MIT Joint Program on the Science and Policy of Global Change

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

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Gilbert E. Metcalf*

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.

While historic improvements in energy intensity suggest great scope for energy conservation in the future, I argue that estimates of avoided energy costs due to energy conservation are overly optimistic. Avoided costs are likely to be significantly higher than estimates from recent energy technology studies suggest once behavioral responses are taken into account.

I then 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 lower 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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1. INTRODUCTION

Efforts to significantly reduce carbon emissions as part of any national strategy to address climate change 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

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emissions relative to GDP). In 2002, the administration called for a reduction in carbon intensity of 18% over the 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% per year beginning in 2010. One of the key recommendations for reaching 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.[1] Pizer (2005) makes an economic and political economy case for intensity targets for carbon emissions.

Reductions in carbon intensity can be achieved in two ways: fuel switching and reductions in energy intensity. Energy intensity is the amount of energy consumed per dollar of GDP (more broadly, per unit of economic activity). I focus in this analysis on the economic forces affecting changes in energy intensity. 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.

Treating energy conservation 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. 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.

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. Using state-level data on energy consumption between 1970 and 2003, I investigate the role that income and prices play in

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
Energy Conservation Since 1970	88.6	55.7
Total	159.2	100.0

[1] While framed in terms of carbon intensity limits, the Bingaman proposal, as submitted as an amendment to the Energy Policy Act of 2005 (S.A. 868), in fact places a cap on carbon emissions but provides for a safety valve at $7 per ton of CO_2.

influencing energy consumption. In addition, following Boyd and Roop (2004) I use a Fisher ideal index number methodology to decompose changes in energy intensity into efficiency and activity components. 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).

This paper builds on Boyd and Roop's work in several ways. First, my analysis focuses on total energy consumption rather than consumption in the manufacturing sector alone. Moreover, I construct and analyze indexes at the state level over a much longer time period. And 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.[2]

I find that improvements in energy efficiency are responsible for between 2/3 and 3/4 of the decline in energy intensity since 1970. In addition, rising per capita income contributes to declines in energy intensity, primarily through improvements in energy efficiency. Finally, the price elasticity of energy intensity is between –0.1 and –0.6, again with price affecting energy intensity primarily through efficiency gains.

2. THE POTENTIAL FOR ENERGY EFFICIENCY

While policy interest in energy conservation is quite high, there are a number of unanswered questions that bear on policy development in this area. First, what is the potential for energy conservation to contribute to climate change mitigation? And second, how costly will enhanced energy conservation be? As noted above in the thought experiment I described, energy conservation appears to have enormous potential to reduce our reliance on carbon-based fuels. Unfortunately researchers have taken widely diverging perspectives on the cost-effectiveness of conservation enhancing measures. On one hand, some analysts are enormously optimistic as the following quotation suggests: "The overall economic benefits of these policies [to stimulate energy conservation] appear to be comparable to their overall costs. The [Clean Energy Future] policies could produce direct benefits, including energy savings, that exceed their direct costs (e.g. technology and policy investments)" (Interlaboratory Working Group (2000), p. ES 1). On the other hand, a German economist in his assessment of utility conservation programs notes that "…conservation will not be a free lunch and will definitely not come cheap" (Wirl (2000), p. 106).

How do we reconcile these differing points of view? At the risk of gross simplification, energy technologists tend to fall into the first group while economists into the second group. These groups differ on three key dimensions. First, energy technologists generally focus on policies that minimize energy use while economists focus on policies that maximize economic welfare. The development of appliance energy standards illustrates the distinction. Appliance standards for

[2] 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.

energy consumption were developed in the 1980s by reviewing the range of possible technologies and comparing the incremental purchase costs of more efficient appliances to their lower operating costs. Standards were set to minimize the lifetime cost of the appliance. The choice of a particular technology standard followed from the choice of a discount rate (to trade-off future savings against current costs) as well as assumptions on use patterns that influence the future savings.

Such a policy *may* be welfare enhancing but ignores important factors that will affect the welfare gains and losses. Heterogeneity in use, for example, influences the cost-benefit calculation. Consider the standards for air conditioners. Someone living in a hot and humid climate will be an intensive user and so likely benefit from an aggressive efficiency standard that trades off considerable up-front incremental cost against large reductions in future energy bills. Another person, however, may be only an occasional user of her air conditioner and so may find that the much higher purchase price of an energy efficient air conditioner does not pay off in future energy savings. There may also be heterogeneity in discount rates. High discount rate households will not benefit as much from future energy savings and so can be adversely affected by an overly aggressive energy efficiency standard. In effect, the efficiency standard is a Procrustean policy that forces all to fit a single standard with concomitant economic efficiency losses. Appliance standards may reduce energy use but may not maximize consumer well-being conditional on a given reduction in energy use. In addition, it is also likely to be a regressive policy given the well-documented higher discount rates for low-income households.[3]

The choice of discount rate is further complicated by issues of risk. Investments in energy efficient capital are inherently risky. The payoff to the investment depends on future energy prices which can rise (as we are now observing) or fall (as they did in the 1990s). Moreover, the investments have an irreversible element; that is, they cannot be unwound without cost. This combination can drive the required discount rate (or hurdle rate) for investment up thereby delaying investment (viz. Hassett and Metcalf, 1996). Empirical evidence bears this out. A recent study of Dutch Greenhouse energy-saving investments finds a hurdle rate 75% higher than calculated in studies with no uncertainty (Diederen et al., 2003).

Second, while both groups focus on correcting market failures, the first group also puts great emphasis on the role of market barriers. To quote a leading energy researcher, "'Market barriers' refer to obstacles that are not based on market failures but which nonetheless contribute to the slow diffusion and adoption of energy-efficient innovations" (Brown, 2001). These include incomplete information, low priority of energy issues, capital market barriers, and incomplete markets for energy efficient products. An economist would characterize many of these issues as unmeasured costs. Information acquisition is costly. A market barrier example that is often cited is the periodic electricity bill that consumers receive. Continuous time awareness of electricity use and cost, it is suggested, will spur conservation. But experimental evidence suggests that instantaneous monitoring has, at best, modest conservation impacts (see Matsukawa, 2004). Thus it is not clear how much we can achieve with information programs. That consumers place a low priority on energy issues also speaks to the costs of information acquisition. To quote from the

[3] Sutherland (1994) makes a similar argument for utility conservation programs.

