a short run and long run effect. The signs of the income coefficients have reversed from those from the regression in column (1) but energy intensity continues to fall with income throughout the sample as the turning point for intensity with respect to income now exceeds the maximum income in the data set. The slope of the intensity index with respect to income at the mean value of log income in the regression in column (1) equals -0.297 and lies between the short-run response at the mean value of log income in the partial adjustment model (-0.173) and the long-run response (-0.490).

The other variables in the second regression have similar effects as in the regression without the partial adjustment. 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 capital and energy are substitutes. Finally the trend in the intensity regression is first rising and then falling with a peak in 1975 just following the first oil shock.

As noted above, energy intensity changes in part from improvements in energy efficiency and in part from changes in economic activity. I next report results from running regressions on the underlying efficiency and activity indexes. The regression in column (3) presents results for the efficiency index assuming an immediate and complete response to changes in the explanatory variables. This index measures the change in energy intensity holding constant the mix of economic activity in each state over time. Comparing this regression to the comparable intensity regression in 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 model specification. The efficiency index falls with income over the range of income in this data set. The marginal impact of income on the efficiency index at the mean of income is -0.465 in this regression compared to -0.297 in the intensity regression in column (1). As with price, income is predominantly affecting intensity through the efficiency channel.

The heating degree day variable has a positive coefficient and is statistically and economically significant. Cooling degree days have little impact on the efficiency index as in the intensity regressions. 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 11.13, just above the mean value in the dataset of 11.04. This turning point corresponds to a capital-labor ratio of $68,381 per worker, around the 75th percentile in the dataset.

In years with above average population growth, states have lower energy intensity through the efficiency channel. This may be related to the capital vintage effect given the correlation between high growth and investment.[14] States with higher than average investment rates have lower energy intensity through the efficiency channel. This is consistent with the fact that newer capital tends to be more energy efficient. Finally, the efficiency index is trending downward though at a slowing rate over the course of the sample period.

In column (4) I report results from the partial adjustment model for the efficiency index. This regression tells a similar story as the regression in column (2). Again, the similarity in results suggests that much of the response of energy intensity to changes in the explanatory variables flows through the efficiency channel. That will be confirmed by the next set of regressions.

The last two columns of Table 4 present results for the activity index. The first point to make is that the price coefficient is much smaller in both the instantaneous response model (column (5)) and the partial adjustment model (column (6)). Indeed, the sign on the coefficient in the instantaneous response model has an unexpected sign. The small and statistically insignificant response provides additional evidence for the view that energy prices influence energy intensity primarily through the efficiency channel.

In both activity index regressions, the index rises with income throughout the range of income exhibited in the dataset. This may be a manifestation of a sunbelt effect where income and manufacturing activity are both migrating to the sunbelt states.

Fast growing states have higher energy intensity through the activity channel in column (5). This may reflect the fact that energy intensive manufacturing activity has exited from northern, previously industrialized sections of the country to faster-growing regions in the south and southwest. But note that the coefficient is negative in the partial adjustment model albeit statistically insignificant.

The coefficients on the capital labor ratio indicate that the activity index is first falling and then rising with the capital-labor ratio in both regressions. The turning point occurs at 11.50 in the instantaneous response regression and at 11.33 in the partial adjustment model. This is just above the mean of ln(K/L) in the dataset.

A comparison of the sign on the investment variables in the efficiency regressions and the activity regressions helps explain why the investment variable has little explanatory power in the intensity index regressions. While higher investment rates lower intensity through the efficiency channel, they are associated with higher intensity through the activity channel. The positive sign on the activity regression coefficient likely captures the effect that energy intensive economic

14. The correlation between the population growth variable and the log of investment relative to the capital stock is 0.40.

activities also tend to be capital intensive and energy using. 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.[15]

