THE FOOTPRINT OF GROWTH: A MULTI-FACETED ENVIRONMENTAL KUZNETS CURVE ANALYSIS OF CO_2 EMISSIONS IN THE U.S.

By

Hunter M. Richards

A Thesis Submitted to the Faculty of the

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In the Graduate College

The University of Arizona

2013

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permissions for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: ______________________

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the dates shown below:

______________________	5/8/13
George Frisvold	Date

Professor of Agricultural and Resource Economics

ACKNOWLEDGEMENTS

I could not have successfully conducted this study without the valuable guidance I received from faculty and friends. First, I must thank Dr. George Frisvold, my thesis advisor, who displayed an enormous amount of patience as I struggled to conquer the research process. He made my success a personal priority, and I owe him a real debt of gratitude for such generosity. I would like to thank Dr. Gary Thompson and Dr. Bruce Beattie for their time and guidance as well. They were very helpful in making themselves available with warm support in the midst of busy schedules. Finally, I would like to thank Marbella for her enduring love and support during many stressful days and nights grappling with research problems. I have been fortunate to have a strong support network during my academic journey.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Using state-level panel data, I revisit literature on the likelihood of an Environmental Kuznets Curve (EKC) relationship among U.S. states with respect to carbon dioxide emissions. Using panel-corrected standard errors to correct for nonspherical error structure, energy intensity, carbon intensity, and electricity trade effects are regressed upon appropriate sets of explanatory variables. Parameter estimates are incorporated into a calculation of total income elasticity of per capita CO_2 emissions, using decomposition analysis inspired by the Kaya equation. I find that econometric flaws in some of the models have skewed the results of prior studies in the form of unrealistically high-income thresholds at which income elasticity turns negative. I find evidence of an EKC curve with respect to trade-adjusted per capita emissions when correcting for these problems.

This paper contributes new analysis in the form of newer data, better-defined resource endowment variables, inclusion of demographic variables and, most importantly, an acknowledgment of possible structural change between two time periods, with the transition occurring in the mid- to late-nineties. Evidence of structural change was found and attributed to a variety of factors, including regional shifts with regard to institutional arrangements concerning the North American Electric Reliability Corporation (NERC) region boundaries, new electricity regulation in the 1990s, and a change in GDP data methodology reported by the Bureau of Economic Analysis (BEA). It is recommended that future studies provide more detail with regard to this structural change and more closely account for complex policy scenarios such as renewable portfolio standards (RPS).

CHAPTER I

INTRODUCTION

Carbon dioxide (CO_2) emission has been a significant topic in the national political dialogue of the U.S. for the past few years, and it is likely to receive further attention in the future in the context of technological change and the continued national debate about climate change. Though no comprehensive national emission regulation has yet taken effect, examination of the socioeconomic processes affecting emissions can be considered a responsible investment in optimal design of future policy goals. This paper has three main parts in pursuit of just such an examination. It aims to explain a method for attributing carbon dioxide emissions more accurately to the states responsible for particular emissions levels, define and investigate a per capita emissions identity equation that accounts for a variety of energy-related economic activities, and to reveal, through econometric analysis, the factors that influence these key economic activities. Econometric analysis will reveal whether or not income growth can lead to actual reductions in per capita emissions.

A considerable body of economics literature exists that focuses on Environmental Kuznets Curves (EKCs). In general, the theory is that the relationship between pollutant levels and per capita income tends to exhibit an inverted U-shape; that is, in the nascent stages of economic development, concentration of pollutants will tend to increase (with diminishing returns) along with rising per capita income until a particular income threshold is reached. Once per capita income surpasses this threshold, further increases will bring about an overall decrease in pollutant levels. This inverted U-shape could result as follows. First, pollution could increase with growth in economic activity such as industrial expansion or a heightened level of manufacturing and other energy-intensive practices. Next, pollution could later decline as enough income is available to pay for pollution-reduction measures or as the economy transitions to a less energy-intensive, more service-based structure. Scholarly research has revealed evidence that supports this theory for some pollutants, while research has also discredited it in the case of others. There has been work that refutes the presence of an EKC in the case of CO_2 emissions, but there remains additional work to be done in this area. This will be further discussed in the literature review section.

The collection of socioeconomic variables affecting climate change originally became known in the form of the Kaya equation, an algebraic identity that links the level of carbon dioxide emissions with several other key variables. The equation is the following (Jancovici 2011):

$$CO_2 = (CO_2/E) \times (E/GDP) \times (GDP/Pop) \times Pop$$

Where CO_2 represents carbon dioxide emissions, E represents world energy consumption, GDP indicates gross domestic product, and Pop is population. The ratios can be considered individually as intuitive economic concepts; (CO_2/E) measures the carbon content of energy, (E/GDP) is the energy intensity of an economy (the amount of energy consumed per dollar of goods and services produced), and (GDP/Pop) is the per capita income. The Kaya equation inspires the decomposition analysis in this paper, in which each constituent part is closely analyzed in terms of how much it contributes to the level of emissions and the potential for a policy change to manipulate emissions through certain components. In addition, each part will be regressed on its own collection of explanatory variables to gain an even deeper glimpse at this identity and the income elasticity of the individual parts.

This paper analyzes the contributing factors that determine differences between emissions levels of states in the U.S. As such, a panel data set is employed that considers annual variables across states, including the District of Columbia, from the year 1990 to 2010. Due to differing size and state population having obvious effects on the absolute emissions differences between states, *per capita* emissions levels will be the focus of the analysis rather than absolute measures. Fortunately, the corresponding modification to the Kaya equation is simple and straightforward. Dividing each side of the equation by population brings attention to per capita emissions without causing any confusing distortions:

$$(CO_2/Pop) = (CO_2/E) \times (E/GDP) \times (GDP/Pop)$$

When appropriate, other variables involved in this paper are also measured on a per capita basis. Using the components of this equation, regression analysis can reveal the possibility of an EKC existing with regard to per capita carbon dioxide emissions in the U.S.

One key distinguishing factor of this study is its organization based on time and its tests for structural change. In the initial research phase, it was discovered that the state-level GDP data reported by the Bureau of Economic Analysis (BEA) underwent a change in classification methodology between 1997 and 1998 that casts doubt on the appropriateness of combining pre-1997 data with later periods. The BEA has recommended not splicing these data together due to this discontinuity, as it could distort analysis of changes through time. Furthermore, the Federal Energy Regulatory Commission (FERC) introduced new regulation in late 1996 that made the U.S. electricity market considerably more open to competition, which could drive structural changes between periods. Consequently, this paper departs from the conventional approach of splicing these data and instead conducts two regressions for each dependent variable. One regression period examines data from 1990-1997, while the other includes data for 1998-2010. If results are consistent between the two periods for each model and there is no detection of structural change, it adds a new degree of reliability to the insight gained from the modeling process. If structural change is detected, it calls for a new way of looking at these periods.

The econometric analysis in this paper includes variables that have been designed to allow more direct and practical conclusions from the modeling process compared to prior studies, and some demographic variables are included as well. Energy resource endowment data were compiled in an especially meticulous manner and aggregated to allow a direct look at the relationship between resource endowments and per capita emissions. Here, data for coal, crude oil, liquid natural gas, and dry natural gas *reserves* (rather than production) are aggregated based on the carbon dioxide emissions their consumption produces. Each fuel type is converted to million metric tons of CO_2 embodied in their possible consumption, using individual specific conversion ratios. The result is an overall measure of fuel reserves that controls for differences in emission intensity between fuel types, allowing a direct interpretation of the link between fuel reserves and emissions levels in a state. In addition, nuclear power capacity is included with hydropower capacity to produce a wide-ranging clean fuel variable.

This paper also addresses the possibility that household energy consumption may vary with age due to behavioral differences among people in different stages of life. The proportional age distribution of each state's population is thus included in econometric analysis. Overall, the goal of this paper is to discover additional nuances to improve the understanding of carbon dioxide emissions levels in the United States in the face of potential structural change, and to determine whether an EKC relationship exists for consumption-based carbon dioxide emissions as opposed to production-based emissions. The economics of energy use is likely to continue to grow in importance for many years in the midst of changing natural and political environments.

CHAPTER 2

LITERATURE REVIEW

2.1 Environmental Kuznets Curves and Carbon Dioxide Emissions

Joseph E. Aldy of Harvard University's Department of Economics has produced substantial research on factors affecting state-level carbon dioxide emissions and the associated Environmental Kuznets Curves (EKCs). He acknowledged that EKCs in most cases do not apply to carbon dioxide as a pollutant, due to its barely detectable presence (Aldy, 2005a). However, he suggests that the relationship between emissions and income may nevertheless exhibit essentially the same inverted U-shape to reflect structural changes in an economy and changing directions of net electricity trade. For example, states with growing per capita incomes are likely to move from agriculture to manufacturing to services, with an inverted U-shaped curve due to differing emissions intensities of these economic activities. With his state-level 1960-1999 data set, Aldy found evidence that "consumption-based EKCs peak at significantly higher incomes than production-based EKCs, suggesting that emissions-intensive trade drives at least in part the income-emissions relationship" (1). Aldy's findings that temperature extremes and coal endowment have been positively associated with state CO_2 emissions inspired this paper's inclusion in the regression analysis of heating degree-days (HDDs) and cooling degree-days (CDDs), which were both employed by Aldy, and historical fuel endowment data (also employed by Aldy, but included here in more specific and direct measurements).

In this thesis, calculation of production- and consumption-based emissions estimates is done the same way as Aldy, subtracting emissions embodied in exports (estimated using the exporting state's average electricity carbon intensity to convert to emissions) from production to calculate consumption-based emissions for net exporters and adding emissions embodied in imports (calculated using the average carbon intensity of electricity imports) in the case of net importers. One attribute of Aldy's study that this paper improves upon is his econometric methodology; Aldy chose a feasible generalized least squares (FGLS) approach to correct for cross-sectional heteroskedasticity with a one-year-lag autoregressive error structure, which has been shown in the literature to be a sub-optimal approach to such error adjustments with panel data sets. As will be discussed later in the literature review, a more reliable approach is to use panel-corrected standard errors (PCSE) in this context.

One paper examined historic international emissions distributions and forecast future distributions to look for evidence of future per capita emissions convergence (Aldy, 2005b). Important for our analysis, Aldy also explained some of the shortcomings of EKC regressions and models in predicting future distributions of emissions. While Aldy finds through graphical analysis that "the EKC yields ambiguous conclusions about convergence during the transition to the steady state," he does not dispute the conceptual relationship between per capita emissions and per capita income for a single cross-sectional entity (13). Aldy acknowledges the importance of understanding factors contributing to future levels of emissions and their relative distribution. He adds that a major shortcoming of EKCs in this context is that "empirical EKC regressions may not appropriately estimate long-run emissions distributions especially if factors such as trade in energy-intensive goods are important, as appears to be the case in work on the U.S. states" (16). This paper's intimate dealings with *trade-adjusted* carbon dioxide emissions attempts to correct for this shortcoming while also identifying the impacts major socioeconomic characteristics have on these emissions levels and their direction of flow, the importance of which Aldy seemed to suggest for further research.

A third paper looked at U.S. states to determine whether or not income convergence is sufficient for per capita CO_2 emissions convergence to take place (Aldy, 2006). This paper also does important work in comparing production- and consumption-based per capita CO_2 emissions among the states, using these measures (along with per capita income) to test for convergence. Aldy claims that, because per capita incomes in the U.S. states have been converging over the past century, he could examine the states to determine whether per capita emissions converge because of this income convergence. The novel aspect of Aldy's paper was his accounting for emissions-intensive trade to produce a measure of consumption-based emissions for testing. Aldy "converted energy consumption to CO_2 emissions using national sector- and fuel-specific emissions factors provided by EIA" (3). Although this paper uses an average carbon-intensity approach, the spirit of the calculation is the same as that employed by Aldy. Aldy found that production-based CO_2 emissions have been *diverging* in the midst of economic convergence in the U.S., while "the consumption CO_2 measure does appear to be converging in a stochastic sense" and "the different distributional dynamics between production emissions and consumption emissions reflect the effect of increasing interstate electricity trade over time" (14). Analysis herein is guided by these revelations while simultaneously expanding upon this conceptual knowledge base.

One previous study is particularly helpful in providing a solid overview of the theoretical and empirical underpinnings relating to the possibility of EKCs occurring with regard to certain types of pollutants (Dinda, 2004). In the study, Dinda recalls that some of the existing literature on the EKC echoes the assumed graphical relationship and, in general, claims, "economic growth may be a precondition for environmental improvement" (433). The survey recalls theory that suggests a lack of environmental awareness and clean technologies at low levels of economic development, which supports the initial portion of the EKC curve. The falling pollutant portion of the EKC curve has been attributed to a variety of actions that can arise after a threshold level of per capita income is reached, including the emergence of information-intensive industry, increased environmental awareness, environmental regulations, cleaner technology, and expenditures relating to environmental improvement (when sufficiently high incomes indicate that such expenditures are affordable). Dinda also acknowledges the importance of trade, albeit in an international context, writing "the pollution from the production of pollution-intensive goods declines in one country as it increases in other country [sic] via international trade" (436). The trade adjustment for carbon dioxide emissions levels in the United States is one way of responding to this trade effect to accurately measure carbon footprints of cross-sectional entities.

In terms of empirical results, Dinda's paper finds that a variety of pollutants empirically exhibit the inverted U-shape of the EKC, while air pollutants that have "little impact on health" fail to show any empirical evidence of the curve (441). Dinda goes further in specificity, stating "both early and recent studies find that the global pollutants (such as carbon dioxide emissions) either monotonically increase or decrease as income grows" (441). According to Dinda, this is likely due to CO_2's nature as a pollutant with indirect impact and the fact that it is a global environmental indicator rather than a local one (442). Inclusion of additional variables and adjustment for trade in the level of emissions could offer different conclusions, however. Thus, our trade adjustments and our attention paid to the multi-variable Kaya equation may contribute to a better-fitting model with regard to per capita carbon dioxide emissions.

Earlier literature more generally examined the relationship between economic growth and carbon dioxide emissions (Holtz-Eakin and Selden, 1995). The paper leveraged a global panel data set to estimate the relationship between per capita income and emissions and to forecast future global emissions. One major conclusion of the paper was recognition of a "diminishing marginal propensity to emit (MPE) CO_2 as economies develop," a result that was more detectable when including a time series element to the econometric analysis rather than using only cross-sectional data (0). Holtz-Eakin and Selden's paper also notes the inverted U-shaped relationship between per capita income and some pollutants *not including* carbon dioxide while emphasizing, like Dinda, the "significant health and environmental effects" characteristic of these pollutants (3).

Holtz-Eakin and Selden, however, acknowledge the possibility of a similar relationship occurring in the case of carbon dioxide. They acknowledge that carbon dioxide's global nature and its high abatement cost make it possible to exhibit a different relationship. Yet, they also argue that greenhouse gases are often "produced jointly with other pollutants" and therefore "emissions of greenhouse gases may fall as a byproduct of other abatement efforts" (4). With their panel data econometric analysis, their paper finds the diminishing MPE along with economic growth. Holtz-Eakin and Selden leave out a number of exogenous variables in their model, that they acknowledge might be worthwhile to include; several of these mentioned variables are employed in this thesis paper, including climate, geography, resource endowments, and others. Furthermore, Holtz-Eakin and Selden's paper omits the emissions embodied in imports and exports, admitting that "trade-adjusted fossil fuel consumption estimates would be preferable," an objective met in this thesis paper through the trade adjustment calculation described later (9).

Additional work also contributed to the CO_2-GDP relationship literature with analysis on an international time series cross-section data set (Tucker, 1995). Like the model presented in this thesis paper, Tucker's regression analysis included a squared term for per capita income (in addition to the simple per capita income variable) as an explanatory variable in his per capita emissions model. As Tucker eloquently puts it, "changes in GDP per capita squared measures the acceleration or deceleration of changes as income increases. If this term is negative, it will reflect declining marginal increases in emissions as GDP across countries increases" (219). Indeed, this squared term was found to be negative and significant in many of Tucker's regressions.