Clean Energy Future study, "energy efficiency is not a major concern for most consumers because energy costs are not high relative to the cost of many other goods and services." (Interlaboratory Working Group (2000), p. 2.13). This is not to say that we should ignore market barriers. But we should be careful to assess the appropriate role for government. Information is a public good and so likely to be underprovided in the private market. On this ground alone, there is likely to be an important role for government to play in providing information.[4]

Third, while economists take into account behavioral responses to policy programs, energy technologists tend to ignore them. As the lead authors of the Clean Energy Future study acknowledge, "as an engineering economic study, the CEF analysis is unable to incorporate the full impact of market-wide behavioral responses to policies" (Brown et al., 2001). The three major behavioral issues are free riding, rebound, and moral hazard. Free riding refers to fact that when a conservation incentive program is offered, it is taken up not only by agents who would not have engaged in the conservation activity in the absence of the program, but also by agents who would have taken up the activity regardless of the program. The result is that any assessment of the program will overestimate the energy savings resulting from the program or— equivalently —underestimate the cost per unit of energy saved from the program. A recent RAND study finds significantly higher costs of avoided electricity in Demand Side Management (DSM) programs than utility estimates, a difference they attribute to free-riding (Loughran and Kulick, 2004). The study estimates the cost of avoided electricity from DSM at $0.14 to $0.22 or $0.06 to $0.12 (depending on the study group) as compared to utility estimates of $0.02 to $0.03 per kWh. Similarly a recent Dutch study estimates that free-riders constitute nearly 50% of subsidy recipients from an energy efficiency subsidy program directed at businesses (Blok et al., 2004).

The rebound effect is simply a restatement of the law of demand: when prices fall, demand rises. Higher fuel efficiency standards for automobiles, for example, lower the cost of driving. This, in turn, increases the demand for driving. A recent survey suggests rebound for residential (and transportation) sectors between 10 and 30% (Greening et al., 2000).[5]

Finally, the presence of moral hazard influences policy design. Investors may delay investments to take advantage of prospective investment subsidies. If we cannot distinguish marginal investors from free-riding delay investors, an optimal subsidy scheme may be to focus a subsidy on the latter group to encourage speedier investment (Wirl, 1999). An additional implication of Wirl's result is that it may be preferable to direct energy efficiency subsidies to energy intensive consumers (e.g. purchasers of hot tubs and heated swimming pools), a policy outcome that many would find counterintuitive.

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[4] New research in behavioral economics also suggests that there may be highly effective, low-cost interventions to enhance energy efficiency. In another context that may be instructive for energy conservation, Beshears et al. (2006) demonstrates a number of low-cost interventions that can raise private saving in pension plans. They find that the default option for opting in or out of volunteer pension plans has a large effect on participation rates. In the context of energy conservation, new home builders, for example, might be required to make energy efficient capital the default option but allow home purchasers to opt for less efficient capital.

[5] Small and Van Dender (2005) find a rebound effect of about 10%. Parry (2006) finds that the failure of CAFE to raise driving costs contributes to it being dominated by other policies to reduce greenhouse gas emissions from passenger vehicles.

This review is not meant to throw cold water on energy efficiency as an element of a climate change program. Indeed, as the Pew study cited earlier suggests, it will be an essential element in any comprehensive climate change program. But it should suggest caution in the face of claims that energy efficiency will come at low or even negative cost. I next turn to a review of energy consumption trends in the United States followed by an analysis of energy intensity improvements in the United States at the state level to see what we can learn from the experience of the past thirty years.

3. BACKGROUND ON ENERGY CONSUMPTION TRENDS

Figure 1 shows energy consumption in the United States from 1900 through 2004.[6] Energy consumption has risen sharply over the century at an annual growth rate of 2.51% per year. Growth rates were higher prior to 1970 (3.66% between 1900 and 1930 and 3.35% between 1931 and 1970) than after 1970 (1.08%).

Energy consumption per capita also grew dramatically over the century (**Figure 2**). Per capita energy consumption rose from 100 million BTUs in 1900 to nearly 350 in 2004. The growth rate between 1900 and 2004 was 1.19%. Again, the growth rate in the pre-1970 era was much higher (2.0%) than in the post-1970 era (0.04%).

Figure 3 shows energy growth per dollar of GDP.[7] Energy intensity peaked in 1917 at 35 thousand BTUs per dollar of GDP ($2000) and has gradually declined to its current level of 9.3.[8] I will focus most on this relationship given the current interest in reducing carbon intensity in United States policy. The initial growth of energy intensity can be explained, according to

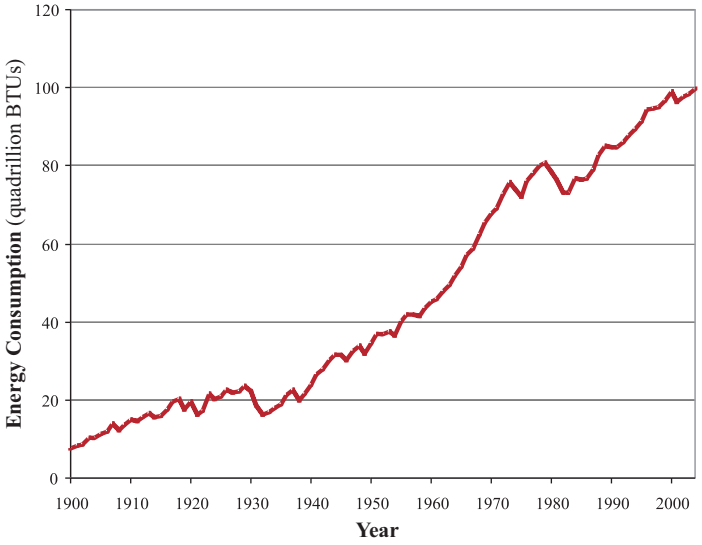

Figure 1. U.S. Energy Consumption.

[6] Data prior to 1949 are taken from Schurr and Netschert (1960) and exclude fuel wood consumption. Data for 1949 and later are taken from Energy Information Administration (2004). Energy consumption is in quads (quadrillion BTUs).

[7] GNP is used for the pre-1929 data.

[8] If animal power were included, the peak might occur sooner.