Summing up, the long-run semi-elasticity of energy intensity with respect to price is -0.178 while the corresponding long-run responses for efficiency and activity are -0.130 and -0.048 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 5 reports price and income elasticity estimates based on the partial adjustment regressions in Table 3 for the energy intensity measures assuming the average state index value in 2001.[16]

Table 5. Price and Income Elasticities

	Intensity	Efficiency	Activity
Price Elasticities			
SR	-0.105	-0.084	-0.018
LR	-0.299	-0.154	-0.058
Income Elasticities			
SR	-0.289	-0.499	0.160
LR	-0.820	-1.077	0.524

Elasticities based on estimated price and income coefficients from Table 4. Values of weighted average intensity, efficiency, and activity are .59, .71, and .84 respectively.

Holding income constant, the price elasticity of demand for energy equals the price elasticity of energy intensity. Price elasticities from the intensity regressions can be compared to estimates of price elasticities in the existing literature. My long-run estimates are somewhat lower than other estimates in the literature. Bjorner and Jensen (2002), for example, cite estimates from a survey by Atkinson and Manning (1995) of median elasticity estimates of -0.5.

The short- and long-run income elasticity estimates suggest that energy intensity (observed and operating through the efficiency channel) falls more in the

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

16. The elasticity of energy intensity with respect to price in period t equals β/I_t where β is the coefficient on log price in the regression and I_t is the intensity index in year t. This is equal to the price elasticity of demand for energy implied by the regression. The elasticity of energy intensity with respect to income equals $\beta_1 + 2\,\beta_2 \ln Y_t / I_t$ where β_1 is the coefficient on ln per capita income (lnY) in the intensity index regression and β_2 is the coefficient on ln per capita income squared. The implied income elasticity of demand is equal to the income elasticity of energy intensity plus one. Similar elasticities can be computed for the measures of intensity working through the efficiency and activity channels.

long-run than in the short-run as income grows. The intensity elasticity working through the activity channel suggests the opposite, rising with income with the long-run impact greater than the short-run impact.

The regressions in Table 4 assume the same effect in all regions of the country. With panel data, I can explore whether the various indexes respond differently to price and income in different regions of the country. Table 6 shows results of these regressions for the four Census regions.[17] While I only report the price and income effects in this table, the regressions include the other covariates included in Table 4 as well as state fixed effects.

Focusing first on the price effects, we observe large responses of energy intensity to price changes in the Northeast, South, and the West. The price response in the Midwest is much smaller (and statistically insignificant in the regressions without partial adjustment). As in national regressions, price operates more predominantly through the efficiency than the activity channel. Indeed, counterintuitive signs appear on price coefficients in some of the activity regressions.

Table 6. State Level Regressions: Regional Variation

	Intensity		Efficiency		Activity	
Northeast						
ln(price)	-0.169 (0.019)	-0.100 (0.014)	-0.252 (0.025)	-0.123 (0.017)	0.128 (0.017)	0.004 (0.007)
ln(per capita income)	-5.452 (1.766)	-3.109 (1.299)	-8.161 (2.338)	-3.792 (1.577)	1.783 (1.281)	1.726 (0.640)
ln(per capita income)^2	0.25 (0.092)	0.146 (0.067)	0.377 (0.122)	0.177 (0.082)	-0.086 (0.067)	-0.087 (0.033)
Long Run Price Effect	—	-0.230 (0.033)	—	-0.315 (0.043)	—	0.025 (0.042)
Midwest						
ln(price)	-0.012 (0.018)	-0.032 (0.014)	0.028 (0.022)	0.011 (0.016)	-0.043 (0.010)	-0.039 (0.005)
ln(per capita income)	1.472 (2.342)	-3.941 (2.121)	0.861 (2.805)	-5.546 (2.423)	1.898 (1.279)	1.507 (0.843)
ln(per capita income)^2	-0.094 (0.125)	0.196 (0.113)	-0.076 (0.149)	0.271 (0.128)	-0.088 (0.068)	-0.073 (0.045)
Long Run Price Effect	—	-0.076 (0.035)	—	0.021 (0.030)	—	-0.106 (0.017)
South						
ln(price)	-0.119 (0.012)	-0.070 (0.008)	-0.140 (0.013)	-0.080 (0.010)	0.010 (0.009)	-0.016 (0.005)
ln(per capita income)	1.243 (0.865)	-1.116 (0.781)	4.611 (0.925)	-0.421 (0.920)	-2.156 (0.642)	-0.404 (0.410)