2.2 Decomposition Analysis and Energy Intensity

As was discussed in the introduction, the Kaya equation introduces multiple components that determine per capita carbon dioxide emissions, one of which is known as energy intensity. A relevant paper in the literature looks at how energy intensity in the United States has changed over time (Metcalf, 2008). Furthermore, the paper looks for empirical changes that can reveal specifically what led to these decreases in energy intensity. Essentially, Metcalf conducted an econometric analysis of energy intensity over time to see if efficiency improvements or changes in the mix of economic activity (both constituents of the decomposition analysis equation for energy intensity) were more substantial in affecting energy intensity over a thirty-year period.

Metcalf also sought to uncover the drivers of changes to these individual efficiency and activity components. He found that rising per capita income and increases in energy prices were significant drivers of decreased energy intensity, mostly in an efficiency sense (e.g. consuming fewer Btus to accomplish a given task) rather than through changes in the mix of economic activity. In the paper, Metcalf applied decomposition analysis to energy intensity, breaking it down mathematically into efficiency and activity components. This provides a precedent for the type of decomposition analysis carried out in this thesis paper, in addition to the regression analysis of constituent parts. Here, we provide a more comprehensive combination of decomposition and regression analysis by including three constituent components of per capita carbon emissions, rather than just one: energy intensity, electricity trade effects, and carbon intensity.

Additional demonstration of relevant decomposition analysis is also provided in another recent paper (Vinuya et al, 2009). The model used by the authors analyzes state-level CO_2 emissions changes from 1990 to 2004, decomposing the changes into emissions per unit of fossil fuel, share of fossil fuel in total energy consumption, energy intensity, gross state product per capita, and population. The paper also attributed gains in energy efficiency, among other effects, to reduction effects in carbon dioxide emissions. Declines in energy intensity were also said to play a large role in emissions reduction, with the authors encouraging deeper research on energy intensity specifically in future studies.

2.3 Panel-Corrected Standard Errors

A critical portion of the econometric techniques employed in this thesis were influenced by a helpful quantitative study (Beck and Katz, 1995). Beck and Katz showed with evidence from Monte Carlo experiments that the generalized least squares (GLS) approach, which was a conventional strategy for this particular type of data in many prior studies, tended to underestimate variability by 50% or more in many cases. Beck and Katz argue that, due to the large number of parameters in the error process of time-series cross-section (TSCS) models, the error process cannot really be known, in contrast to the assumption of the feasible generalized least squares (FGLS) approach; therefore, in these cases, FGLS estimation leads to understating the true variability of estimated coefficients' standard errors. In this sense, confidence is unrealistically high when FGLS is employed for TSCS models.

Beck and Katz's proposed method retains OLS estimates of model parameters but replaces their standard error estimates with panel-corrected standard errors (PCSE), the accuracy of which was supported by additional Monte Carlo analysis. The PCSE method was shown to perform very well, even in cases of highly complex error structures. Beck and Katz also show that the Parks FGLS method would not sensibly apply to this thesis due to the structure of the data set; they find that "it is impossible to use the Parks method if the length of the time frame, T, is smaller than the number of units, N" (644). In light of this analysis, this paper uses the PCSE approach when necessary to correct for nonspherical error structure.

2.4 Combination of Decomposition Analysis with EKC Analysis for Trade-Adjusted CO_2 Emissions

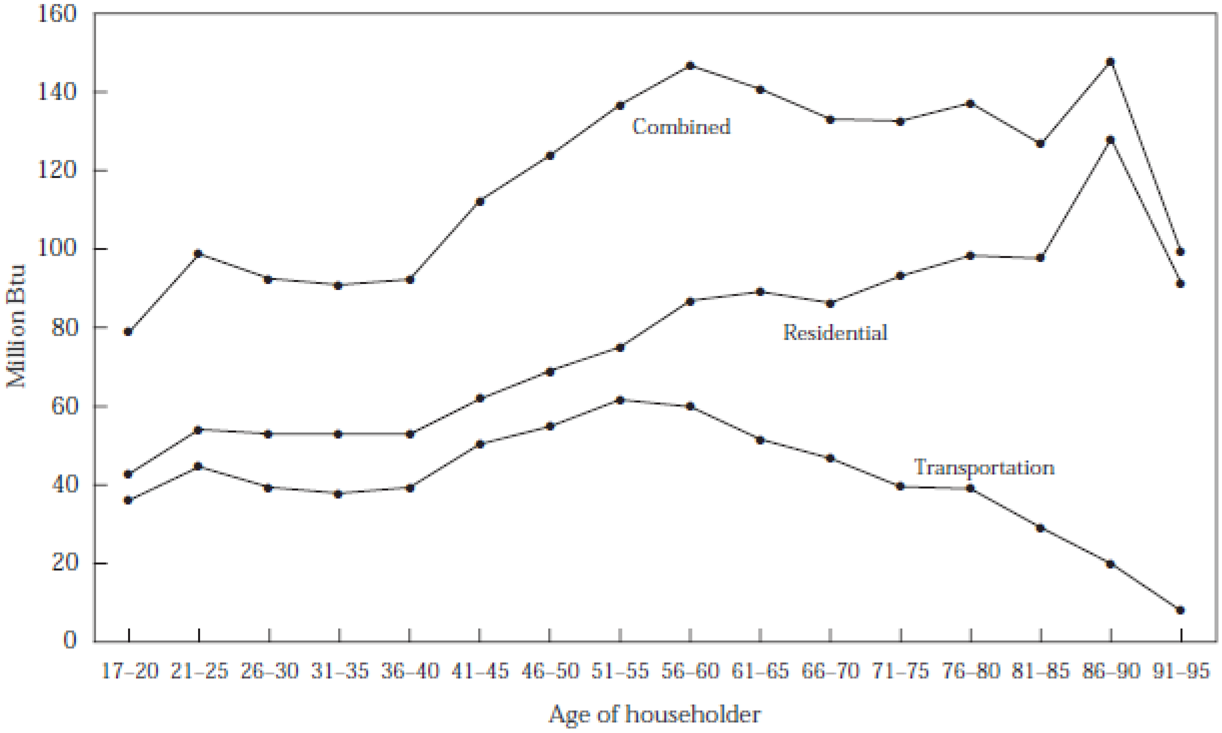
Many fundamental aspects of this paper – the panel data structure, the PCSE estimation methodology, the EKC exploration, and others – are inspired by a recent master's thesis (Subramaniam, 2010). In many ways, this paper is a spiritual successor to Subramaniam's study. Subramaniam performed decomposition analysis and regressed energy intensity, carbon intensity, and electricity trade effects using PCSE in large part to determine the elasticities of these components with respect to income. Evaluating these elasticities at their minimum, mean and maximum values, she showed the point at which each elasticity became negative. Summing up all the constituent elasticities, Subramaniam found evidence of an EKC curve from 1990 to 2007, with just a few high-income states having surpassed the threshold at which additional per capita income gains bring about a reduction in carbon dioxide emissions. Subramaniam utilized trade-adjusted – or consumption-based – emissions in her study, just as this paper does.

This paper contributes more data, more detailed natural resource endowment variables, and inclusion of demographic variables for the energy intensity regression. Importantly, this study also recognizes the temporal break in the BEA's public GDP data as well as its warning not to combine these data for analyses through time. Finally, this paper introduces the idea that changing electricity market mechanisms in the mid-1990s creates the possibility of structural change that could necessitate estimating separate regressions for periods before and after these regulations were established. The analysis herein will check whether Subramaniam's detection of an EKC with respect to carbon dioxide emissions can be upheld in the context of these market changes and the data discontinuity. This paper also compares the income-emissions relationship between production- and consumption-based CO_2 emissions.

2.5 Age Distribution and Energy Use

A new element to the econometric analysis in this paper with regard to energy intensity is the influence of age demographics. Inclusion of age group variables takes inspiration from prior work (O'Neill and Chen, 2002). O'Neill and Chen suggest that, in addition to direct effects, "aging could also have indirect impacts through an associated decline in household size and consequently a loss of economies of scale in energy use at the household level," leading to possible increases in per capita energy use (53). Other factors affected by age that might change energy use include income and labor force status. The authors also point to possible cohort effects (characteristics of people born in the same period), which can be estimated using the age range variables in our energy intensity regression model. In addition, other studies have found ample reason to consider population by age group as a relevant demographic variable that could affect energy consumption and carbon dioxide emissions; some have even suggested that aging leads to lowered transportation energy demand but higher residential energy demand (Dalton et al, 2006; Hardee and Jiang, 2010). Figure 1.1 depicts mean per capita energy consumption by age of householder (or head of household) for 1993 and 1994. Although the plausibility of some spikes in this figure could be questioned, one can see that there is clear variation with respect to age.

Figure 1.1: Mean Per Capita Energy Consumption by Age of Householder 1993-94



Source: Chen, Belinda S. and Brian C. O'Neill, "Demographic Determinants of Household Energy Use in the United States," *Methods of Population-Environment Analysis, A Supplement to Population and Development Review*, 2002, Web, figure 1.

CHAPTER 3

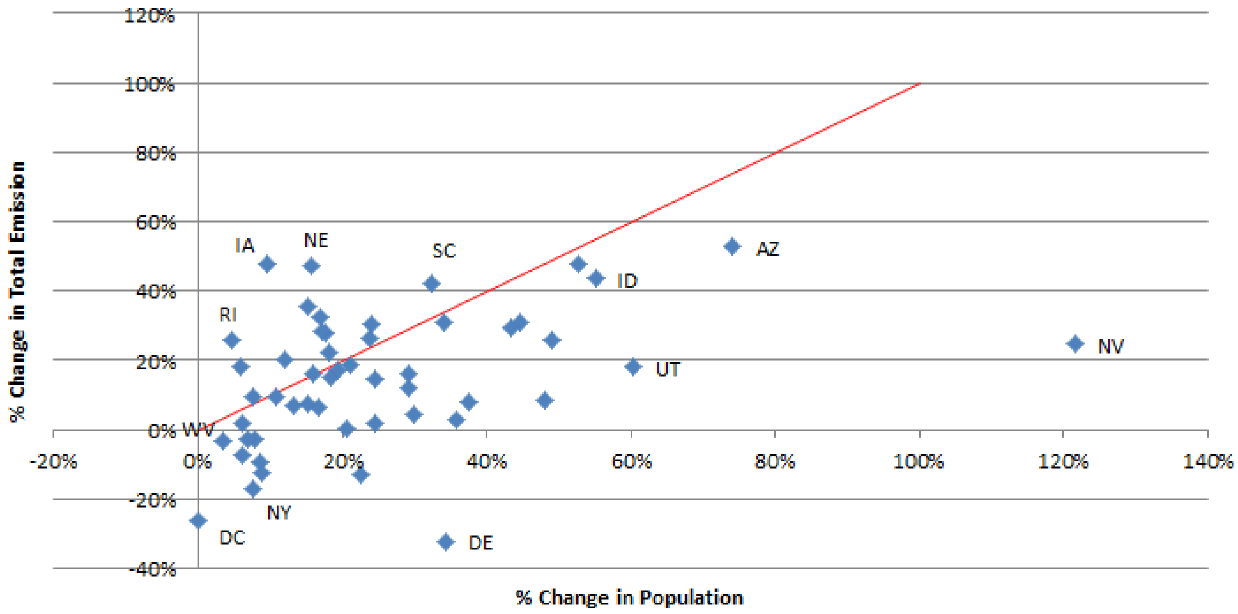
STATE-LEVEL CO_2 EMISSIONS

3.1 Production-Based Emissions and Population Change

While absolute emissions are important from the perspective of climate science, per capita emissions are especially indicative of an overall state's carbon footprint that results from the structure of its economy and its policies. Examining emissions growth in conjunction with population growth yields the most accurate glimpse of each state's emissions trajectory over time due to its specific characteristics (states with higher populations are obviously predisposed to higher emissions due to more total consumption). In some cases, absolute emissions have actually declined; from figure 3.1, this appears to be the case for several states including New York, Delaware, and Washington, D.C. between 1990 and 2010. In the case of Washington, D.C. it seems to have helped the city to go through essentially a net zero change in population, while it seems particularly striking that Delaware, New York, and a handful of other states were able to reduce absolute emissions even in the midst of a net gain in population. This is, of course, ignoring the possibility that electricity and other goods could have been imported from elsewhere, thereby giving rise to emissions not observed at home.

The percent change in total emissions is plotted together with percent change in population growth in figure 3.1, separated by a 45-degree line. States falling below this line have undergone emissions growth at a slower pace than population growth, indicating a drop in CO_2 emissions per capita. In total, there were 36 states with declining emissions per capita from 1990 to 2010, while 15 states experienced increases in per capita emissions. Iowa had the largest gain in per capita emissions with a 35% gain, while Delaware had the largest decline in emissions per capita at -49%. It is visible from the graph that West Virginia experienced declines in both absolute and per capita emissions (-3% and -6%, respectively) from 1990 to 2010 despite consistently leading the nation in carbon dioxide emissions embodied in electricity exports. It will be apparent later that, when considering emissions in trade-adjusted amounts, West Virginia's decline in emissions was even greater. Indeed, this graph shows that population growth can be associated with growth in emissions, but that loose association does not tell the whole story.

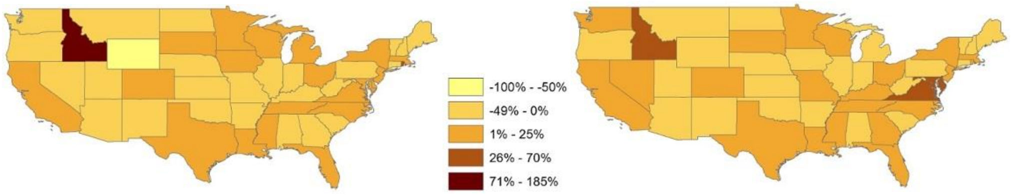
Figure 3.1: Percent Change in Total Production-Based CO_2 Emissions vs. Percent Change in Population, 1990-2010



3.2 Discussion and Comparison of State Production- and Consumption-Based CO_2 Emissions

The traditionally reported method of carbon dioxide emissions, with its basis on production within a state’s geographic borders, often does not fully account for the emissions incurred because of *consumption* within a given state. Consequently, some states’ reported per capita emissions actually underestimate the emissions resulting, however indirectly, from populations within them. Electricity trade is a large source of this discrepancy; often, states with relatively high population density, high income, or low reserves of conventional fuels import electricity from other states. The emissions resulting from the electricity produced elsewhere can be said to result from activity within the importing states, rather than those that actually produce the electricity. The difference between these two measures can be quite striking.

Figure 3.2: Percentage Difference Between Adjusted and Unadjusted Emissions Per Capita



1990 **2010**

Positive percentage values in Figure 3.2 above indicate states that have higher adjusted emissions per capita than unadjusted emissions; that is, when emissions per capita is transformed from a production-based value to a consumption-based one, emissions figures go up. A value of 200% in a map above indicates a state that consumes twice as much in carbon dioxide as the amount produced at home. It is clear that, in 1990, Wyoming’s consumption-based emissions figure is over 50% *lower* than the amount emitted within the state. Wyoming is a significant electricity exporter to states such as California, whose consumption-based emissions per capita were between 1% and 25% higher than its production-based emissions in both 1990 and 2010. These discrepancies of course fluctuate over time. Virginia's consumption-based emissions rose to over 25% greater than its production-based emissions between 1990 and 2010, so it is clear that Virginia began importing proportionally more electricity throughout that period. These complex geographical and temporal fluctuations make this situation well suited for econometric analysis that involves cross-section time-series data.

3.3 Delineation of Periods; Electricity Deregulation and Structural Change in the Mid-Nineties

Apart from the changing nature of the income data in this study, there exists additional motivation to split analysis into two periods. The Federal Energy Regulatory Commission (FERC), which regulates prices and access concerning interstate electricity transmission, issued new regulations in the mid-1990s that considerably changed the nature of electricity trade in the United States, which has a direct bearing on the economic forces surrounding trade-adjusted carbon dioxide emissions. Transmission has historically behaved like a natural monopoly, because there has usually only been one regional owner or operator with access to the necessary infrastructure for electricity delivery. Owners of these transmission systems have, for the most part, also owned generation assets. This relationship between generation and delivery assets has made it difficult for new competitors to enter the electricity generation market (FFC 7).