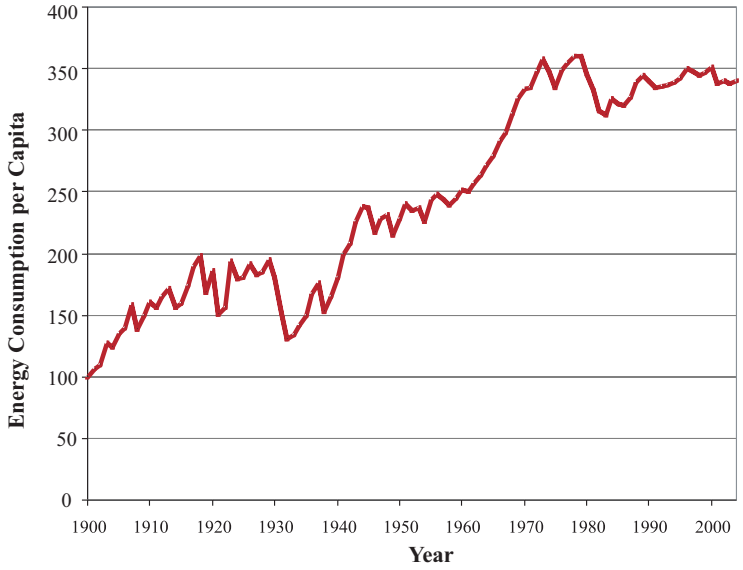

Figure 2. U.S. Energy Consumption Per Capita.

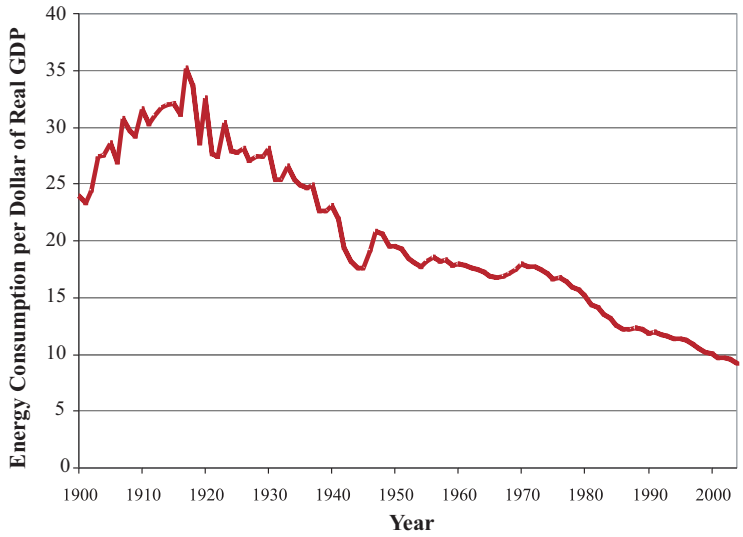

Figure 3. Energy Consumption Per Dollar of Real GDP.

Schurr and Netschert (1960), by the electrification of the country that began in earnest at the turn of the century and contributed to rapid growth in manufacturing. By 1920, however, the improved thermal efficiency associated with electricity combined with a shift from coal to petroleum as well as increasing productivity led to a turning point and the beginning of a long and gradual decline in energy intensity.

An important point emerging from Figure 3 is that improvements in energy intensity are not entirely a post-oil shock phenomenon. While energy intensity fell at a rate of 1.9% after 1970, it was falling at a rate of 0.9% between 1931 and 1970. The acceleration in the rate of decline following the 1970s oil shocks suggests the sensitivity of energy intensity to economic forces. I next turn to an econometric analysis to further investigate the underlying forces driving this decline.

4. DECOMPOSING ENERGY INTENSITY INTO STRUCTURAL AND EFFICIENCY EFFECTS

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

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

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}).

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.[9] 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 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.[10] 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 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) use this 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 the state-level in this study.

Denoting e_0 as the aggregate energy intensity for a base year, we can construct an energy intensity index as e_t/e_0. Following Diewert (2001), it can be shown that we can accomplish this decomposition if 1) we can construct sectors that account for all energy use in the economy

[9] Ang and Zhang (2000) provide a survey of this literature. My discussion of this literature draws on their survey.
[10] Greening et al. (1997) compare six different decomposition methodologies on the basis of their residuals.

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:

$$L_t^{act} = \frac{\sum_i e_{i0} s_{it}}{\sum_i e_{i0} s_{i0}} \tag{2.1}$$

$$L_t^{eff} = \frac{\sum_i e_{it} s_{i0}}{\sum_i e_{i0} s_{i0}} \tag{2.2}$$

and the Paasche indexes are

$$P_t^{act} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{it} s_{i0}} \tag{3.1}$$

$$P_t^{eff} = \frac{\sum_i e_{it} s_{it}}{\sum_i e_{i0} s_{it}}. \tag{3.2}$$

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:

$$F_t^{act} = \sqrt{L_t^{act} P_t^{act}} \tag{4.1}$$

$$F_t^{eff} = \sqrt{L_t^{eff} P_t^{eff}}\ . \tag{4.2}$$

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:

$$\frac{e_t}{e_0} \equiv I_t = F_t^{act} F_t^{eff}\ . \tag{5}$$

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:

$$\begin{aligned}\Delta E_t &= E_t - \hat{E}_t \\ &= Y_t(e_t - e_0) = Y_t e_0 (I_t - 1) \\ &\cong Y_t e_0 \ln(I_t) = Y_t e_0 \ln\left(F_t^{act}\right) + Y_t e_0 \ln\left(F_t^{eff}\right)\end{aligned} \tag{6}$$

where $\hat{E}_t$ is the level of energy consumption that would have occurred had energy intensity remained at 1970 levels and the first equality in the last line of (6) is a first order Taylor Series approximation. Equation (6) gives us a way to decompose the change in energy use perfectly into an efficiency and activity component. I will carry out this decomposition in the data using the following equality:

$$\Delta E_t = \Delta E_t\left(\frac{\ln(F_t^{act})}{\ln(I_t)}\right) + \Delta E_t\left(\frac{\ln(F_t^{eff})}{\ln(I_t)}\right) \equiv \Delta E_t^{act} + \Delta E_t^{eff}. \tag{7}$$

4.1 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.[11] **Table 2** 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.

Figure 4 shows the results of this decomposition analysis for the United States taking 1970 as the base year for the analysis.[12] Aggregate energy intensity in 2003 was 53% of its intensity level

Table 2. Sectors for Decomposition Analysis at National Level.

	Economic Activity			Sectoral Energy Efficiency		
Sector	**Measure**	**Mean**	**Std. Dev.†**	**Measure**	**Mean**	**Std. Dev.**
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/dollar ($2000)	13,333	2,717

† Standard deviation.

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.

[11] 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.