17. A listing of the states in the four Census regions is provided at http://www.census.gov/geo/www/us_regdiv.pdf.

ln(per capita income)^2	-0.079 (0.047)	0.056 (0.042)	-0.275 (0.050)	0.006 (0.049)	0.129 (0.035)	0.029 (0.022)
Long Run Price Effect	—	-0.257 (0.038)	—	-0.192 (0.023)	—	-0.071 (0.028)
West						
ln(price) (0.014)	-0.085 (0.010)	-0.054 (0.020)	-0.044 (0.014)	-0.025 (0.013)	-0.051 (0.008)	-0.035
ln(per capita income)	-1.370 (1.350)	-0.300 (1.276)	-5.645 (1.985)	-3.195 (1.741)	3.829 (1.285)	2.301 (0.917)
ln(per capita income)^2	0.056 (0.072)	0.004 (0.067)	0.274 (0.105)	0.148 (0.092)	-0.197 (0.068)	-0.115 (0.048)
Long Run Price Effect	—	-0.117 (0.024)	—	-0.048 (0.028)	—	-0.137 (0.032)

All regressions include fixed effects and other covariates listed in Table 4. Regressions with lagged dependent variable are run using Arellano-Bond estimator. Standard errors are reported in parentheses. Full regression results are available upon request.

Table 7 reports regional price and income elasticities for the regressions in Table 6. Again, considerable variation exists across regions in the responsiveness to economic variables. For the Northeast and the South, a comparison of the price elasticities across the indexes suggests the primacy of the efficiency channel in driving changes in energy intensity. The picture is less clear-cut for the Midwest and West. Income elasticities are consistently negative at the mean level of log income for the intensity and efficiency indexes and positive for the activity indexes. As noted above, the positive elasticity estimates for the activity index likely results from the correlation between income growth and economic development in a region.

Table 7. Long Run Price and Income Elasticities

	Intensity	**Efficiency**	**Activity**
Price Elasticities			
Northeast	-0.390	-0.444	0.030
Midwest	-0.129	0.030	-0.126
South	-0.436	-0.270	-0.085
West	-0.198	-0.068	-0.163
Income Elasticities			
Northeast	-1.351	-1.598	0.595
Midwest	-0.937	-1.126	0.407
South	-0.351	-1.039	0.764
West	-0.824	-1.068	0.583

Elasticities based on estimated price and income coefficients from Table 6. Values of weighted average intensity, efficiency, and activity are 0.59, 0.71, and 0.84 respectively.

5. POLICY IMPLICATIONS OF REGRESSIONS

We can draw a number of conclusions from the regressions above that inform our thinking about energy policy. First, rising prices and income drive reductions in energy intensity in the United States. That higher energy prices should lead to lower energy intensity is no surprise, but economic theory is agnostic whether higher income should lead to higher or lower energy intensity. Moreover, the regressions suggest that the improvements in energy intensity are driven more through the efficiency than the activity channel. As noted in section 2, my level of aggregation of sectors attributes some changes in economic activity to the efficiency channel – in particular movements away from more energy intensive manufacturing to less energy intensive manufacturing. But the disaggregated analysis I carried out within the manufacturing sector suggests that my level of aggregation is not unduly biasing my findings towards efficiency improvements. This conclusion is strengthened by the fact that the dramatic shift from manufacturing to services in the U.S. economy over the past thirty years or more is captured by the activity channel given my level of disaggregation. While further analysis can confirm at a more disaggregated level whether rising energy prices and incomes drive changes in energy intensity predominantly through the efficiency channel, the evidence here suggests the primacy of efficiency over activity.