These strong barriers to entry caused high price variability because buyers and sellers could not behave as freely as in typical markets. In 1996, the FERC issued Order 888 and Order 889 in order to, according to the Federal Facilities Council (FFC), "speed the progress of the electric utility industry toward a competitive structure" (FFC 7). These orders required all public utilities to file tariffs to provide open transmission access in a non-discriminatory manner to all wholesale users, set up a framework for stranded cost recovery (with regard to debt or other obligations resulting from existing infrastructure investment prior to regulatory change), established procedures and guidelines for sharing information about transmission systems, and implemented various additional guards against discrimination, among other things. Transmission owners also had an information monopoly in the past, with private access to essential technical data; for example, transmission owners could refuse access to competing generation suppliers claiming no available capacity, while those seeking access had no information of their own to verify such claims. Order 889 established the Open Access Same-Time Information System (OASIS), an online database that transmission owners are required to maintain, that makes more of this crucial information available to interested parties. Utilities were required to post information concerning total transfer capability and available transfer capability for the next hour, day, and week (FFC 10). Requests for transmission service as well as responses to these requests were required to be made through the OASIS, keeping such interactions public and less vulnerable to preferential bias. The OASIS and related market changes were planned for implementation in late 1996. Given that this system likely took some time to become widely adopted, our break in time between 1997 and 1998 is appropriate to test for structural change beginning in this new era of regulation.

In addition to establishing the OASIS around this time, the FERC began to require “functional unbundling.” This requirement was designed to reduce unfair market advantage that resulted from the vertically integrated structure of most major transmission owners. This effectively split vertically integrated utilities into relatively separate power services and transmission services, with the requirement that each utility obtain transmission from itself with the same priority and under roughly the same terms as other market participants. Advantages such as being first in line for available service or unfair price deals were prevented through mandatory separation of utilities’ marketing functions and transmission functions, which were thereafter required to “deal with each other at arm’s length” (FFC 9).

Public utility transmission owners were required to provide transmission services to other market participants in roughly the same way it provided for itself; furthermore, the utilities were required to provide all transmission services they were capable of providing, rather than capping transmission services at the supply they needed only for themselves. In addition, all wholesale customers became eligible for transmission under a FERC tariff, including foreign utilities, as long as they were willing to provide similar market access to U.S. producers. This invited additional market participation, further smoothing price variability across the country and increasing competition. Transmission owners were also required to gain their information in the same way as everyone else – through OASIS – rather than passing information from their transmission operation branch to the wholesale marketing portion of the utility; such an exchange would now be considered unfair provision of inside information. It is clear that these new regulations were a game changer for the U.S. electricity market, and the splitting of this study’s regressions allow empirical testing of the consequences.

CHAPTER 4

GROWTH DECOMPOSITION ANALYSIS, DESCRIPTION OF THEORY, AND TRADE ADJUSTMENT CALCULATIONS

4.1 Review of Carbon Emissions Identity

Decomposition of carbon dioxide emissions is inspired from the Kaya equation, which was modified in the introduction to reflect *per capita* emissions:

$$(CO_2/Pop) = (CO_2/E)^1 \times (E/GDP) \times (GDP/Pop)$$

Whereas the usual reporting method conveys production-based carbon dioxide emissions, a method that is consumption-based in nature yields the more accurate carbon footprint measurement. The difference between the two is due to interstate electricity trade, such that the traditional method reports larger emissions measurements for net electricity exporting states and reports smaller figures for net importers compared to the emissions resulting from their consumption. Fortunately, the necessary calculations for obtaining the consumption-based emissions estimates are straightforward. Adjustments depend on emissions embodied in each state's net electricity exports or imports.

First, carbon emissions embodied in state electricity exports (C^X_{it}, with i standing for state and t for year) must be approximated. This is accomplished with the following formula:

$$C^X_{it} = X^e_{it} \times [C^e_{it} / E^e_{it}]$$

---

[1] The "E" above refers to total energy consumption as reported by the EIA; rather than reporting this consumption as a sum of different end-use types such as transportation, commercial, industrial, and residential, this amount was calculated by summing the consumption of each fuel type – including consumption of fossil fuels, nuclear power electricity, renewable energy, U.S. electricity imports, and net interstate electricity sales.

Here, X^e_{it} stands for net exports of electricity in Btus, C^e_{it} represents carbon emissions from total electricity generation, and E^e_{it} stands for the electric power sector's energy consumption in Btus in each state (interpreted as the state's electricity generation in Btus). Now the trade-adjusted emissions figures for net exporting states can be determined simply by subtracting the emissions embodied in electricity exports C^X_{it} from each state's total carbon dioxide emissions (from all sources), C_{it}:

$$C^T_{it} = C_{it} - C^X_{it}$$

The above formula yields the trade-adjusted measure of carbon dioxide emissions (C^T_{it}) from states that are net exporters of carbon dioxide based on interstate electricity trade.

For net importers, the process is slightly different. Because the Energy Information Administration (EIA) does not track where imports are coming from in the case of states that are net electricity importers, the emissions approximation cannot use a state-specific ratio as in the case of exports. Therefore, a national-level ratio (average) is used to approximate the amount of emissions present in each Btu of imported energy. Intuitively, one can think of this approximation as if electricity is sent to a central node in which all traded electricity is mixed together, taking on one uniform level of carbon dioxide per Btu of electricity. This method also ensures a trade balance in carbon dioxide; emissions of exports equals emissions of imports.To obtain this overall ratio for a particular year, it is necessary to first sum up all the values of C^X_{it} from each exporting state and derive the total amount of carbon emissions embodied in electricity exports, $\sum_i C^X_{it}$. Dividing this by the total exports of electricity in Btus, $\sum_i X^e_{it}$, derives the overall average emissions per Btu in interstate electricity exports:

$$\sum_i C^X_{it} / \sum_i X^e_{it}$$

Then, this average ratio can be multiplied by a state's net imports of electricity in Btus, I^e_{it}, to approximate the carbon emissions embodied in imports, C^I_{it} (for each net importing state only):

$$C^I_{it} = \{\sum_i C^X_{it} / \sum_i X^e_{it}\} \times I^e_{it}$$

Finally, the trade-adjusted carbon emissions figures can be calculated for net importing states by simply adding the emissions embodied in each state's electricity imports to their reported "production-based" total carbon dioxide emissions (from all sources), C_{it}. The following formula represents this final step:

$$C^T_{it} = C_{it} + C^I_{it}$$

Now one can see the differences between trade-adjusted (consumption-based) and the traditionally reported production-based emissions figures, which can be substantial.

There is a way to express trade-adjusted emissions figures such that a common notation can be used for both net exporters and net importers. This common notation can be achieved with the expression

$$C^T_{it} = (1 + S) \times C_{it},$$

where S is equal to a state's *share* or percentage of C_{it} when expressed in a ratio along with net imports C^I_{it}. This net import variable is defined such that it is negative in the case of a net exporter, equal to the negative of the net electricity exports. While sharing a common notation, we can also think of this intuitively as two similar equations:

$$(1 + S) = 1 - (C^{X}_{it} / C_{it})$$

for net exporters, and

$$(1 + S) = 1 + (C^{I}_{it} / C_{it})$$

for net importers. Notice that $(1 + S) < 1$ for net exporters while $(1 + S) > 1$ for net importers. This is because, for net importers, consumption-based emissions are greater than the production-based figures; meanwhile, net exporters have lower consumption-based emissions than the emissions resulting from production.

The (1 + S) variable can be particularly handy in several cases. For example, in constructing a regression equation to analyze or predict trade-adjusted emissions, a natural logarithm can be applied to turn the formula into a simple sum that can be used to obtain intuitive parameter estimates. In addition, it is rather easy to see that a larger value of (1 + S) will reflect regions in which electricity imports make up a larger amount relative to total emissions produced within geographical boundaries. In our analysis, we were able to rank regions by (1 + S) and observe that Washington, DC was consistently at the top. This fueled speculation that certain attributes of the District of Columbia – such as relatively high per capita income and population density with small land area – likely drove relatively high interstate electricity imports flowing into the area.

Orienting our per capita Kaya equation toward trade-adjusted emissions, the identity becomes

$$(CO_2^{T}/Pop) = (CO_2^{T}/E) \times (E/GDP) \times (GDP/Pop)$$

which, when we substitute the formula for trade-adjusted emissions, becomes

$$(CO_2^{T}/Pop) = (CO_2^{P}/E) \times (1 + S) \times (E/GDP) \times (GDP/Pop)$$

with the P superscript denoting production-based emissions. This can be rewritten in turn as

$$CO_2^C = CI \times (1 + S) \times EI \times Y$$

where CO_2^C is consumption-based per capita emissions, CI is carbon intensity, (1 + S) is the trade variable, EI is energy intensity, and Y is per capita income. Taking the natural logarithm of this formula results in a convenient sum:

$$\ln CO_2^C = \ln CI + \ln(1 + S) + \ln EI + \ln Y$$

If one were to simply regress $\ln CO_2^C$ on the right-side variables, the effect of income on per capita emissions would be simple; its influence would not be detectable in a way that leads to the inverted U-shape in a typical EKC. However, as Subramaniam shows in her 2010 thesis, such a shape would be detectable if one were to treat each of these right-side variables as functions of income themselves – such that:

$$\ln CO_2^C = \ln CI(Y) + \ln[(1 + S)(Y)] + \ln EI(Y) + \ln Y$$

The derivative of this equation with respect to income yields the following, which represents the total elasticity of consumption-based emissions with respect to per capita income:

$$d\ln CO_2^C/d\ln Y = [\partial \ln CI/\partial \ln Y]d\ln Y + [\partial \ln(1-S)/\partial \ln Y]d\ln Y + [\partial \ln EI/\partial \ln Y]d\ln Y + d\ln Y$$

The following must hold at some observed level of income for an inverted U-shape to describe the income-per capita emissions relationship:

$$[\partial \ln CI/\partial \ln Y] + [\partial \ln(1-S)/\partial \ln Y] + [\partial \ln EI/\partial \ln Y] < -1$$

Thus it is possible to explore the existence of such a relationship through growth decomposition analysis and regression analysis of each of the components (which obtains income elasticity values). This paper aims to see if these results are obtained for consumption- and production-based emissions in the presence of new data and variables, and while accounting for regulation-driven structural change between periods.

4.2 Growth Decomposition and the Log-Log Specification

Natural logarithms can be subtracted from one another - the "before" quantity from the "after" quantity – to give rise to what some call a "platonic change" between the two (Kimball 2012). In this sense, one can take the identity we have set up and simply subtract the initial quantities from the later ones to display an equation that expresses the percent change between two periods, paying attention to all individual components of the carbon dioxide emissions equation:

$$\ln(CO_{2t}) - \ln(CO_{20}) = [\ln(CI_t) - \ln(CI_0)] + [\ln(EI_t) - \ln(EI_0)] + [\ln(Y_t) - \ln(Y_0)]$$

where the initial year is marked with a 0 subscript and the later year is marked with subscript t. This provides a simple way to examine the relative proportions in which each component contributes to an overall change in carbon dioxide emissions. Figures 4.1, 4.2 and 4.3 show the relative contributions of changes in carbon intensity, electricity trade effects, per capita income, and energy intensity to per capita emissions. Each color-coded section shows the individual contribution of each effect, and the total height equals the sum of the total positive or negative percent changes. For example, Connecticut from 1990 to 1997 experienced positive effects from a 24% increase in trade effects and a 13% increase in per capita income, totaling a 37% positive influence on emissions. This is, however, not the *net* percentage change; each figure shows both positive and negative effects (Connecticut showed declining energy intensity in this period).