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

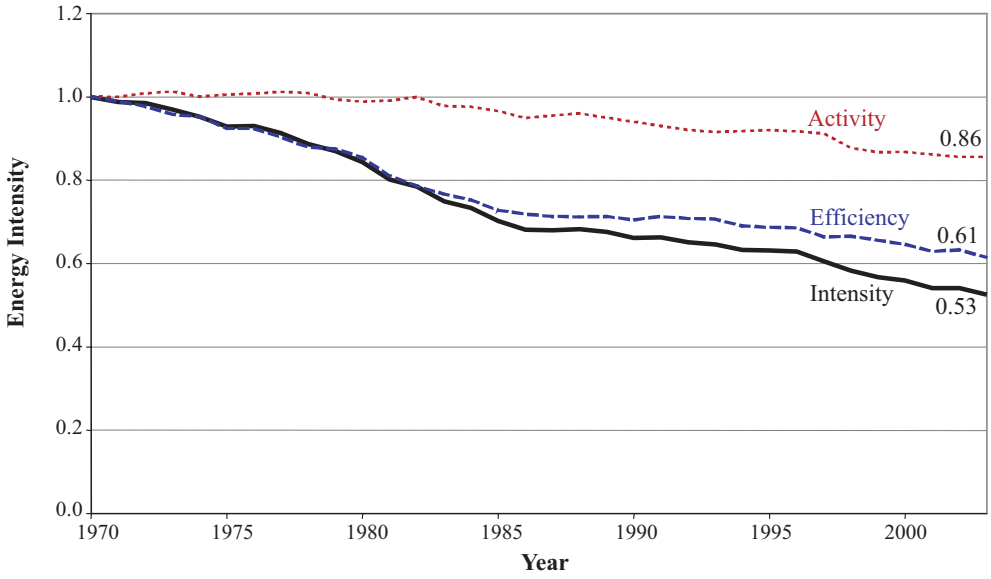

Figure 4. Aggregate Energy Intensity.

in 1970. The activity index was 86% of its level in 1970 while the efficiency index was 61% 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% 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% reduction in energy intensity. This decomposition allows us to estimate the impact of changes in energy prices and income on energy intensity holding constant either changes in sectoral energy efficiency or economic activity.

Using equation (7), 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.[13] **Figure 5** 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.[14] By 1990 changes in economic activity were beginning to contribute substantially to energy savings with major increases in the activity component around 1997.

[13] 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% of the improvement in energy intensity and changes in economic activity for 18% as of 1997. Thus it does not appear that I am imparting significant bias by failing to disaggregate the industrial sector further.

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

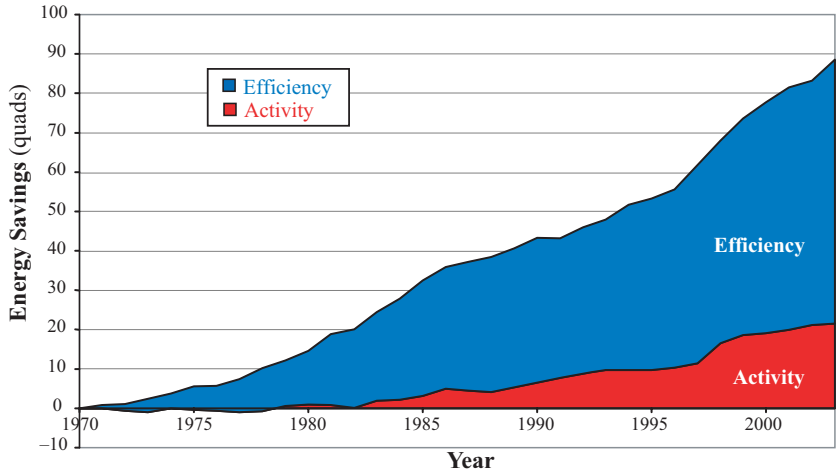

Figure 5. Energy Savings Relative to 1970 Intensity.

4.2 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.[15] **Table 3** shows my sectors and measures of economic activity that I use to construct the indexes. 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.[16] 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 4 provides summary statistics on the energy intensity index for the 48 continental states for various years between 1960 and 2001. Several facts emerge from this table. First, (unweighted) average energy intensity has been declining at a 1.2% 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% between 1960 and 2001), other states have failed to reduce their energy intensity at all (North Dakota's intensity increased by nearly 10% over this period). **Figure 6** 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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[15] 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.

[16] 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% of its 1970 value, as compared to 53% 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.

Table 3. Sectors for Decomposition Analysis at State Level.

	Economic Activity			Sectoral Energy Efficiency		
Sector	**Measure**	**Mean**	**Std. Dev.**	**Measure**	**Mean**	**Std. Dev.**
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.

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. † Standard deviation.

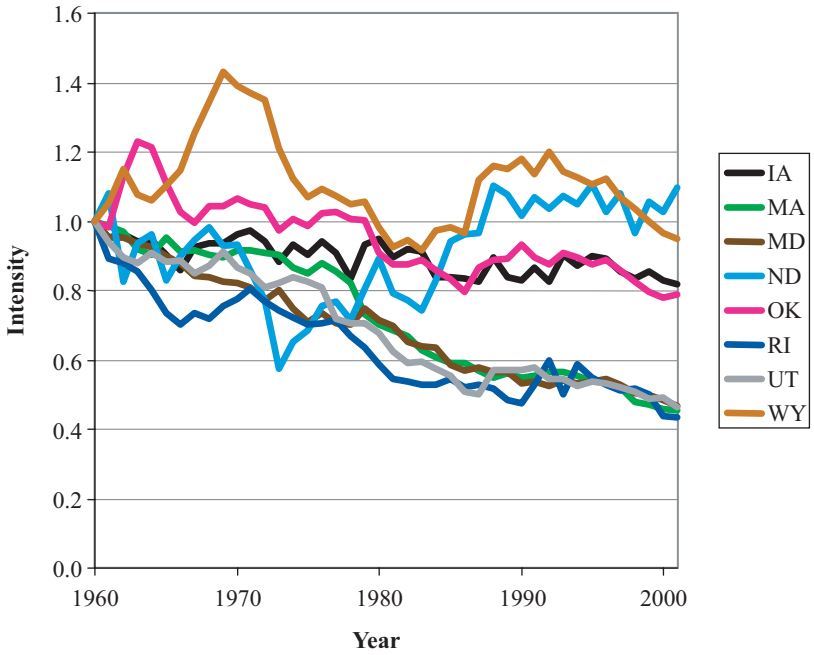

Figure 6. State Level Intensity Trends.

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 in efficiency led to a 0.2% 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% 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 rose by 44% between 1960 and 2001, an annual increase of 0.9%. **Figure 7** 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. 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 8** shows the change over time in the structural index for the four states with the largest and smallest changes in the index respectively.