Second, energy intensity is an important determinant of carbon emissions since energy combustion is responsible for roughly 98 percent of carbon emissions (Energy Information Administration (2006)). Fossil-fuel related carbon emissions can be reduced through fuel switching and by reducing the demand for energy. Our reduction in energy demand can be effected by our becoming more efficient at using energy whether in production or consumption. Alternatively, the U.S. economy can shift away from more to less energy-intensive production and consumption activities. From the perspective of carbon emissions, this second channel may reflect to some extent carbon leakage as energy (and carbon) intensive manufacturing is moved off-shore and the resulting consumer products reimported. Thus an important question is whether the improvement in energy intensity since 1970 is the result of true efficiency improvements or simply a by-product of the deindustrialization of the U.S. economy over this period and consequent off-shoring of carbon emissions. Again, the results above suggest that the United States is not simply outsourcing its energy (and carbon) intensive production.

Third, the Bush Administration in 2002 called for an eighteen percent reduction in carbon intensity (carbon emissions per dollar of GDP) over this decade. The intensity regressions in Table 4 can help us determine if goal is feasible without substantial policy intervention. The trend coefficients from column (2) 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 as well as significant fuel switching, the Administration's goal then would not likely be met. Growth in income, however, suggests we should observe a larger decline in energy (and thus carbon) intensity. Using projections from *The Annual Energy Outlook 2007* (Energy Information Administration (2007)) for real per capita income growth over the decade (21 percent), energy intensity would fall by just under 15 percent over the decade from trend and income growth alone. This matches the decline in carbon intensity between 1990 and 2000 and suggests that little policy intervention may be required to achieve the Bush Administration's goal of an 18 percent reduction in carbon intensity by the end of this decade.[18]

6. 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.

The decomposition – either at the federal or the state level – suggests that most of the reduction in energy intensity have occurred because of improvements in energy efficiency as opposed to shifts from energy intensive to less intensive economic activity. At the national level, my decomposition suggests that roughly three-quarters of the reduction in energy intensity is due to improvements in energy efficiency. This should allay concerns that the United States is reducing its energy (and carbon) intensity by simply moving its energy-intensive economic activities off shore and then reimporting carbon-intensive consumer products.

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 – 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.

18. This does not take into account the dramatic run up in energy prices in the past few years. As a (near) mid-decade check, carbon intensity has fallen by 6 percent between 2000 and 2004. See EIA (2006b).

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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

$$L_t^{act} = \frac{\sum_i e_{i0} s_{it}}{\sum_i e_{i0} s_{i0}} \tag{A1}$$

$$L_t^{eff} = \frac{\sum_i e_{it} s_{i0}}{\sum_i e_{i0} s_{i0}} \tag{A2}$$

and the Paasche indexes are

$$P_t^{act} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{it} s_{i0}} \tag{A3}$$

$$P_t^{eff} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{i0} s_{it}} \tag{A4}$$

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

$$F_t^{act} = \sqrt{L_t^{act} P_t^{act}} \tag{A5}$$

$$F_t^{eff} = \sqrt{L_t^{eff} P_t^{eff}}\,. \tag{A6}$$

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:

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

At the national level, I use measures of economic activity related to the underlying demand for demand within each sector. A key driver for residential energy consumption is personal consumption expenditures.[19] This is preferable to disposable income since a portion of disposable income goes to savings which should have no appreciable impact on residential energy demand. For commercial and industrial energy demand, I use value added in these two sectors of the economy. Value added is a measure of the contribution to final production from a given sector. For transportation I use vehicle miles traveled rather than a monetary measure of economic activity.[20]

Table A1 shows my sectors and summary statistics for the measures of economic activity in that sector that I use for the decomposition as well as summary statistics on sectoral energy efficiency.

Table A1. 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 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.