Figure 4.1: Percent Change in Per Capita Emissions Components, 1990-1997

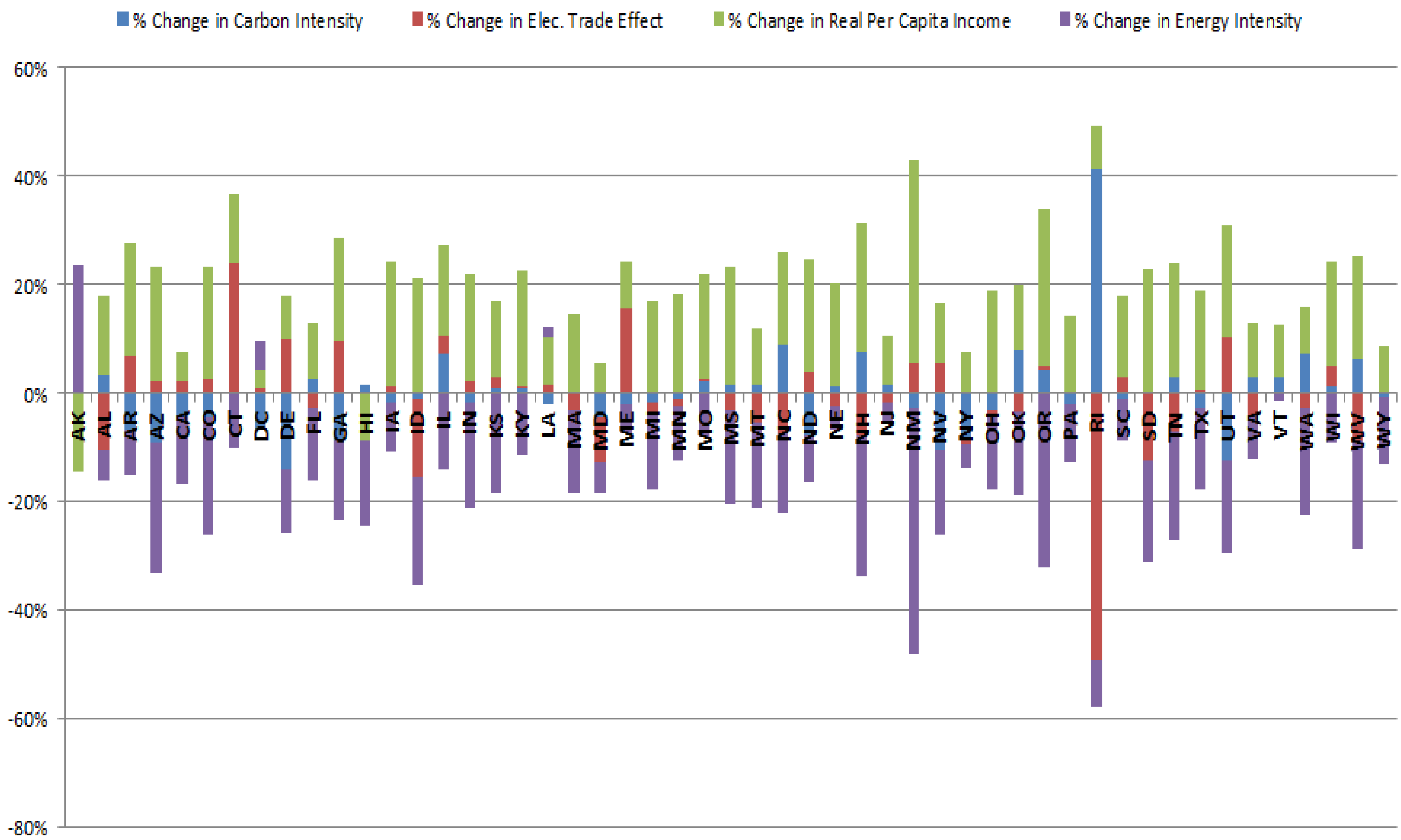


Figure 4.2: Percent Change in Per Capita Emissions Components, 1998-2004

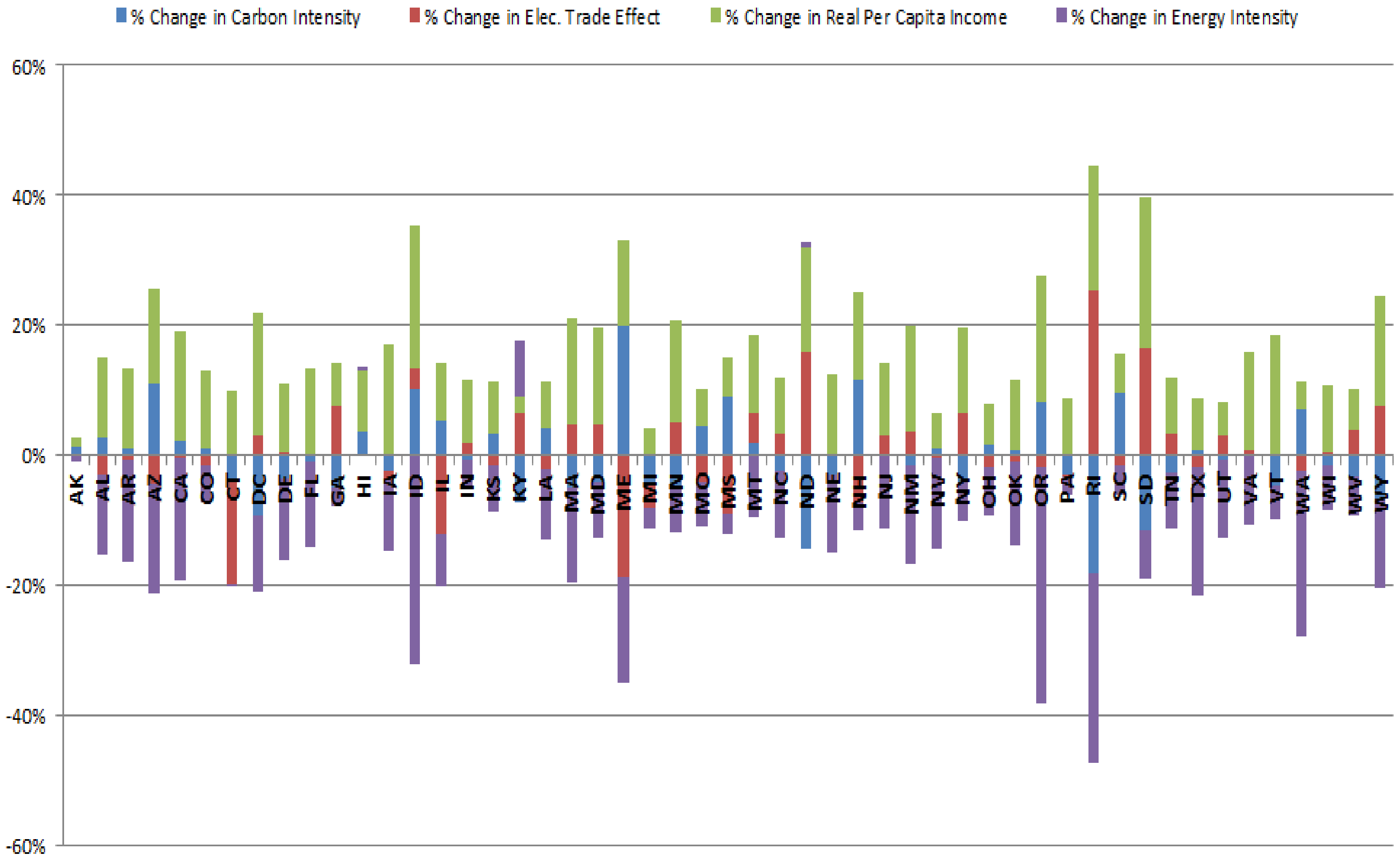
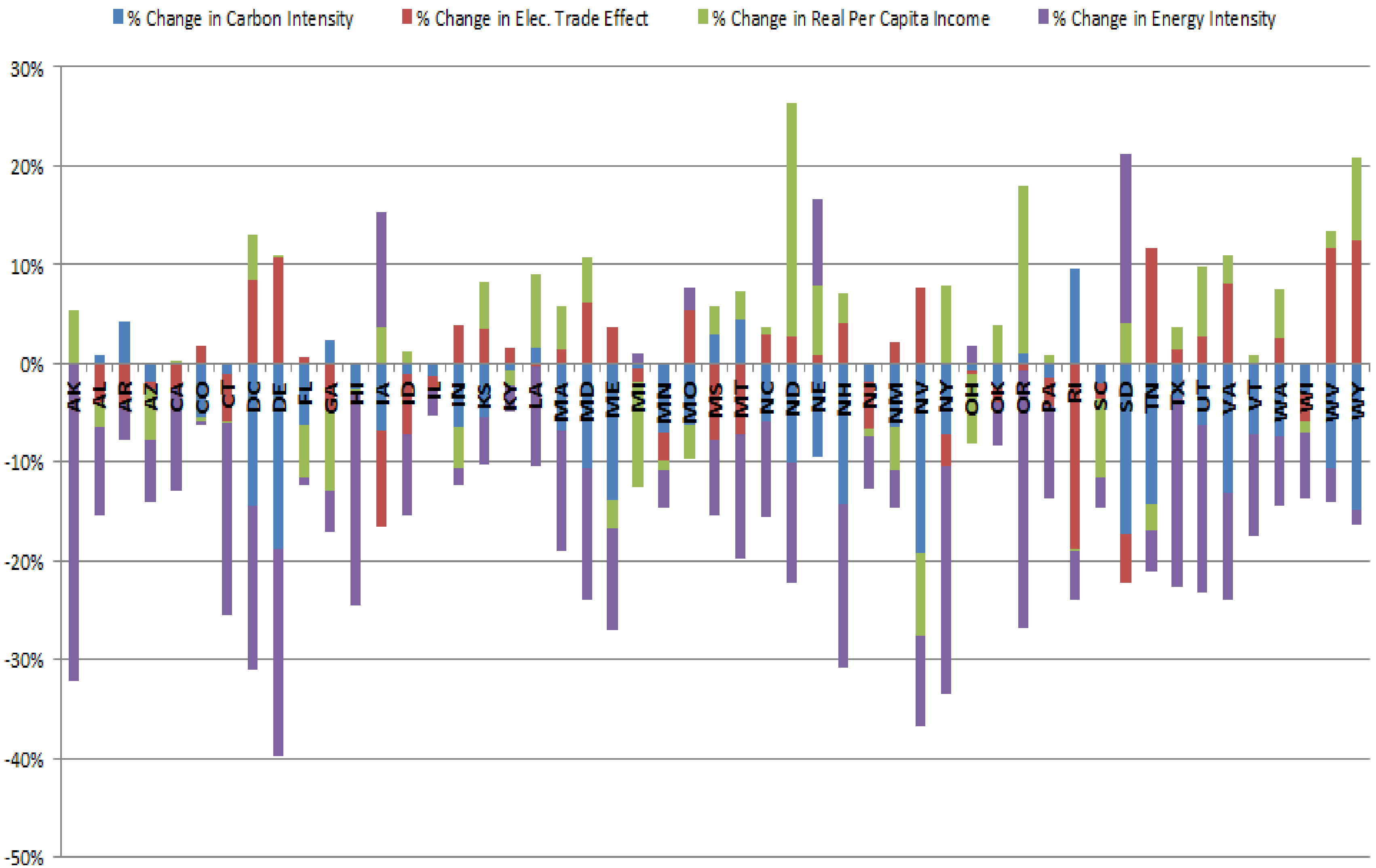


Figure 4.3: Percent Change in Per Capita Emissions Components, 2004-2010



In the 1990-1997 period, growth in per capita income was the main driving force of growth in per capita emissions in almost all states. There are a few striking outliers, though; Rhode Island's positive influences came mainly from an increase in carbon intensity, while Connecticut's main positive influence arose from an increase in electricity imports. This makes intuitive sense, as Connecticut is a relatively small state with a dense population and generally high income – which makes it a very sensible candidate as an electricity importer. Higher incomes denote the ability to pay, while dense populations usually indicate a general preference to place electricity-generating infrastructure elsewhere. Alaska's gains came almost entirely from increases in energy intensity – not too surprising, considering the fact that Alaska's relatively extreme climate includes the need to use electricity for heating households.

Given that policy controls generally do not aim to lower incomes, it is helpful to examine the components that can reasonably be controlled should it become a serious objective to lower per capita emissions. On a national level, the distribution of emissions should not be a major concern because CO_2 is a nonlocal pollutant; therefore, electricity trade effects might also become a lower priority than the other components. That leaves carbon intensity and energy intensity. From 1990 to 2004, energy intensity appears to have played a major role in declining influences on per capita emissions, which suggests that electricity has been used more efficiently over the years. It appears that carbon intensity has had moderate effects in both directions across all states; this effect deserves further study as another possible policy lever.

The picture looks a bit different when viewed in the context of time from 2004 to 2010. Per capita income growth plays a positive role in fewer states and to a lesser extent, while it also has a downward effect in many states for this period; this is likely due to the financial crisis and subsequent slow rate of economic growth starting around early 2008. For the most part, energy intensity and carbon intensity both had negative influences on per capita carbon emissions throughout this time period; this suggests hope for future policy initiatives that aim to continue or possibly intensify this downward trend, especially when per capita income returns to pre-recession growth rates.

CHAPTER 5

ECONOMETRIC SPECIFICATION AND DATA

5.1 Brief Description of Data

Data for this study came from a variety of sources (mainly federal agencies), and often required some manipulation or estimation for aggregation purposes. The following section provides a brief description of the data compiled for regression analysis. For additional details on sources, the data gathering process, and variable construction, see Appendix 1.

CO_2 Emissions, Trade Balance, and (1+S)

Data for total (energy-related) state-level carbon dioxide emissions from all sectors were downloaded in January 2013 from the Energy Information Administration's website. Construction of the variable (1+S) required these data along with interstate electricity trade data (reporting billion Btu of net interstate sales of electricity) and *electricity sector* carbon dioxide emissions, both of which came from the EIA. In the manner previously described, electricity sector emissions were used in conjunction with the EIA's state-level energy production data to estimate the average amount of carbon dioxide released per Btu of importers and exporters. Then, these averages were applied to trade balance data to adjust total carbon dioxide emissions and to construct the (1+S) variable for each state.

Carbon Intensity

Carbon intensity, measured as the general amount of carbon dioxide released per Btu of energy consumed in each state, was created from two different data series. The previously discussed all-sector CO_2 emissions data were divided by total state energy consumption as reported online by the EIA (originally reported in billions of Btu). Giving an indication of the degree to which "dirty" fuel is used in each state, carbon intensity was used as another dependent variable.

Energy Intensity

Energy intensity, or total energy consumed per chained 2005 dollar of real gross domestic product, was another state-level dependent variable. This variable was gathered online directly from the EIA. Energy intensity can be said to represent how efficient a state uses its energy with respect to economic activity, and can even show similarity to a representation of energy demand.

Population Density

Population density, expected to have a positive effect on (1+S) due to a preference of concentrated populations to locate energy generation elsewhere, was created from two data series. The population component was available online from the Bureau of Economic Analysis (BEA). Population figures were divided by time-invariant state land area figures. State land area information was gathered online from the U.S. Census Bureau.

Per Capita Income

Per capita income, an essential component of income elasticity calculations, was created from two data series. Real GDP was gathered for construction, in addition to the previously discussed population data. GDP data came from the BEA website in the “Regional Data - GDP & Personal Income” section. GDP figures were deflated as necessary for comparability, such that the entire time series represented GDP in chained 1997 dollars. The change of industrial classification methodology between 1997 and 1998 raises questions on the validity of bridging these data for a single time series. The details are provided in the data section of this paper’s appendix.

Natural Resource Endowment Data

Natural resource endowment data were included to account for the likelihood that states will react accordingly to the fuel supplies they have in relative abundance – that is, they will leverage these assets for economic gain in the form of exports and will have relatively more carbon intensive economies when fossil fuels are abundant. Two major variables were included to represent relatively carbon-intensive or “dirty” fuels (fossil fuel endowment) and the cleaner renewable sources (nuclear and hydropower). The latter variable is comprised of the sum of hydroelectric and nuclear nameplate capacity in each state in Megawatts, per capita. These data were gathered from the EIA’s website, summed together, and divided by the previously mentioned population data.

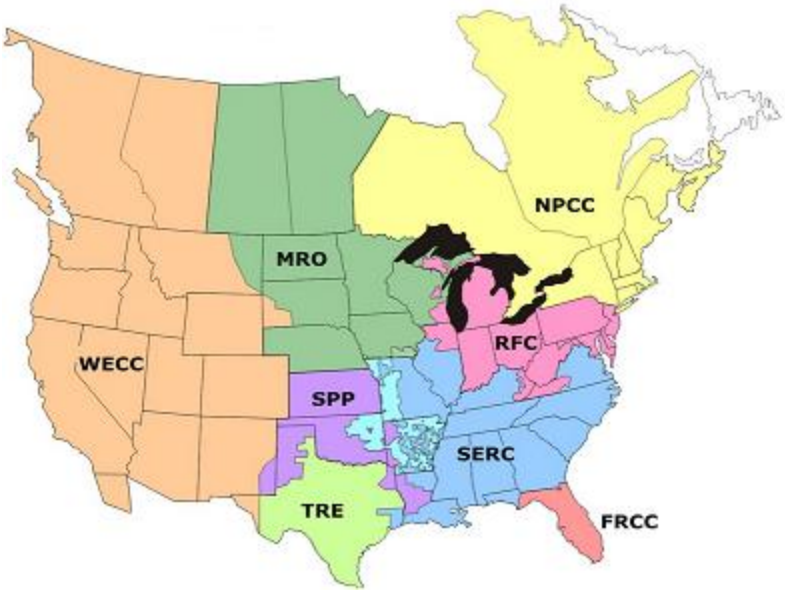
Fossil fuel endowment data were treated as carbon dioxide emissions embodied in the supply of fuel. Construction of this variable started with collection of reserve data for coal, dry natural gas, liquid natural gas, and crude oil. All four reserve types were downloaded online from the EIA. Various conversion techniques were used to aggregate these endowment variables into one measure, utilizing formulas from the EIA and Iowa State University. Much more detail concerning this process is provided in the data section of the appendix.

NERC Regional Dummy Variables

Regional dummy variables were employed to allow for regional fixed effects. Included were the eight regional entities that work with the North American Electric Reliability Corporation (NERC) to ensure power supply reliability and manage risk in North America. They include the Florida Reliability Coordinating Council (FRCC), Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability*First* Corporation (RFC), SERC Reliability Corporation (SERC), Southwest Power Pool Regional Entity (SPP), Texas Reliability Entity (TRE), and the Western Electricity Coordinating Council (WECC). All dummies were included in regressions with no penalty from a “dummy variable trap” because each state can be a part of more than one region. State dummies were treated as time-invariant with the exception of Florida; Florida is treated purely as part of SERC until the year 1996 in the dataset, at which point it is treated as part of both FRCC and SERC due to an organizational change.

There is much regulatory complexity arising from the definition of these regional dummies, and future researchers would be wise to spend more time researching how they change over time. Such a process, however, is outside the scope of this study. The map below, Figure 5.1, was used to construct the state regional dummy variables.

Figure 5.1: Map of NERC Regions



Source: North American Electric Reliability Corporation, "NERC Regions" (2013): Web.

Fossil Fuel Composite Price

Annual real fossil fuel composite prices were incorporated into the analysis, gathered online from the EIA. The EIA derived these data by multiplying price per Btu by the total Btu content of the production of each fossil fuel, then dividing this accumulated value of total fossil fuel production by the accumulated Btu content of total production of fossil fuel. Among other forms, the natural logarithm of the five-year lagged moving average of the real fossil fuel composite price was used; that is, for example, the 1990 five-year moving average was calculated as the average real fossil fuel composite price among the years 1985, 1986, 1987, 1988, and 1989. It was expected that this variable's coefficient would reflect a negative influence on energy intensity. Future studies might benefit by using more detailed prices instead of a composite price; this price was at the national level and did not vary between states.

State-Level Age Group Distribution

Four age range variables are included in the energy intensity model. The ranges correspond to percentages falling between the ages of zero and 19, 20 and 39, 40 and 54, and 55 and over. The 40 to 54 age range was dropped in the regression equation to serve as a base range. Counts of individuals in each age group were divided by population to construct the percentages, which are theorized to influence energy intensity as detailed in the literature review. The age group data is time varying, and the original counts were reported as of July 1st for each year. For 1990-1999, the estimates were computed by the U.S. Census Bureau using a demographic change model that accounts for birth and death rates as well as migration since the previous census date of April 1st, 1990. A similar methodology is used for 2000-2010 resident population estimates; the July 1st, 2010 value applies estimates of population change to the 2010 census count. While it does not explicitly say so in the metadata, it can be inferred that the 2000 census count used similar demographic change methods to estimate the 2000-2009 values.

Climate Variables: HDD and CDD

Data for heating degree days (HDD) and cooling degree days (CDD) were gathered from the National Climatic Data Center's website. These figures represent cumulative degrees by which mean daily temperatures exceeded or dipped below a temperature threshold considered comfortable for humans. The expectation is that higher values of HDD and CDD represent increased climate variability that drives additional energy demand. Consequently, they are both expected to show a positive influence on energy intensity.