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.

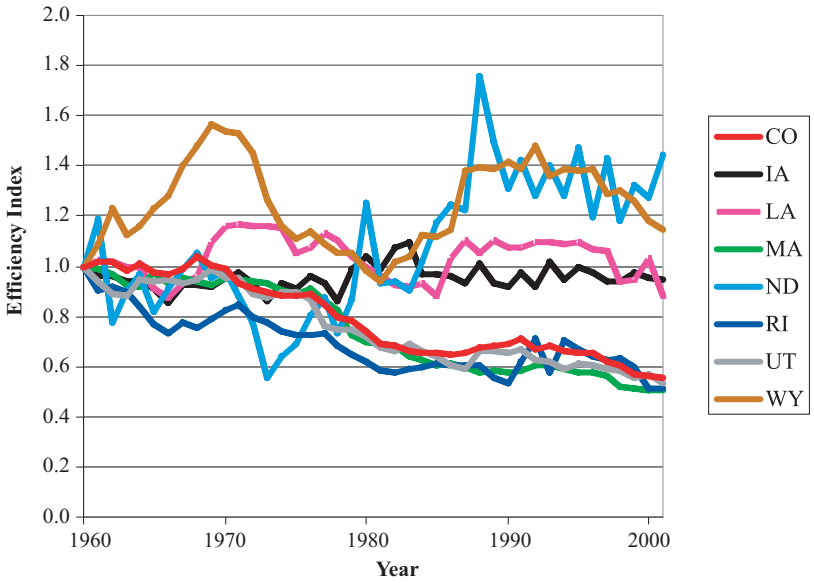

Figure 7. State Level Efficiency Trends.

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.

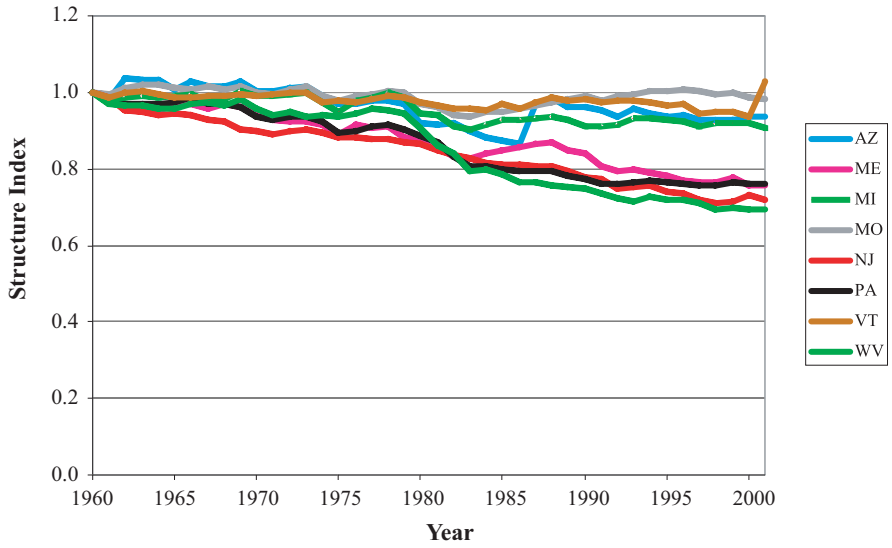

Figure 8. State Level Structural Trends.

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. 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.[17]

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 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,

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.

[17] Wyoming's efficiency contribution is –258%. This state had a 5% decline in energy intensity but its efficiency index actually rose by 14% while its structural index fell by 17%. As a consequence its share due to structural change rose by 358%. There is one other major outlier. North Dakota's intensity index rose by 10% with its efficiency index rising by 44% and its structural index falling by 24%. Including these two states does not change the average share contributions appreciably. It does drive up the standard deviation sharply.

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, I use the Fisher ideal index decomposition to separate out efficiency and composition effects explicitly. The advantage of the approach I propose is that compositional change 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 composition index on prices (along with other variables) to measure the impact. Fifth, their study's weather data are at the census region rather than state level (as in my dataset).[18]

5. EMPIRICAL WORK

I next present results from various regressions of the different indexes on economic and weather related variables. Under the assumption that states are price takers in energy markets, I interpret these as energy demand-style regressions.[19] I've included an energy price variable, per capita income, climate data (heating and cooling degree days) and year effects (to capture autonomous technological change effects along with other macro level impacts). Summary statistics for the regression data are in **Table 8**. The energy price variable is the average weighted price of energy in the state based on fuel uses as computed by EIA and includes taxes.

Table 9 presents results for the energy intensity index. The first column presents results from a regression of the intensity index on the log of price, per capita income, log-per capita income squared, and climate variables.[20] The first three regressions include the current energy price only and differ in their inclusion of fixed state and/or year effects. In the first regression there are neither state or year effects. Energy intensity falls with higher energy prices with a semi-elasticity (change in index due to a one percent change in energy price) of –0.144. A ten percent rise in energy prices is associated with a 1.4 percentage point drop in energy intensity. In this (and subsequent) regressions, energy intensity is falling with respect to income given the range of income in the data set. Energy intensity is higher in colder climates (more heating degree days (HDD)) with a statistically significant coefficient in the first three regressions. Finally, energy intensity is lower in warmer climates.

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[18] 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.

[19] 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% level.

[20] The energy price is the average weighted price of energy in the state based on fuel uses as computed by EIA.

Table 8. Summary Statistics.

Variable	Mean	Std. Dev.	Min	Max
Intensity	0.772	0.149	0.433	1.390
Efficiency	0.860	0.155	0.505	1.757
Activity	0.898	0.065	0.628	1.131
Real energy price ($1982-84/million BTUs)	6.366	1.579	2.454	12.532
Real income per capita ($1982-84)	13087	2669	6758	24235
Heating degree days (HDD) (1000)	5.37	2.09	0.48	11.12
Cooling degree days (CDD) (1000)	1.06	0.77	0.07	3.85
ln(income per capita)	9.459	0.200	8.818	10.096
ln(income per capita)^2	89.5	3.8	77.8	101.9
ln(heating degree days)	1.576	0.510	–0.742	2.409
ln(cooling degree days)	–0.210	0.759	–2.617	1.347
ln(energy price)	1.821	0.247	0.898	2.528

Summary statistics on 48 continental states between 1970 and 2001 (1,536 observations).