Table A2 provides summary statistics on the data used to construct indexes at the state level. As noted in the text, I use income and earnings based

19. Greening, Ting and Krackler (2001) note that prices and income are a "primary driver" (p. 154) of residential energy consumption. They also note a number of other factors (e.g. square footage of housing, number of occupants) that are driven in part by income. While income or expenditures are not the sole determinants of residential energy demand, expenditures is not inappropriate to use in the construction of an index of energy intensity.

20. Greening (2004) discusses index measures for the transportation sector and cites a number of studies that use mileage rather than income or some other monetary measure as a measure of economic activity.

measures rather gross state product given issues in the time series construction of those data at the state level. As noted in the main text, there is a high correlation in the time series of national level trends in the indexes for data constructed from GDP and data aggregated up from the state level using the economic measures listed in Table A2.

Table A2. 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 communication, wholesale and retail trade, finance, services, and government. Sectoral energy efficiency summary statistics weighted by personal income.

Source: See Table A1.

Table A3 and A4 present index values at the national level and at the state level for various years. Complete index data at the tate level are available from the author.

Table A3. 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 A4. State-Level Indexes: Various Years

	1970			1980			1990			2000		
State	**Int**	**Eff**	**Act**	**Int**	**Eff**	**Act**	**Int**	**Eff**	**Act**	**Int**	**Eff**	**Act**
AL	1.04	1.06	0.98	0.87	0.93	0.94	0.68	0.77	0.88	0.68	0.82	0.83
AR	1.00	1.03	0.97	0.83	0.95	0.88	0.65	0.77	0.85	0.67	0.81	0.83
AZ	0.95	0.95	1.00	0.78	0.85	0.92	0.65	0.67	0.96	0.56	0.60	0.94
CA	0.98	1.03	0.95	0.84	0.90	0.93	0.67	0.71	0.95	0.55	0.61	0.90
CO	0.96	0.99	0.97	0.74	0.74	0.99	0.62	0.69	0.90	0.49	0.57	0.87
CT	0.86	0.91	0.94	0.74	0.80	0.92	0.55	0.62	0.88	0.49	0.58	0.85
DE	0.92	0.96	0.96	0.88	0.88	1.00	0.63	0.66	0.96	0.59	0.69	0.86
FL	0.94	1.00	0.94	0.89	0.95	0.94	0.71	0.85	0.84	0.65	0.79	0.83
GA	1.03	1.06	0.97	0.99	1.08	0.92	0.84	0.97	0.87	0.72	0.85	0.85
IA	0.96	0.95	1.01	0.95	1.04	0.91	0.83	0.92	0.90	0.83	0.96	0.87
ID	1.02	1.07	0.95	0.78	0.88	0.89	0.74	0.82	0.90	0.66	0.77	0.86
IL	1.02	1.05	0.97	0.90	1.00	0.91	0.71	0.83	0.85	0.62	0.75	0.82
IN	1.00	1.03	0.97	0.88	0.99	0.88	0.77	0.93	0.83	0.69	0.85	0.81
KS	0.99	1.08	0.92	0.90	1.03	0.88	0.77	0.89	0.86	0.63	0.75	0.85
KY	0.85	0.84	1.02	0.78	0.79	0.98	0.69	0.77	0.90	0.66	0.76	0.87
LA	1.15	1.16	0.99	1.00	0.99	1.01	0.91	1.08	0.84	0.82	1.03	0.80
MA	0.92	0.95	0.96	0.70	0.70	1.01	0.55	0.58	0.95	0.46	0.51	0.91
MD	0.82	0.95	0.86	0.71	0.86	0.83	0.53	0.70	0.76	0.48	0.62	0.78
ME	0.93	0.98	0.95	0.90	1.02	0.88	0.77	0.92	0.84	0.74	0.99	0.76
MI	0.99	1.00	0.99	0.87	0.92	0.94	0.74	0.81	0.91	0.66	0.72	0.92
MN	0.95	0.95	1.00	0.83	0.87	0.95	0.71	0.78	0.92	0.67	0.76	0.88
MO	1.01	1.01	1.00	0.93	0.97	0.97	0.78	0.79	0.99	0.72	0.73	0.99
MS	1.11	1.13	0.99	0.86	0.96	0.90	0.88	0.97	0.90	0.79	0.89	0.89
MT	1.04	1.01	1.02	0.87	1.00	0.87	0.77	0.95	0.82	0.71	0.92	0.77
NC	0.95	0.96	0.99	0.86	0.92	0.94	0.72	0.80	0.90	0.64	0.74	0.86
ND	0.93	0.99	0.95	0.89	1.25	0.71	1.01	1.31	0.77	1.03	1.28	0.81