5.2 Electricity Trade Effect

As previously stated, three econometric regression models were examined to determine the multiple ways in which income affects overall consumption-based emissions. The data set used in analysis was comprised of fifty states and the District of Columbia from the year 1990 to 2010, totaling 1,071 observations; 408 observations from 1990 to 1997 and 663 observations from 1998 to 2010. The first equation takes (1 + S) as the dependent variable; a large value for this variable indicates a positive influence on total trade-adjusted carbon dioxide emissions due to imports. The equation is specified thus:

$$\ln(1 + S)_{it} = \alpha_1 + \beta_1' X_{1it} + \gamma_{11} \ln Y_{it} + \gamma_{22} (\ln Y_{it})^2 + \delta_1 \ln POP_{it} + \eta_2 R_{it} + \varepsilon_{1it}$$

Where X_{1it} is a vector of energy resource endowment variables, including carbon dioxide embodied in fossil fuel reserves (crude oil, liquid and dry natural gas, and coal) and renewable reserves, lnPOP is the natural logarithm of a state's population density in a particular year, Y is a state's per capita income, and R is a vector of the regional dummy variables (created from NERC regions).

The energy resource endowment variables in X are all expected to have a negative effect on (1+S) because, whether they come from fossil fuels or from renewable energy sources, abundance of resources makes it less necessary for a state to import electricity; a state is more likely to generate its electricity independently or even to export electricity, both of which lower (1 + S). Population density, conversely, is likely to have a positive effect on (1 + S), for the reason that states with denser populations typically have tighter regulations on electricity production. These processes generate additional carbon dioxide. The attentive reader will point out that carbon dioxide emissions alone are unlikely to disturb population dense areas because CO_2 is a global pollutant with no immediate local adverse effects. However, as Aldy and others have pointed out, electricity production is also associated with higher emissions of other, more local pollutants that can cause immediate adverse impacts to public health. Because these local pollutants would likely spur opposition, electricity is more likely to be imported in population dense states, thus raising $(1 + S)$. The per capita incomes are included to test for the presence of an EKC curve, with a positive sign expected on the first coefficient and a negative one associated with the squared term.

5.3 Carbon Intensity Effect

Carbon intensity is a reflection of the fuel mix a state has employed to generate its energy. Just as it sounds, a fuel mix with higher carbon intensity typically leads to higher emissions of carbon dioxide (all else constant). I regress the natural logarithm of carbon intensity CI (measured in metric tons of carbon dioxide per billion Btu of total energy consumed) on a host of explanatory variables with the following equation:

$$\ln CI_{it} = \alpha_2 + \beta_2' X_{2it} + \gamma_{21}\ln Y_{it} + \gamma_{22}(\ln Y_{it})^2 + \delta_2 \ln POP_{it} + \eta_2 R + \mu_2 P_{it} + \varepsilon_{2it}$$

The variables here are all the same as in the (1 + S) regression equation, with the exception of one new variable, P. This is the national composite price of fossil fuels. Although this price was included in various forms throughout regression analysis, its most prominent form was the lagged five-year moving average because states are expected to take some time to adjust their fuel mix in response to price changes. These adaptations are, in other words, not instantaneous.

Again, the coefficient for population density is expected to have a negative sign in this equation, due to the previously discussed pollutants often released in conjunction with carbon dioxide during fossil-fuel burning activities, which have localized adverse effects. These effects can be thought of as especially pernicious when taking place in densely populated areas due to the more concentrated effect on public health. Of course, the fossil fuel endowment variables are expected to have a positive sign here, whereas the renewable (combined hydro and nuclear) capacity variable will be likely to have a negative sign. The effect of an increase in P is also expected to be negative, especially as constructed when a state has ample time to respond to a trend of price increases. One key take-away from this regression and the others is the particular elasticity with respect to per capita income. Here, the elasticity is as follows:

$\mathrm{dlnCI}_{it} / \mathrm{dlnY}_{it} = \gamma_{21} + 2\gamma_{22}\mathrm{lnY}_{it}$

The value depends on the parameter estimates and the particular value of income. The elasticities with respect to income of all three regression equations will be examined jointly to determine whether an EKC curve exists for per capita carbon dioxide emissions in the United States.

5.4 Energy Intensity Effect

Perhaps the most complex regression equation in this analysis is that for the energy intensity effect, measured by the number of Btu consumed in a state per dollar of real GDP (in 2005 dollars). The EIA provides a direct source for energy intensity data on their website, so no additional calculations were needed to construct this variable. The energy intensity effect can be said to represent energy efficiency because it represents how much "bang for the buck" each state gets out of its energy consumption. It is quite intuitive that high energy intensity is likely to lead to high carbon dioxide emissions, all else constant. The initial equation used in regression analysis is the following:

$\mathrm{lnCI}_{it} = \alpha_3 + \beta_3'X_{3it} + \gamma_{31}\mathrm{lnY}_{it} + \gamma_{32}(\mathrm{lnY}_{it})^2 + \delta_3\mathrm{lnPOP}_{it} + \eta_3 R + \mu_3 P_{it} + \lambda' Z_{it} + \theta' A_{it} + \varepsilon_{3it}$

Here the variables are largely the same as in the carbon intensity equation, with the introduction of a few new ones.

In this model, new variable coefficients are contained within the λ and θ vectors, while the observations are contained in the associated matrices (Z and A, respectively). The former contains coefficients for climate variables HDD and CDD. HDD, or heating degree days, represents the annual cumulative number of degrees by which daily mean temperature dropped below what is considered comfortable for human living (usually around 65 degrees Fahrenheit), thus requiring indoor heating to reach the comfortable temperature threshold. A cooling degree day, or CDD, is just the opposite; CDD measures by how many cumulative degrees mean daily temperature exceeded the comfortable threshold in a given year, thus requiring cooling to reach a comfort level. θ contains coefficients for age distribution variables. These variables describe the percentage of each state’s population falling into a particular age group. The groups are organized loosely around what was found in the literature to be age ranges between which energy use varied considerably due to behavioral norms, changing household structure, and other characteristics typical to individuals of particular ages.

It is acknowledged that the presence of income in both sides of the regression equation could be problematic for the model. GDP appears in the denominator of the dependent variable, energy intensity (Btu per dollar of real GDP), in addition to appearing in the numerator of per capita income (real GDP divided by population). Thus, to promote a well-rounded view of regression results and allow for a different (perhaps more reliable) perspective on the relationship between energy consumption and the explanatory variables, an additional regression was performed to examine any major differences between forms. This secondary regression equation retains the same explanatory variables but uses the natural log of *total energy consumption* (in billion Btu), rather than energy intensity, as the dependent variable to eliminate any problems of a shared variable between both sides of the equation. These regression results show some reversals in sign of parameter estimates. Using these estimates changes the total elasticity calculation we later examine to determine the possible presence of an EKC.

CHAPTER 6

REGRESSION RESULTS AND CONCLUSIONS

6.1 Time and Structural Change in the Data Set

As previously mentioned, this paper breaks up each regression into two periods, 1990-1997 and 1998-2010, to allow for structural change rather than estimating each model exclusively over one continuous time. Regulation-driven electricity market changes and discontinuous classification methodology in BEA income data suggest the periods should be treated differently in regression analysis. Indeed, two different tests of structural change were conducted on each model – one for panel-corrected standard errors (PCSE), and one for pooled OLS – and the null hypothesis of equal slope coefficients was rejected every time. Thus, it is deemed appropriate that – in contrast to prior studies – these two periods should be treated separately in making conclusions about trade-adjusted carbon dioxide emissions. Two separate periods of results will be reported for each specification. All specifications, unless otherwise noted, use Beck and Katz's panel-corrected standard errors estimation method, due to the finding that each regression equation displayed heteroskedasticity, contemporaneous correlation and autocorrelation; see the appendix for these test calculations and the tests of structural change.

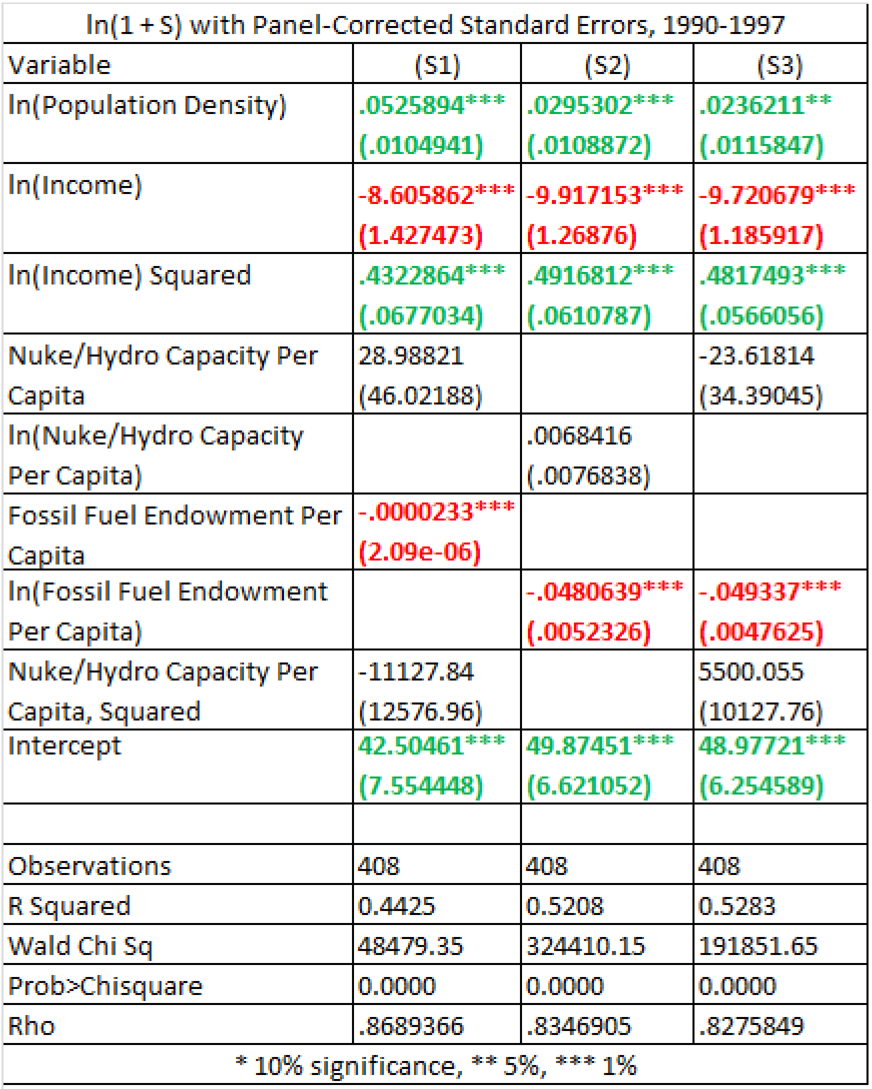
6.2 Electricity Trade Effect Regression Results

Three specifications were tested for the electricity trade effect: (S1) a model with "raw" measurements of natural resource endowments in embodied metric tons of carbon dioxide (for fossil fuel reserves) and megawatts of renewable capacity (nuclear and hydropower), including a squared renewable term; (S2) "transformed" natural logarithm versions of the endowment variables, excluding the squared renewable term; and (S3) one with the "raw" capacity value for the renewables but with the transformed fossil fuel endowment variable, including the squared renewable term. The transformed fossil fuel variable was the natural logarithm of the original observation plus one (to avoid undefined solutions concerning the natural log of zero), while the renewable energy adjustment was the natural logarithm of the original observation multiplied by one million and adding one. The multiplication was simply to change the data from very small decimals to larger numbers that were easier to handle. Adding one was expected to make very little difference on the parameter estimates, making it worthwhile to transform them for the sake of the simpler elasticity interpretation. All specifications included the eight NERC region dummy variables, natural log of population density, natural log of per capita income, and the squared natural log of per capita income.

The population density variable is significant in the expected direction across all specifications for both periods; its positive sign indicates that more population-dense areas are inclined to import more electricity, which agrees with theory and prior studies. These population dense areas are more sensitive to the emission of local harmful pollutants that occur with domestic electricity production. The log of income is negative and significant across all periods and specifications, while the square of the log of income is unanimously positive and significant. This could be reflective of the development path, as later rises in income may be coming from services that do not generate electricity at home. Fossil fuel endowment variables have significant effects in the negative direction as expected, indicating a shift to electricity exports with a richer fossil fuel endowment. One striking difference between periods is worth noting. While the renewable endowment variable is never significant in the initial period, the model with the best fit (R squared = .5133) in the latter period shows significance in both renewable capacity variables. The first term is positive, while the squared term is negative – indicating that states with low levels of renewable capacity might import more, whereas states with relatively higher capacity start to import less or export electricity.

This difference in signs demonstrates a difference in electricity trade between states with lower renewable capacity and those with a higher capacity. More research could illuminate why this would be the case, but one possible explanation could be Renewable Portfolio Standards (RPS), policies which require electricity supply companies to produce a specified percentage of their electricity from renewable sources. When the process is expensive to meet these goals, the result could be a small investment in renewable capacity and the shift to importing a higher percent of electricity to meet the goal. States with higher renewable capacity, on the other hand, might have invested more heavily in renewable technologies, to the point of shifting the trade balance toward exports. More research is needed to add reliability to this explanation, however. All regression results for the electricity trade effect are provided in Table 6.1 and Table 6.2; see the appendix for “all years” regressions and dummy variable coefficients.

Table 6.1: Electricity Trade Effect Parameter Estimates, Period 1[2]

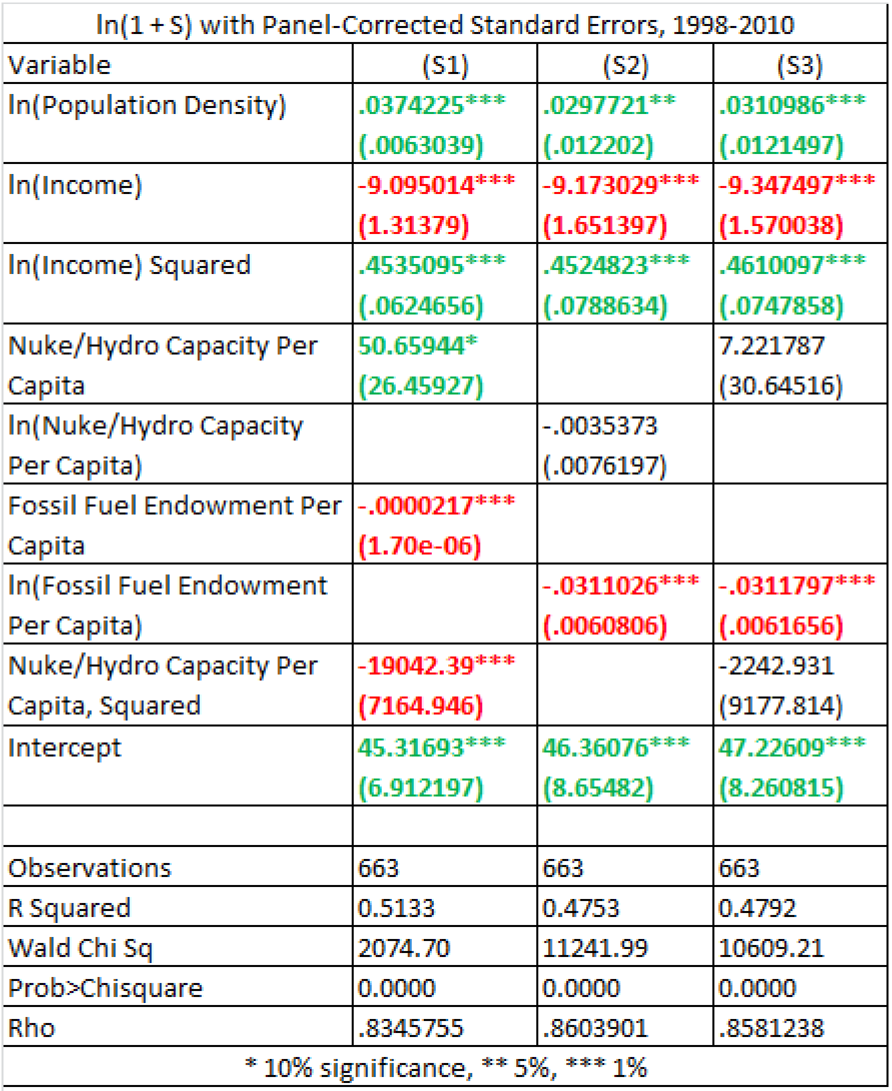


ln(1 + S) with Panel-Corrected Standard Errors, 1990-1997			
Variable	(S1)	(S2)	(S3)
ln(Population Density)	.0525894*** (.0104941)	.0295302*** (.0108872)	.0236211** (.0115847)
ln(Income)	-8.605862*** (1.427473)	-9.917153*** (1.26876)	-9.720679*** (1.185917)
ln(Income) Squared	.4322864*** (.0677034)	.4916812*** (.0610787)	.4817493*** (.0566056)
Nuke/Hydro Capacity Per Capita	28.98821 (46.02188)		-23.61814 (34.39045)
ln(Nuke/Hydro Capacity Per Capita)		.0068416 (.0076838)	
Fossil Fuel Endowment Per Capita	-.0000233*** (2.09e-06)		
ln(Fossil Fuel Endowment Per Capita)		-.0480639*** (.0052326)	-.049337*** (.0047625)
Nuke/Hydro Capacity Per Capita, Squared	-11127.84 (12576.96)		5500.055 (10127.76)
Intercept	42.50461*** (7.554448)	49.87451*** (6.621052)	48.97721*** (6.254589)
Observations	408	408	408
R Squared	0.4425	0.5208	0.5283
Wald Chi Sq	48479.35	324410.15	191851.65
Prob>Chisquare	0.0000	0.0000	0.0000
Rho	.8689366	.8346905	.8275849
* 10% significance, ** 5%, *** 1%			

---

[2] Here, and in all subsequent regression results tables, values in parentheses indicate corresponding standard errors.