Table 9. Semi-Log Intensity Regressions.

ln(price)	–0.144 (0.012)	–0.179 (0.006)	–0.588 (0.017)	–0.027 (0.018)	–0.493 (0.033)
ln($price_{t-1}$)	––	––	––	–0.182 (0.026)	–0.016 (0.040)
ln($price_{t-2}$)	––	––	––	.007 (0.026)	–0.043 (0.039)
ln($price_{t-3}$)	––	––	––	–0.005 (0.026)	.007 (0.039)
ln($price_{t-4}$)	––	––	––	.042 (0.026)	–0.027 (0.038)
ln($price_{t-5}$)	––	––	––	–0.082 (0.016)	–0.062 (0.029)
ln(per capita income)	3.743 (0.984)	2.651 (0.495)	1.738 (0.402)	2.788 (0.577)	1.380 (0.485)
ln(per capita income)^2	–0.220 (0.052)	–0.174 (0.026)	–0.120 (0.021)	–0.183 (0.030)	–0.102 (0.025)
ln(HDD)	.017 (0.009)	.107 (0.016)	.080 (0.015)	.056 (0.015)	.068 (0.015)
ln(CDD)	–0.018 (0.006)	–0.017 (0.007)	.000 (0.007)	–0.013 (0.006)	–0.003 (0.006)
Intercept	–14.70 (4.66)	–8.58 (2.34)	–4.08 (1.92)	–8.85 (2.75)	–2.07 (2.34)
permanent price change				–0.247 (0.009)	–0.635 (0.021)
Fixed Effects	no	yes	yes	yes	yes
Year Effects	no	no	yes	no	yes
Adj. R^2	0.42	0.82	0.90	0.80	0.87

Including fixed state effects increases the size of the price coefficient a bit. Adding year effects substantially increases the price coefficient from –0.179 to –0.588. It may be that the exclusion of year effects forces the price variables to pick up the effect of nation-wide macro shocks that are correlated with price changes. In addition, the sensitivity of energy consumption

(and intensity) to price changes is likely higher at the state than at the national level given the ability to shift economic activity among the states. It may be that price effects in regressions without year effects are obscuring the impact of state-level competition that makes energy consumption more sensitive at this lower level to price changes. The year effects are jointly significant and their inclusion does not impart any bias to the price variables.

Energy prices likely affect energy intensity with some lag. The next set of regressions in columns 4 and 5 of Table 9 provide results for current price plus five years of lags. More recent price changes (either current or a first lag) have stronger impacts on intensity than do more distant lags. When price coefficients are positive, the effect is modest. It may be more instructive to consider the impact of a permanent price change. In both regressions reported, the response to a permanent price change is comparable in magnitude to the regression in current price only and precisely estimated.[21]

I report results from regressions with the efficiency index as the dependent variable in **Table 10**. Regression results are similar to those from the intensity index regressions. Higher income is associated with a lower efficiency index over the range of income in the sample. Price effects are not substantially affected by the inclusion of state fixed effects but are significantly

Table 10. Semi-Log Efficiency Regressions.

ln(price)	–0.183 (0.013)	–0.170 (0.009)	–0.751 (0.025)	–0.115 (0.026)	–0.655 (0.050)
$\ln(price_{t-1})$	––	––	––	–0.130 (0.038)	–0.020 (0.061)
$\ln(price_{t-2})$	––	––	––	–0.020 (0.038)	–0.103 (0.059)
$\ln(price_{t-3})$	––	––	––	.020 (0.038)	–0.024 (0.059)
$\ln(price_{t-4})$	––	––	––	–0.000 (0.037)	.023 (0.059)
$\ln(price_{t-5})$	––	––	––	–0.001 (0.037)	–0.014 (0.045)
ln(per capita income)	6.161 (1.104)	5.500 (0.688)	3.172 (0.612)	3.333 (0.842)	0.152 (0.740)
$\ln(\text{per capita income})^2$	–0.343 (0.058)	–0.317 (0.036)	–0.211 (0.032)	–0.209 (0.044)	–0.055 (0.039)
ln(HDD)	0.021 (0.010)	0.072 (0.022)	0.095 (0.023)	0.014 (0.023)	0.037 (0.024)
ln(CDD)	–0.016 (0.007)	–0.007 (0.010)	0.013 (0.010)	–0.003 (0.009)	0.012 (0.009)
Intercept	–26.40 (5.23)	–22.62 (3.25)	–9.38 (2.92)	–11.53 (4.02)	5.86 (3.57)
permanent price change				–0.246 (0.013)	–0.839 (0.032)
Fixed Effects	no	yes	yes	yes	yes
Year Effects	no	no	yes	no	yes
Adj. R^2	0.33	0.60	0.74	0.55	0.69

[21] In all the sets of regressions, the coefficient on the permanent price change in regression with lagged prices is larger than the estimate for regressions with current price only. This suggests the Le Chatelier Principle at work.

larger when year effects are included. The long-run price effects are larger than the short-run effects. Finally, the magnitude of the coefficients on the price variables is similar to those from the intensity regressions.

A very different pattern emerges from regressions with the activity index as the dependent variable (**Table 11**). The coefficient on price is considerably smaller in magnitude and often positive in sign. Climate variables and income also have a much smaller impact on the mix of economic activity and the fit of the regression is much poorer. Even with a five year set of price lags, it appears that prices affect energy intensity primarily through changes in efficiency.

Summing up, it appears that rising income contributes to declines in energy intensity. Second, the long-run semi-elasticity of energy intensity with respect to price is between –0.25 and –0.63, and changes in energy price affect energy intensity through changes in efficiency more than changes in the mix of economic activity.

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. With an average state index level of 0.59 in 2001, the high-end price coefficient estimate implies a price elasticity of demand of roughly –1. Bjorner and Jensen (2002) cite estimates from a survey by Atkinson and Manning (1995) of median elasticity estimates of –0.5. Time series estimates—often associated with short-run effects—tend to be lower (median of –0.4) and cross-sectional

Table 11. Semi-Log Activity Regressions.