continued

Table A4. State-Level Indexes: Various Years (continued)

	1970			1980			1990			2000		
State	Int	Eff	Act	Int	Eff	Act	Int	Eff	Act	Int	Eff	Act
NE	1.13	1.13	1.00	0.98	1.10	0.89	0.81	0.87	0.93	0.77	0.88	0.88
NH	1.01	1.09	0.93	0.76	0.84	0.90	0.61	0.72	0.85	0.55	0.67	0.82
NJ	0.96	1.06	0.90	0.86	1.00	0.87	0.68	0.87	0.78	0.57	0.78	0.73
NM	1.01	1.10	0.92	0.67	0.72	0.94	0.64	0.76	0.84	0.54	0.65	0.83
NV	0.96	1.05	0.91	0.80	0.89	0.90	0.66	0.75	0.89	0.55	0.66	0.84
NY	1.01	1.10	0.92	0.90	0.95	0.94	0.62	0.69	0.90	0.59	0.67	0.89
OH	0.92	0.94	0.97	0.81	0.88	0.92	0.64	0.76	0.84	0.60	0.74	0.81
OK	1.06	1.12	0.96	0.91	0.93	0.97	0.93	1.04	0.90	0.78	0.87	0.90
OR	1.02	1.06	0.97	0.84	0.91	0.93	0.73	0.80	0.90	0.59	0.66	0.90
PA	0.89	0.95	0.94	0.75	0.85	0.89	0.56	0.72	0.77	0.50	0.66	0.76
RI	0.77	0.83	0.94	0.58	0.62	0.94	0.47	0.54	0.89	0.44	0.51	0.86
SC	0.86	0.87	0.99	0.81	0.88	0.92	0.71	0.82	0.87	0.66	0.84	0.79
SD	1.02	1.06	0.96	0.95	1.12	0.86	0.83	0.94	0.88	0.77	0.91	0.85
TN	0.88	0.88	1.00	0.77	0.83	0.93	0.60	0.70	0.86	0.52	0.61	0.85
TX	0.93	0.97	0.96	0.76	0.77	0.98	0.63	0.76	0.83	0.51	0.63	0.80
UT	0.87	0.96	0.91	0.68	0.72	0.94	0.57	0.66	0.86	0.49	0.57	0.86
VA	0.85	0.91	0.94	0.72	0.81	0.88	0.61	0.71	0.86	0.56	0.69	0.82
VT	1.00	1.01	0.99	0.85	0.87	0.98	0.64	0.65	0.98	0.62	0.66	0.94
WA	1.01	1.07	0.95	0.87	0.92	0.95	0.80	0.88	0.91	0.59	0.73	0.80
WI	1.00	1.04	0.96	0.89	0.96	0.93	0.76	0.84	0.92	0.75	0.85	0.88
WV	1.03	1.08	0.96	0.77	0.85	0.91	0.69	0.93	0.75	0.56	0.81	0.69
WY	1.39	1.54	0.91	0.98	0.98	1.00	1.18	1.42	0.83	0.96	1.18	0.82

Source: Author's calculation. Int refers to intensity, Eff refers to efficiency, and Act refers to activity.