Table 6.2: Electricity Trade Effect Parameter Estimates, Period 2



ln(1 + S) with Panel-Corrected Standard Errors, 1998-2010

Variable	(S1)	(S2)	(S3)
ln(Population Density)	.0374225*** (.0063039)	.0297721** (.012202)	.0310986*** (.0121497)
ln(Income)	-9.095014*** (1.31379)	-9.173029*** (1.651397)	-9.347497*** (1.570038)
ln(Income) Squared	.4535095*** (.0624656)	.4524823*** (.0788634)	.4610097*** (.0747858)
Nuke/Hydro Capacity Per Capita	50.65944* (26.45927)		7.221787 (30.64516)
ln(Nuke/Hydro Capacity Per Capita)		-.0035373 (.0076197)	
Fossil Fuel Endowment Per Capita	-.0000217*** (1.70e-06)		
ln(Fossil Fuel Endowment Per Capita)		-.0311026*** (.0060806)	-.0311797*** (.0061656)
Nuke/Hydro Capacity Per Capita, Squared	-19042.39*** (7164.946)		-2242.931 (9177.814)
Intercept	45.31693*** (6.912197)	46.36076*** (8.65482)	47.22609*** (8.260815)
Observations	663	663	663
R Squared	0.5133	0.4753	0.4792
Wald Chi Sq	2074.70	11241.99	10609.21
Prob>Chisquare	0.0000	0.0000	0.0000
Rho	.8345755	.8603901	.8581238

* 10% significance, ** 5%, *** 1%

Staying focused on the potential for an EKC, it is prudent to examine the values of each dependent variable's elasticity with respect to income. Thanks to the natural logarithm form of income, it is relatively simple here to examine the elasticity. Temporarily referring to the ln(Income) coefficient as β_1 and calling the ln(Income) Squared coefficient β_2, the income elasticity of the electricity trade effect is derived by simply differentiating ln(1+S) with respect to ln(Income), obtaining:

$$d\ln(1+S)/d\ln Y = \beta_1 + 2\beta_2 \ln Y$$

Figures 6.1 and 6.2 show the relationship between ln(Income) and the income elasticity of the electricity trade effect. In each time period, the outliers with high income and high (1+S) include only the District of Columbia. Table 6.3 presents the elasticities evaluated at the minimum, mean, and maximum for the two periods as well as the ”all years” period.

Figure 6.1: Income Elasticity of Electricity Trade Effect, Period 1 (408 Observations)

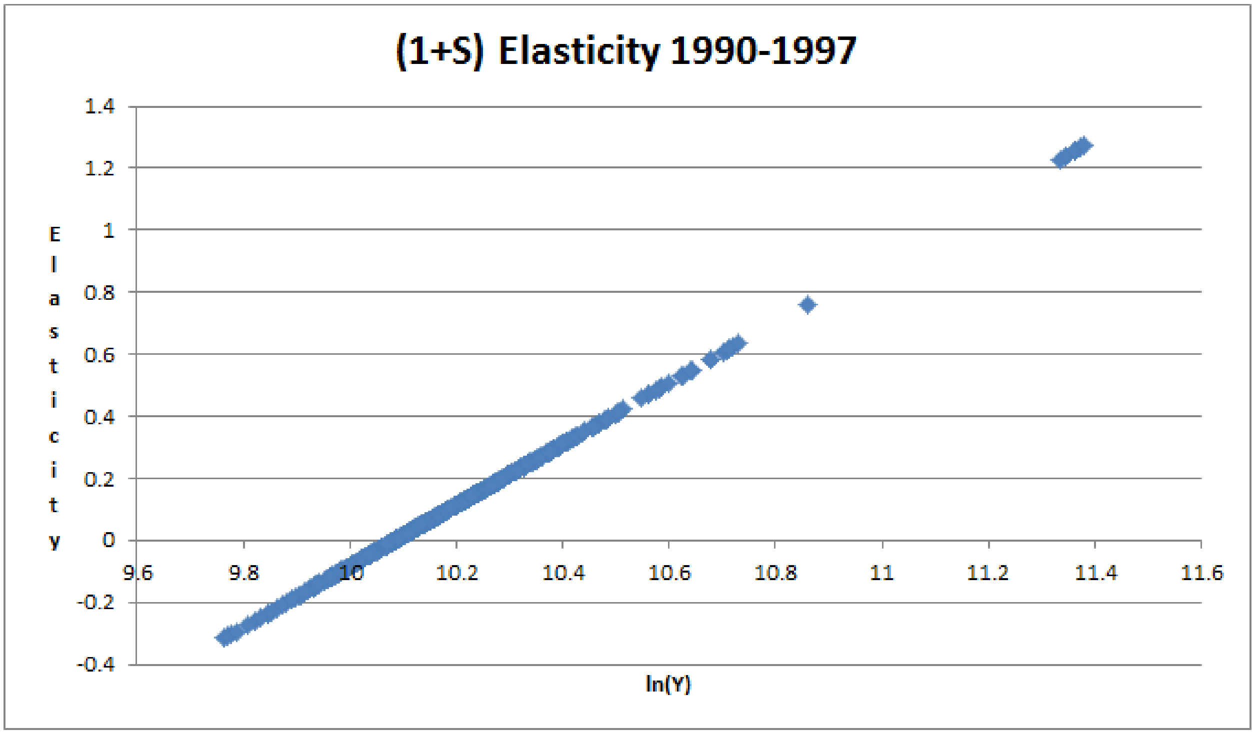


Figure 6.2: Income Elasticity of Electricity Trade Effect, Period 2 (663 Observations)

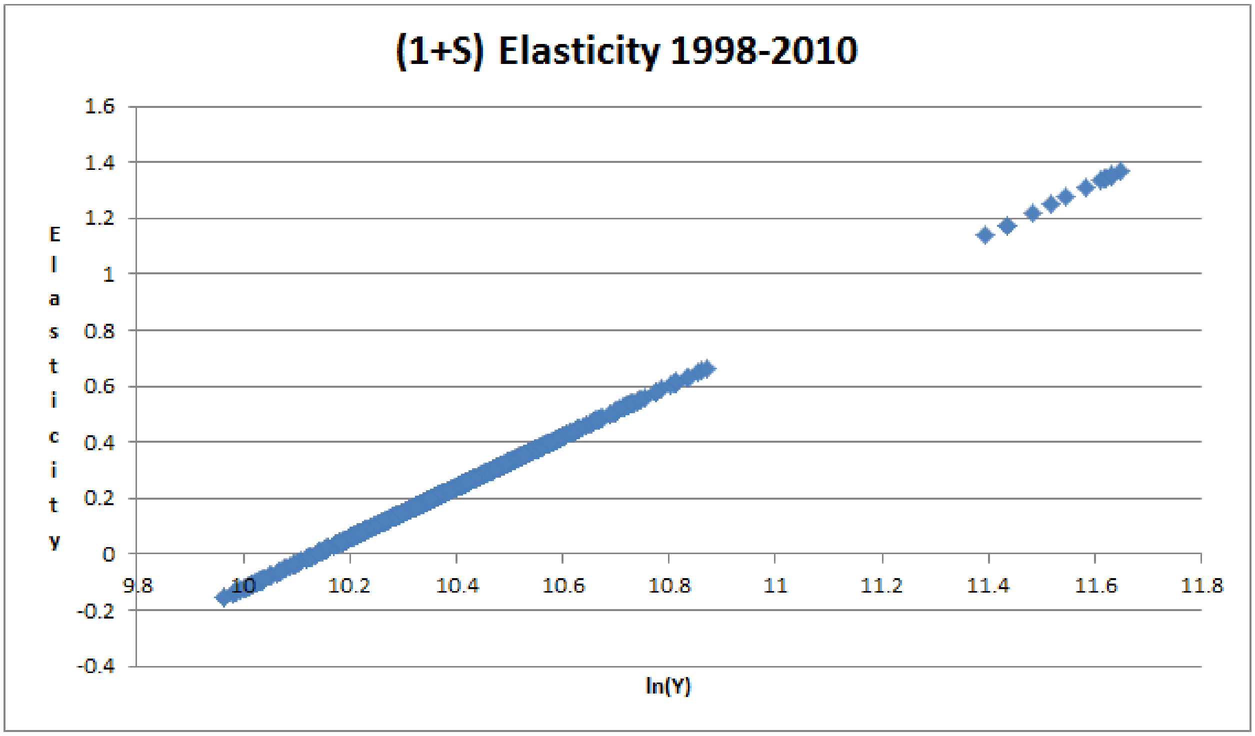


Table 6.3: Selected Income Elasticities of Electricity Trade Effect

All Numbers are Percents			
Period	Elasticity at Min	Elasticity at Mean	Elasticity at Max
1990-1997	-0.316	0.121	1.273
1998-2010	-0.157	0.248	1.369
ALL	-0.297	0.131	1.120

It is clear from these figures that, no matter which time period is under consideration, the income elasticity of the electricity trade effect does indeed cross over from a net negative to a net positive influence. In contrast to the overall message of EKCs, this shows that initial increases in income have a negative effect on carbon dioxide embodied in electricity imports; in fact, they may cause more exports. However, when a certain per capita income is exceeded, further increases are likely to cause more electricity to be imported. Thus, increasing incomes have a positive effect after this point, increasing *trade-adjusted* per capita emissions. If this positive effect is strong enough, it could prevent a true EKC structure from taking hold for consumption-based per capita carbon dioxide emissions.

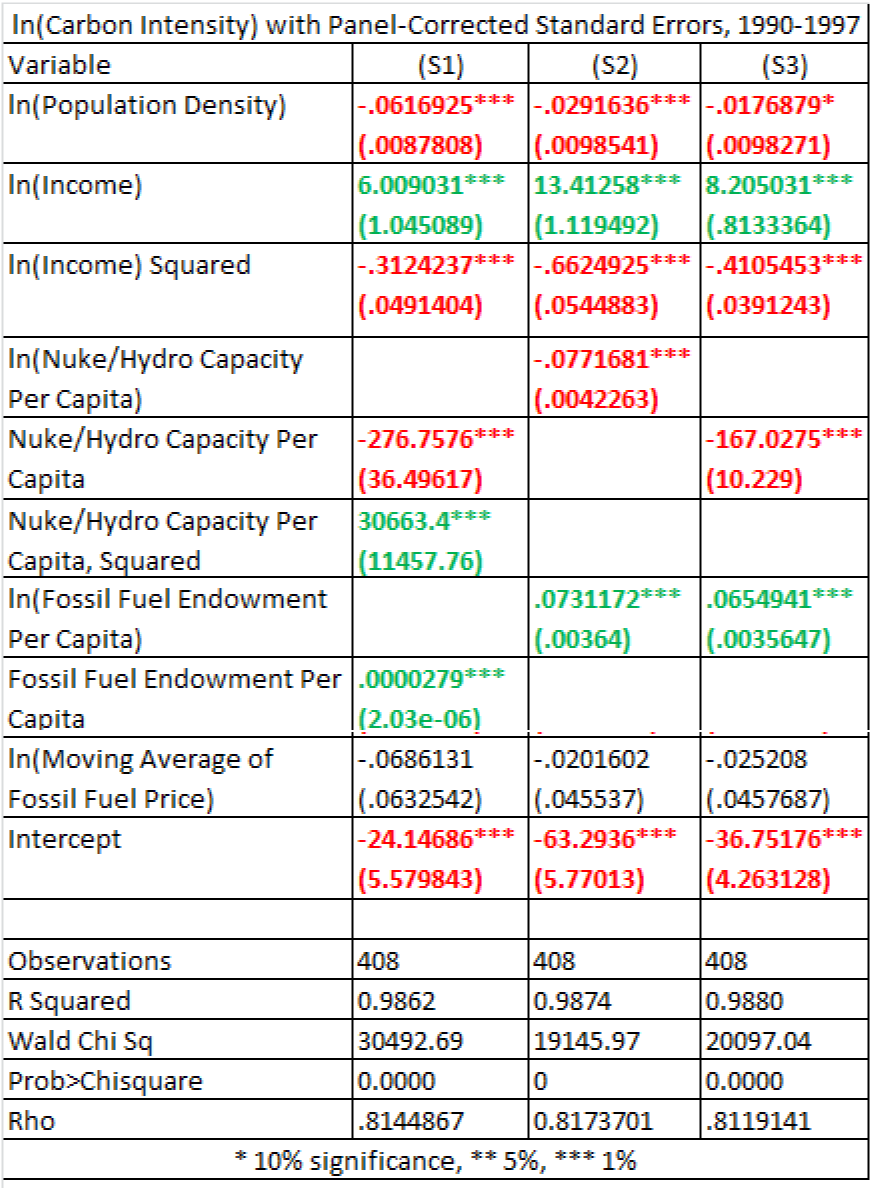
6.3 Carbon Intensity Regression Results

Three main specifications were analyzed for the carbon intensity regression. All three included the familiar log of population density and log of per capita income (including the squared term), including various combinations of logarithm-adjusted and raw endowment variables, including the squared nuclear/hydropower term. A key difference here also was the inclusion of price as a variable; the natural logarithm of the national composite fossil fuel price was included in all regressions in various forms. Goodness of fit is solid in all specifications, exceeding 0.98 in each regression. Population density is negative and significant across all specifications and time periods, again showing that dense populations prefer cleaner electricity production when such activity is more likely to affect concentrated groups of people living in the area.

Tables 6.4 and 6.5 show that, unanimous across periods and specifications, the log of per capita income is positive while its squared term is negative. Again, this likely represents a shift in favor of carbon-intensive manufacturing and other activities at initial rises in income, followed by a willingness and ability to pay for cleaner energy generation at high incomes. Nuclear and hydropower capacity is negatively significant, as expected, in each case. Cleaner endowment naturally leads to less carbon-intensive production. What seems perplexing is the significance and positive sign of the nuclear-hydro squared term when it is included in regression. This would imply that, after an initial phase in which more clean energy infrastructure leads to lower carbon intensity, it begins to increase carbon intensity after a certain threshold. Alternatively, it could imply that the negative influence of the first term is simply diminishing in magnitude.

Fossil fuel endowment variables are always positive and significant, as was expected. The fossil fuel price was largely insignificant, with the exception of a few transformations being positive and significant, which is counterintuitive. This is likely because the variable was constructed at the national level. Its composite nature, coupled with its lack of variation between states (an unrealistic construction), explains its flawed interpretation. This variable should be disaggregated into detail for future regressions. The difference between periods here is most likely explained by differences in the NERC regions, which underwent some structural change in the mid-nineties. The specific nature of these changes could be addressed in more detail in future research.