ln(price)	0.025 (0.006)	–0.024 (0.005)	0.064 (0.013)	0.079 (0.015)	0.093 (0.027)
$\ln(price_{t-1})$	––	––	––	–0.080 (0.022)	–0.007 (0.033)
$\ln(price_{t-2})$	––	––	––	0.018 (0.021)	0.039 (0.032)
$\ln(price_{t-3})$	––	––	––	–0.019 (0.022)	0.026 (0.032)
$\ln(price_{t-4})$	––	––	––	0.048 (0.021)	–0.018 (0.032)
$\ln(price_{t-5})$	––	––	––	–0.081 (0.013)	–0.056 (0.024)
ln(per capita income)	–1.211 (0.519)	–1.739 (0.383)	–0.931 (0.323)	0.184 (0.475)	1.360 (0.403)
$\ln(\text{per capita income})^2$	0.057 (0.027)	0.080 (0.020)	0.057 (0.017)	–0.018 (0.025)	–0.062 (0.021)
ln(HDD)	0.000 (0.005)	0.044 (0.012)	–0.004 (0.012)	0.051 (0.013)	0.042 (0.013)
ln(CDD)	–0.005 (0.003)	–0.011 (0.006)	–0.010 (0.005)	–0.008 (0.005)	–0.013 (0.005)
Intercept	7.24 (2.46)	10.17 (1.81)	4.59 (1.54)	0.78 (2.27)	–1.04 (0.225)
permanent price change				–0.034 (0.007)	0.076 (0.018)
Fixed Effects	no	yes	yes	yes	yes
Year Effects	no	no	yes	no	yes
Adj. R^2	0.17	0.48	0.69	0.45	0.65

estimates—often associated with long-run effects—higher (–0.8). My high-end estimates are for permanent changes in energy prices and so should be compared with the cross-sectional estimates and are on the upper range of these estimates.

Table 12 provides information for the top-ten energy consuming states in 2001. These ten states accounted for over half the energy consumption in that year. The first section of the table provides information on improvements in energy intensity since 1960. Texas had the greatest decline in energy intensity with its 2001 value less than half its 1960 value. It ranked seventh among the 48 continental states for improvements in energy intensity over that period. Relative to a weighted average improvement of forty percent between 1960 and 2001 for the continental states, the top-ten states varied between 30 and 50% in their energy improvement.

The state fixed effect reported indicates unmeasured and unvarying influences within the state that affect the intensity index. Texas, for example, has a state fixed effect of –0.153. After controlling for prices, income, and climate variation (as well as year specific effects), the average predicted intensity absent the fixed state effect would be 0.153 higher than actually observed. The fixed state effects are important in determining the relative gains across the states in energy intensity between 1970 and 2001. Ignoring the fixed state effect, Texas drops from fifth in energy intensity improvements among the forty-eight states to twenty-sixth over this time period. Several states have large and positive fixed effects (CA, FL, NY) that increase their energy intensity substantially. Two of the states (TX and PA) have large and negative state fixed effects.

The state fixed effect shifts the average (over time) energy intensity for the different states. There are several possible reasons for variation in the fixed effect. One possibility is that states may simply have cultural, political, or other propensities for energy conservation. A state that had social or institutional rigidities that obstructed energy conservation efforts would have a

Table 12. Top 10 Energy Consuming States in 2001.

		Intensity				Efficiency				Activity			
State	Consumption (Quads)	Index Value in 2001	Rank of Index	FE	Adj. Rank	Index Value in 2001	Rank of Index	FE	Adj. Rank	Index Value in 2001	Rank of Index	FE	Adj. Rank
TX	12.03	0.496	7	–0.153	26	0.620	11	–0.198	29	0.799	11	0.013	16
CA	7.85	0.538	13	0.168	5	0.603	9	0.204	4	0.892	41	0.000	41
FL	4.13	0.643	33	0.320	3	0.779	33	0.392	6	0.826	19	–0.029	30
NY	4.13	0.578	22	0.197	4	0.645	15	0.278	3	0.896	43	–0.039	45
OH	3.98	0.567	21	–0.068	24	0.702	21	–0.064	22	0.808	13	–0.016	27
PA	3.92	0.503	8	–0.113	17	0.663	19	–0.060	17	0.759	4	–0.078	33
IL	3.87	0.606	27	0.090	16	0.736	27	0.143	15	0.824	18	–0.039	37
LA	3.50	0.694	39	–0.074	44	0.885	45	–0.161	45	0.784	6	0.054	2
MI	3.12	0.642	32	0.015	30	0.708	23	–0.013	27	0.907	45	0.035	29
GA	2.88	0.681	38	0.124	21	0.812	37	0.114	23	0.839	23	0.018	20

FE: fixed state effect from fixed effect and year regressions. Rank is the rank order from lowest to highest. The adjusted rank is the rank of the predicted index in 2001 from the regression excluding the fixed state effect.

higher state fixed effect. Another possibility is that states may have made great gains in energy conservation prior to 1970 and that gains after that time are more costly. Thus energy intensity would not have fallen as much between 1970 and 2001 leading to a higher state fixed effect. The data do not support this latter hypothesis. I ran a regression of the fixed effect from the intensity index regression on the energy intensity in 1970 relative to energy intensity in 1960. If this hypothesis were true, the coefficient estimate would be negative. In fact the estimated coefficient is positive though not statistically significant (t-statistic of 1).

The pattern of rankings and fixed effects for the intensity index data and regressions are very similar to those of the energy intensity regressions, a not surprising result given the regression results suggesting the predominant role changes in energy efficiency play in affecting energy intensity. In the same vein, the magnitude and variability of the fixed effects from the activity index regressions are much smaller than for the efficiency index regressions.

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 consequences of the recent increase in energy prices for energy intensity. The most recent *Short Term Energy Outlook* from the Energy Information Administration (2006) predicts that energy prices will rise by between 20 and 50 percent in real terms between 2001 and 2007. Focusing on the regressions with fixed state effects but no year effects, 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:

$$\Delta\left(\frac{E}{Y}\right)\frac{1}{e_0} = -0.073 = \left(\frac{\Delta E}{E} - \frac{\Delta Y}{Y}\right)\frac{E}{Ye_0}$$

or

$$\frac{\Delta E}{E} = \frac{-0.073}{I} + \frac{\Delta Y}{Y}.$$

Using the state average energy intensity of 0.59 for 2001 (weighted by energy consumption) and a growth rate in real personal income of 14% between 2001 and 2007, energy use should be 1.6% higher in 2007 than it was in 2001. This is roughly ten percent of the increase that would have occurred had the energy intensity ratio stayed the same between the two periods (14%). Obviously, this is a crude calculation but suggests the magnitude of energy efficiency improvements in response to price changes.

A second policy experiment we can consider is whether the Bush Administration reduction in carbon intensity is feasible without substantial policy intervention. In regressions not reported here, I added a time trend (and trend squared) to the regressions without year effects. The trend coefficients suggest that absent changes in price, income, or weather conditions, energy intensity will trend downward over this decade by between 3 and 4%.[22]

[22] Growth in income suggests we should observe a larger decline in energy (and thus carbon) intensity. In fact carbon intensity fell by 16% between 1990 and 2000 suggesting that little policy intervention will be required to achieve the Bush Administration's goal of an 18 percent reduction in carbon intensity.