Table 6.4: Carbon Intensity Parameter Estimates, Period 1

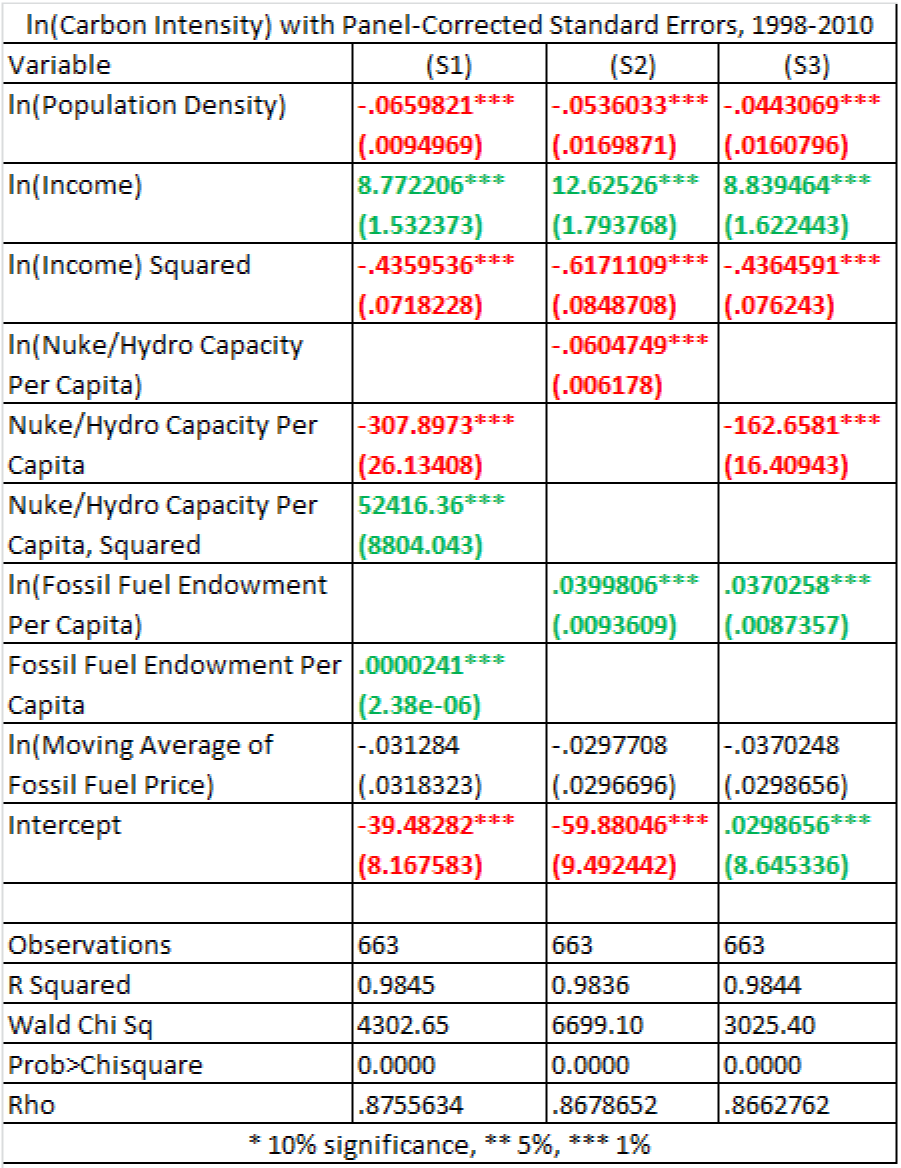


ln(Carbon Intensity) with Panel-Corrected Standard Errors, 1990-1997

Variable	(S1)	(S2)	(S3)
ln(Population Density)	-.0616925*** (.0087808)	-.0291636*** (.0098541)	-.0176879* (.0098271)
ln(Income)	6.009031*** (1.045089)	13.41258*** (1.119492)	8.205031*** (.8133364)
ln(Income) Squared	-.3124237*** (.0491404)	-.6624925*** (.0544883)	-.4105453*** (.0391243)
ln(Nuke/Hydro Capacity Per Capita)		-.0771681*** (.0042263)	
Nuke/Hydro Capacity Per Capita	-276.7576*** (36.49617)		-167.0275*** (10.229)
Nuke/Hydro Capacity Per Capita, Squared	30663.4*** (11457.76)		
ln(Fossil Fuel Endowment Per Capita)		.0731172*** (.00364)	.0654941*** (.0035647)
Fossil Fuel Endowment Per Capita	.0000279*** (2.03e-06)		
ln(Moving Average of Fossil Fuel Price)	-.0686131 (.0632542)	-.0201602 (.045537)	-.025208 (.0457687)
Intercept	-24.14686*** (5.579843)	-63.2936*** (5.77013)	-36.75176*** (4.263128)
Observations	408	408	408
R Squared	0.9862	0.9874	0.9880
Wald Chi Sq	30492.69	19145.97	20097.04
Prob>Chisquare	0.0000	0	0.0000
Rho	.8144867	0.8173701	.8119141

* 10% significance, ** 5%, *** 1%

Table 6.5: Carbon Intensity Parameter Estimates, Period 2



ln(Carbon Intensity) with Panel-Corrected Standard Errors, 1998-2010

Variable	(S1)	(S2)	(S3)
ln(Population Density)	-.0659821*** (.0094969)	-.0536033*** (.0169871)	-.0443069*** (.0160796)
ln(Income)	8.772206*** (1.532373)	12.62526*** (1.793768)	8.839464*** (1.622443)
ln(Income) Squared	-.4359536*** (.0718228)	-.6171109*** (.0848708)	-.4364591*** (.076243)
ln(Nuke/Hydro Capacity Per Capita)		-.0604749*** (.006178)	
Nuke/Hydro Capacity Per Capita	-307.8973*** (26.13408)		-162.6581*** (16.40943)
Nuke/Hydro Capacity Per Capita, Squared	52416.36*** (8804.043)		
ln(Fossil Fuel Endowment Per Capita)		.0399806*** (.0093609)	.0370258*** (.0087357)
Fossil Fuel Endowment Per Capita	.0000241*** (2.38e-06)		
ln(Moving Average of Fossil Fuel Price)	-.031284 (.0318323)	-.0297708 (.0296696)	-.0370248 (.0298656)
Intercept	-39.48282*** (8.167583)	-59.88046*** (9.492442)	.0298656*** (8.645336)
Observations	663	663	663
R Squared	0.9845	0.9836	0.9844
Wald Chi Sq	4302.65	6699.10	3025.40
Prob>Chisquare	0.0000	0.0000	0.0000
Rho	.8755634	.8678652	.8662762

* 10% significance, ** 5%, *** 1%

In both periods, the income elasticity of carbon intensity goes from positive values at low incomes to negative ones at high incomes. Consistent with theory, this suggests that incomes initially increase as relatively cheap emissions-intensive fuels are relied upon to develop the economy and societies begin to invest in cleaner technologies when they are able to pay for such an investment. Sufficient wealth also allows people to care more about their impact on the environment, driving research and investment due to this attitudinal shift. The same eventual transition from positive to negative is shown for both periods, as presented in figures 6.3 and 6.4. As has been observed fairly consistently, the outliers with high income (and highly negative elasticity) in each time period are composed solely of the District of Columbia.

Figure 6.3: Income Elasticity of Carbon Intensity, Period 1

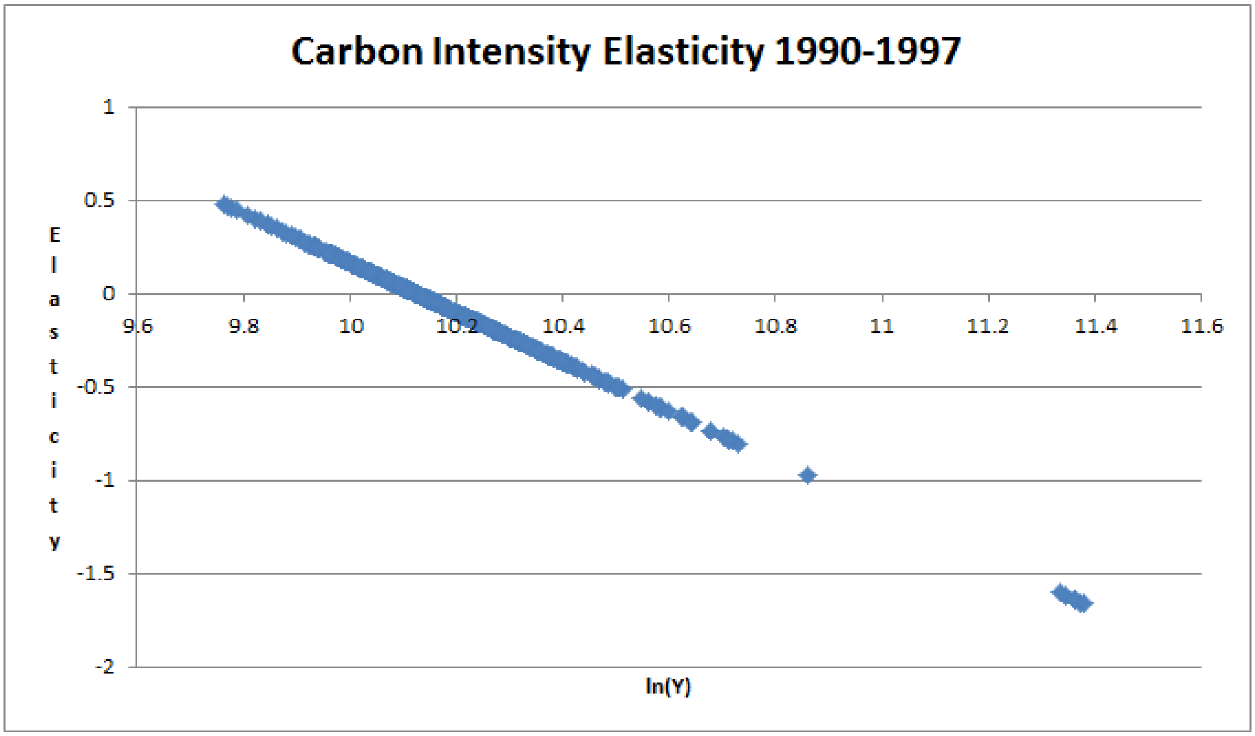


Figure 6.4: Income Elasticity of Carbon Intensity, Period 2

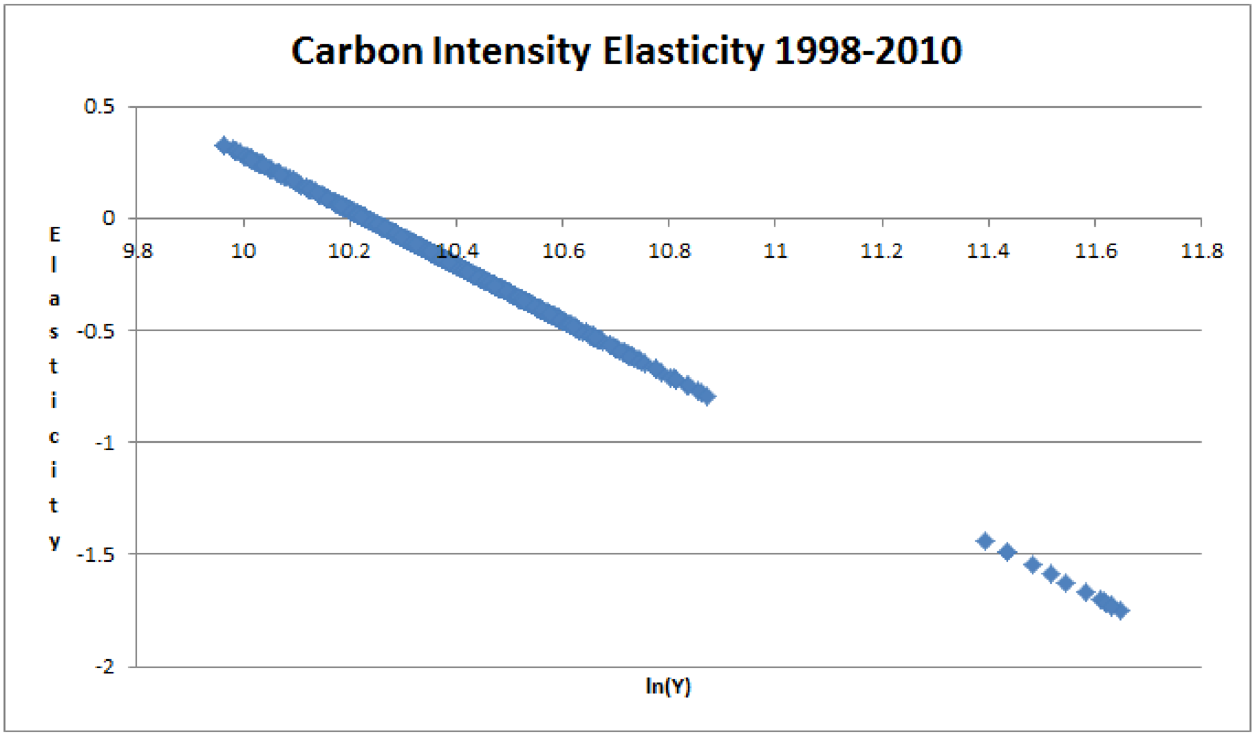
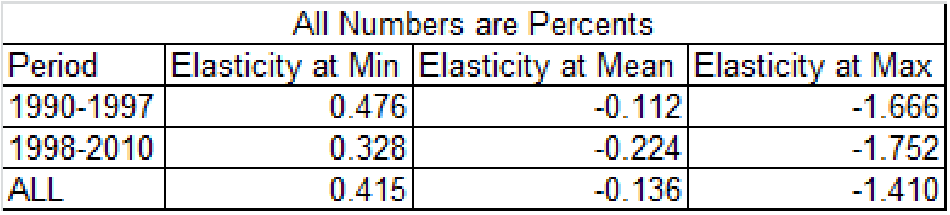


Table 6.6: Selected Income Elasticities of Carbon Intensity



All Numbers are Percents			
Period	Elasticity at Min	Elasticity at Mean	Elasticity at Max
1990-1997	0.476	-0.112	-1.666
1998-2010	0.328	-0.224	-1.752
ALL	0.415	-0.136	-1.410

6.4 Energy Intensity Regression Results

Energy intensity was regressed on a set of explanatory variables for the two separate periods as well, including a new set of demographic variables indicating the share of each state's population in each year of several distinct age groups. Also included were the two climatic variables HDD and CDD. Except for one specification in the 1998-2010 period, the log of the per capita income variable is significant and negative in all cases, while its squared term is positive in all cases. Initially, it appears that increases in income cause diminishing marginal *reductions* in energy intensity, possibly becoming positive at higher levels of income due to the positive sign of the squared term's coefficient. This counterintuitive result is similar to that observed by Subramaniam (2010), who was also surprised by the significant negative coefficient on the log-linear term. It is likely that the shared presence of GDP in the dependent variable and in the per capita income explanatory variables caused bias to give rise to the observed negative coefficient of income. This justifies investigation of the alternative *total energy consumption* model rather than relying upon the typical energy intensity model.

When the alternative *total energy consumption* specification was regressed, the income coefficients were more consistent with theory. Two different specifications were analyzed for each period – one with the "raw percentage" age distribution variables, and one without. Indeed, the natural log of per capita income became positive and significant, while its squared term was negative and significant. These results make much more sense, indicating increased energy consumption per dollar as new infrastructure and technology becomes available with rising incomes; the negative direction of the squared term indicates that this positive effect is diminishing and can even cause net decreases once a particular income threshold is surpassed, possibly implying higher efficiency. This also resembles the general structure of the EKC, making these results more solid.

One striking result of this new regression is the reversal in direction of the log of population density, which is significant and positive; denser populations typically use electricity more heavily in daily life. All endowment variables are significant and positive, as expected, as is the case with HDD. Oddly, CDD was insignificant in each of these regressions. This is likely due to the fact that heating and cooling often consume energy in different ways, and the use of air conditioning differs from heating oil and natural gas in terms of how much CO_2 is released. The "55 and over" variable was significant in the negative direction, consistent with theory, across periods. In the literature, a significant dip in electricity use is noted past the age of 55 due to less extensive use of transportation with age, among other factors. The 0-19 percentage is significantly negative as expected, as well; young people living with parents likely use energy more efficiently due to shared household activities, while those living independently typically have lower incomes that are used primarily on more essential consumption. Future work will be well informed to remain aware of the possible impact of these demographics, and can perhaps improve upon this way of estimating their effects. See Tables 6.7 and 6.8 for the energy consumption regression results; the energy intensity results are contained in the appendix.