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.

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. Unobserved state fixed effects vary substantially across the states and suggest that state-specific cultural or institutional factors play an important role in predicting the degree to which states may be able to reduce energy intensity in the future. Understanding these state-specific influences is an important component of future research.

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.

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7. REFERENCES

Ang, B. W. and F.Q. Zhang. "A Survey of Index Decomposition Analysis in Energy and Environmental Studies." *Energy*, *25*, pp. 1149-1176, 2000.

Atkinson, J. and N. Manning. "A Survey of International Energy Elasticities," B. Terry, P. Elkins and N. Johnstone, *Global Warming and Energy Demand.* London: Routledge, 1995.

Auffhammer, Maximillian and Ralf Steinhauser. "The Future Trajectory of U.S. CO_2 Emissions: The Role of State vs. Aggregate Information," Department of Agricultural and Resource Economics, University of California, Berkeley, 2005.

Bernstein, Mark; Kateryna Fonkych; Sam Loeb and David Loughran. "State-Level Changes in Energy Intensity and Their National Implications," Santa Monica, CA: RAND, 2003.

Beshears, John; James J. Choi; David Laibson and Brigitte C. Madrian. "The Importance of Default Options for Retirement Savings Outcomes: Evidence From the United States," NBER Working Paper No. 12009. Cambridge, MA, 2006.

Bjorner, Thomas and Henrik Holm Jensen. "Energy Taxes, Voluntary Agreements and Investment Subsidies - a Micro-Panel Analysis of the effect on Danish Industrial Companies' Energy Demand." *Resource and Energy Economics*, *24*, pp. 229-249, 2002.

Blok, Kornelis; Henri L. F. de Groot; Esther E. M. Luiten and Martijn G. Rietbergen. *The Effectiveness of Policy Instruments for Energy-Efficiency Improvements in Firms*. Dordrecht: Kluwer Academic Publishers, 2004.

Boyd, Gale A.; J.F. McDonald; M. Ross and D. Hanson. "Separating the Changing Composition of U.S. Manufacturing Production from Energy Efficiency Improvements: A Divisia Index Approach." *The Energy Journal*, *8*(2), pp. 77-96, 1987.

Boyd, Gale A. and Joseph M. Roop. "A Note on the Fisher Ideal Index Decomposition for Structural Change in Energy Intensity." *Energy Journal*, *25*(1), pp. 87-101, 2004.

Brown, Marilyn A. "Market Failures and Barriers as a Basis for Clean Energy Policies." *Energy Policy*, *29*, pp. 1197-207, 2001.

Brown, Marilyn A.; Mark D. Levine; Walter Short and Jonathan G. Koomey. "Scenarios for a Clean Energy Future." *Energy Policy*, *29*, pp. 1179-1196, 2001.

Diederen, Paul; Frank Van Tongreren and Hennie Van Der Veen. "Returns on Investments in Energy-Saving Technologies Under Energy Price Uncertainty in Dutch Greenhouse Horticulture." *Environmental and Resource Economics*, *24*, pp. 379-394, 2003.

Diewert, W.E. "The Consumer Price Index and Index Number Theory: A Survey," 0102. Vancouver: Department of Economics, University of British Columbia, 2001.

Energy Information Administration. "Annual Energy Review 2003," Washington, DC: Energy Information Administration, 2004.

Energy Information Administration. "Short Term Energy Outlook," Washington, DC: Energy Information Administration, 2006.

Fisher, Irving. "The Best Form of Index Number." *Quarterly Publications of the American Statistical Association*, *17*(133), pp. 533-537, 1921.

Greening, Lorna A.; William B. Davis; Lee Schipper and Marta Khrushch. "Comparison of Six Decomposition Methods: Application to Aggregate Energy Intensity for Manufacturing in Ten OECD Countries." *Energy Economics*, *19*(3), pp. 375-390, 1997.

Greening, Lorna A.; David L. Greene and Carmen Difiglio. "Energy Efficiency and Consumption - the Rebound Effect - A Survey." *Energy Policy*, *28*(6-7), pp. 389-401, 2000.

Hassett, Kevin and Gilbert E. Metcalf. "Can Irreversibility Explain the Slow Diffusion of Energy Saving Technologies?" *Energy Policy*, *24*, pp. 7-8, 1996.

Interlaboratory Working Group. "Scenarios for a Clean Energy Future," ORNL/CON-476, LBNL-44029, NREL-TP-620-29379. Berkeley, CA: Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, and National Renewable Energy Laboratory, 2000.

Loughran, David S. and Jonathan Kulick. "Demand-Side Management and Energy Efficiency in the United States." *Energy Journal*, *25*(1), pp. 19-43, 2004.

Matsukawa, Isamu. "The Effects of Information on Residential Demand for Electricity." *The Energy Journal*, *25*(1), pp. 1-17, 2004.

National Commission on Energy Policy. "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges," Washington, DC: NCEP, 2004.

Pacala, S. and R. Socolow. "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science*, *305*, pp. 968-972, 2004.

Parry, Ian. "On the Costs of Policies to Reduce Greenhouse Gases from Passenger Vehicles," RFF DP 06-14. Washington, DC: Resources for the Future, 2006.

Pew Center on Global Climate Change. "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future," Washington, DC: Pew Center on Global Climate Change, 2004.

Pizer, William. "The Case for Intensity Targets," Discussion Paper 05-02. Washington, DC: Resources For The Future, 2005.

Schurr, Sam H. and Bruce C. Netschert. *Energy in the American Economy, 1850-1975*. Baltimore: Johns Hopkins Press, 1960.

Small, K.A. and K. Van Dender. "The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using US State Data 1966-2001," Irvine, CA: Department of Economics, University of California, 2005.

Sue Wing, Ian and Richard S. Eckaus. "Explaining Long-Run Changes in the Energy Intensity of the U.S. Economy," Report No. 116. Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change, 2004.

Sutherland, Ronald J. "Income Distribution Effects of Electric Utility DSM Programs." *Energy Journal*, *15*(4), pp. 103-118, 1994.

Wirl, Franz. "Conservation Incentives for Consumers." *Journal of Regulatory Economics*, *15*(1), pp. 23-40, 1999.

Wirl, Franz. "Lessons From Utility Conservation Programs." *Energy Journal, 21*(1), pp. 87-108, 2000.

APPENDIX

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.

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