Table 6.7: Energy *Consumption* Parameter Estimates, Period 1

ln(Energy *Consumption*) with Panel-Corrected Standard Errors, 1990-1997		
Variable	(S1)	(S2)
ln(Population Density)	.5041831*** (.0205584)	.5290692*** (.0169904)
ln(Income)	50.88809*** (3.502204)	48.87626*** (3.272731)
ln(Income) Squared	-2.456244*** (.1660311)	-2.367381*** (.1547477)
ln(Nuke/Hydro Capacity Per Capita)	.2221212*** (.0077904)	.224582*** (.0076472)
ln(Fossil Fuel Endowment Per Capita)	.0939392*** (.0041574)	.08864*** (.0041598)
NERC_FRCC	.1237558 (.1767164)	.1753407 (.2373527)
NERC_MRO	-.2099542*** (.0341586)	-.0319341 (.0349558)
NERC_NPCC	-1.331217*** (.0573329)	-1.261061*** (.0539068)
NERC_RFC	-.2085294*** (.0333784)	-.1620611*** (.0311403)
NERC_SERC	.1737332*** (.0257233)	.1871558*** (.0277908)
NERC_SPP	.133364*** (.0295448)	.1734137*** (.0307647)
NERC_TRE	1.889066*** (.0447776)	1.715953*** (.038884)
NERC_WECC	-.2087682*** (.04292)	-.1405829*** (.0414943)
ln(Moving Average of Fossil Fuel Price)	.1745265** (.0823895)	.241581** (.1063365)
% Age 0-19		-.6331349*** (.0693226)
% Age 20-39		-.8432673 (.7910955)
% Age 55 and Over		-4.378592*** (.7634647)
HDD	.0000342* (.0000178)	.0000315* (.0000162)
CDD	-.0000263 (.000028)	-.0000125 (.0000235)
Intercept	-253.3949*** (18.50488)	-241.0037*** (17.44587)
Observations	408	408
R Squared	0.9920	0.9920
Wald Chi Sq	848830.89	5.14e+07
Prob>Chisquare	0.0000	0.0000
Rho	.7892538	.7806077
* 10% significance, ** 5%, *** 1%		

Table 6.8: Energy *Consumption* Parameter Estimates, Period 2

log(Energy *Consumption*) with Panel-Corrected Standard Errors, 1998-2010		
Variable	(S1)	(S2)
ln(Population Density)	.4816446*** (.0204821)	.4976228*** (.0200272)
ln(Income)	50.43622*** (3.603)	50.85291*** (3.10835)
ln(Income) Squared	-2.396036*** (.1708954)	-2.423164*** (.1485236)
ln(Nuke/Hydro Capacity Per Capita)	.2340111*** (.0062594)	.2444619*** (.0059044)
ln(Fossil Fuel Endowment Per Capita)	.0662758*** (.009523)	.0669745*** (.0088789)
NERC_FRCC	.7479294*** (.0446963)	1.098416*** (.067174)
NERC_MRO	-.1422867*** (.0395248)	-.0323427 (.0433467)
NERC_NPCC	-1.277185*** (.0421128)	-1.13067*** (.0495306)
NERC_RFC	-.0522897 (.0431016)	.0327059 (.0388887)
NERC_SERC	.203661*** (.0201893)	.1570574*** (.0226193)
NERC_SPP	.2451731*** (.0233607)	.3097035*** (.0235609)
NERC_TRE	1.768681*** (.0553949)	1.55434*** (.0562792)
NERC_WECC	-.1051441*** (.0346544)	-.1120852*** (.0335347)
ln(Moving Average of Fossil Fuel Price)	-.0375924 (.0363712)	.2431903*** (.0665618)
% Age 0-19		-.1323079 (.152072)
% Age 20-39		1.266086 (1.034744)
% Age 55 and Over		-5.694351*** (.9463883)
HDD	.0000294** (.0000127)	.0000311** (.0000133)
CDD	-.0000269 (.0000271)	-.0000116 (.0000281)
Intercept	-254.9709*** (19.00702)	-255.896*** (16.42074)
Observations	663	663
R Squared	0.9912	0.9913
Wald Chi Sq	159213.14	68042.38
Prob>Chisquare	0.0000	0.0000
Rho	.8104481	.7991818
* 10% significance, ** 5%, *** 1%		

The elasticity curves for energy intensity effects, shown below in Figures 6.5 and 6.6, are somewhat surprising, just like its parameter estimates. Again, the District of Columbia is responsible for all the high income outliers in each period. The elasticity is always negative; although it diminishes in absolute value with higher incomes, it never quite crosses the threshold into positive values. This suggests that people tend to use their electricity more efficiently per dollar as income increases. A more intuitive parameter result would be a positive elasticity at lower incomes, with negative elasticity later on. It appears that the *total energy consumption* parameter estimates might yield this more intuitive result. That will be addressed in a moment, but first let us observe energy intensity elasticity for comparison.

Figure 6.5: Income Elasticity of Energy Intensity, Period 1

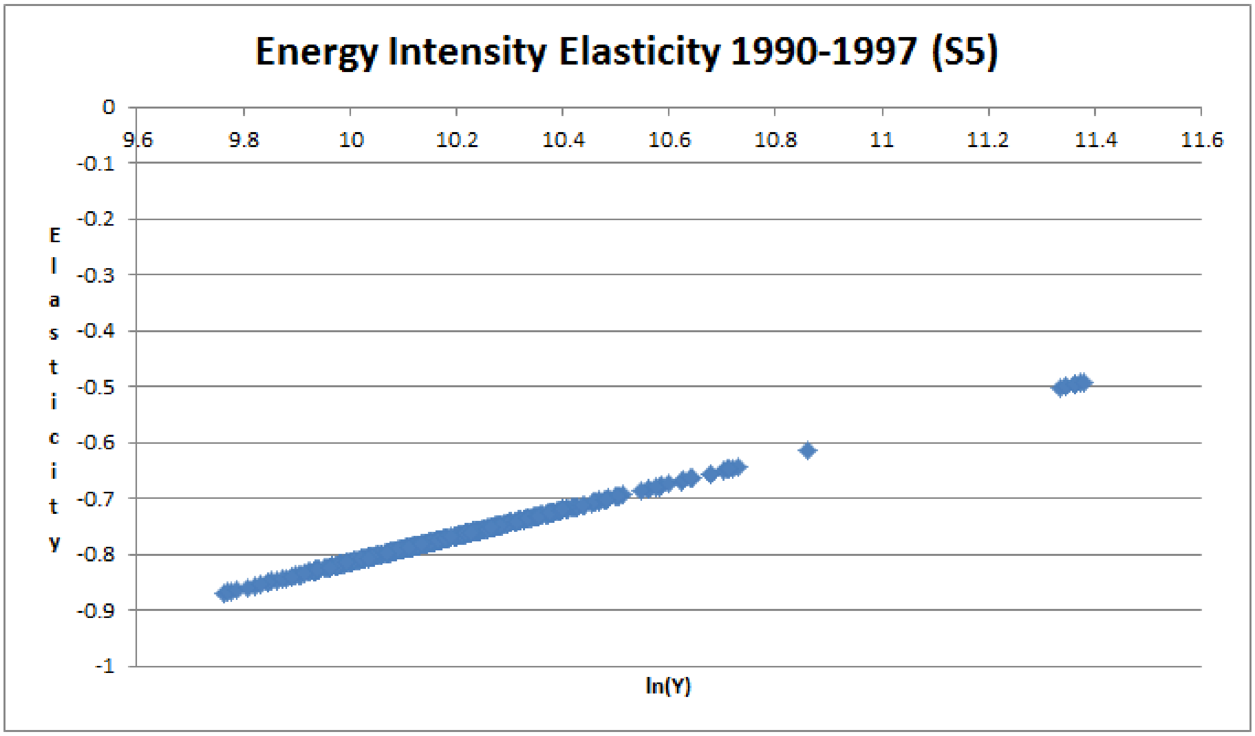


Figure 6.6: Income Elasticity of Energy Intensity, Period 2

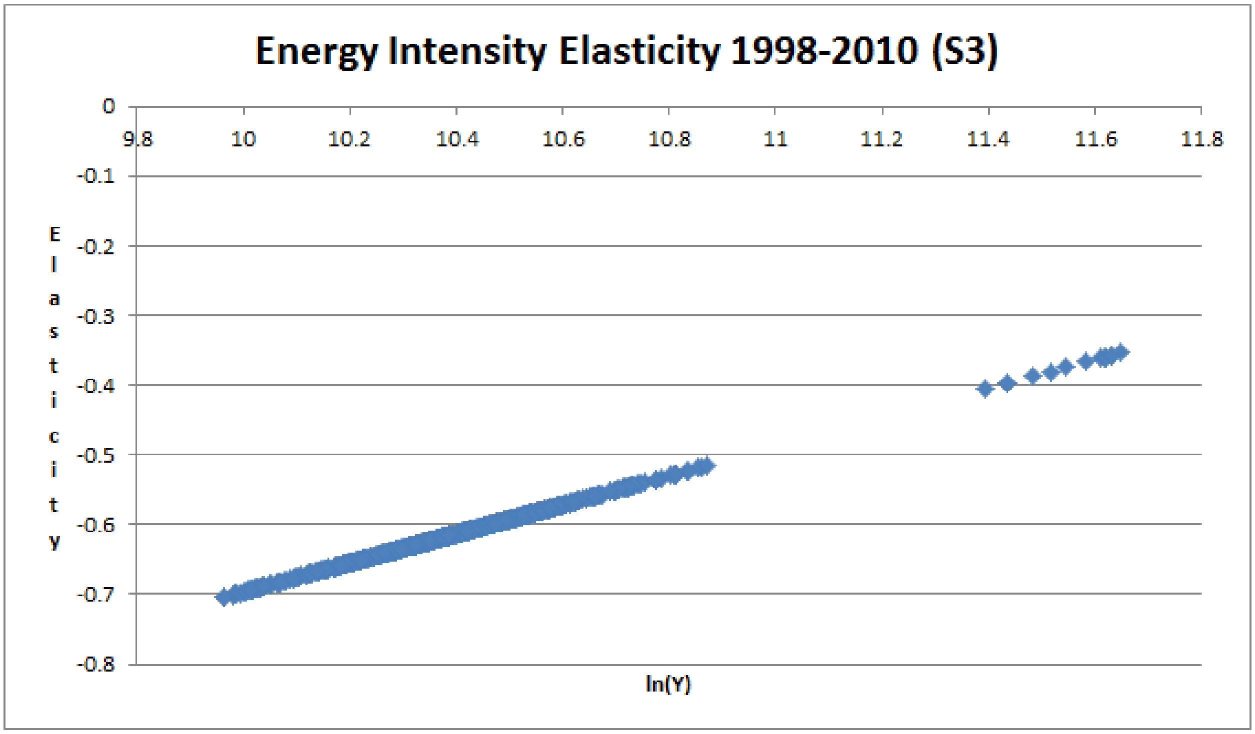
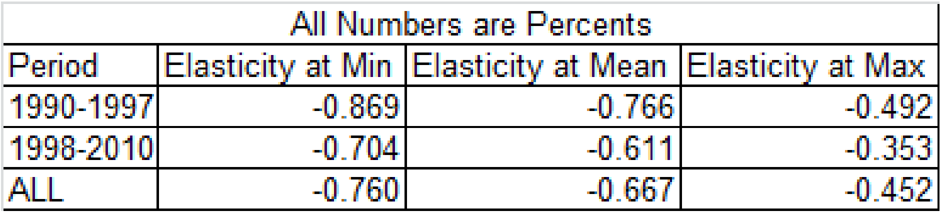


Table 6.9: Selected Income Elasticities of Energy Intensity



All Numbers are Percents			
Period	Elasticity at Min	Elasticity at Mean	Elasticity at Max
1990-1997	-0.869	-0.766	-0.492
1998-2010	-0.704	-0.611	-0.353
ALL	-0.760	-0.667	-0.452

As has been shown in previous studies, *total elasticity* of consumption-based per capita emissions with respect to income, with Y representing per capita income, is calculated as follows:

$$\partial \text{Per Capita Carbon Emissions}/\partial \ln Y = [\partial \ln CI/\partial \ln Y] + [\partial \ln(1+S)/\partial \ln Y] + [\partial \ln EI/\partial \ln Y] + [\partial \ln Y/\partial \ln Y]$$

and, in words, this can be stated thus (Subramaniam 72):

Total Elasticity = Elasticity of Carbon Intensity + Elasticity of Electricity Trade Effect + Elasticity of Energy Intensity + 1

Calculating the individual components of elasticity at the level of income corresponding to each observation, one can generate graphs of the total elasticity at various income levels and determine whether an EKC takes shape for the total effect of income. Observing the relevant visuals, we can see that there is no relationship resembling an EKC with respect to trade-adjusted emissions in our data when we ignore the energy intensity model's flaws. See Figures 6.7 and 6.8 for the total income elasticities of period 1 and period 2, respectively.

Figure 6.7: Total Income Elasticity of Emissions, Period 1

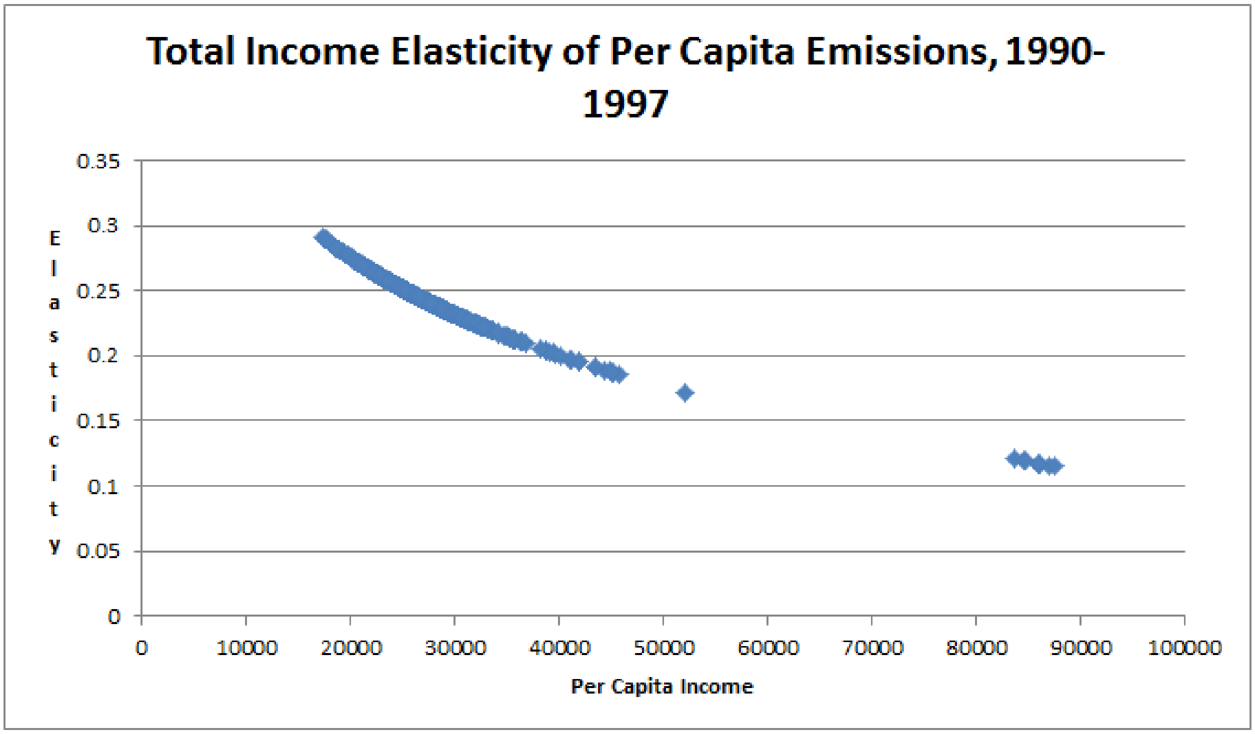
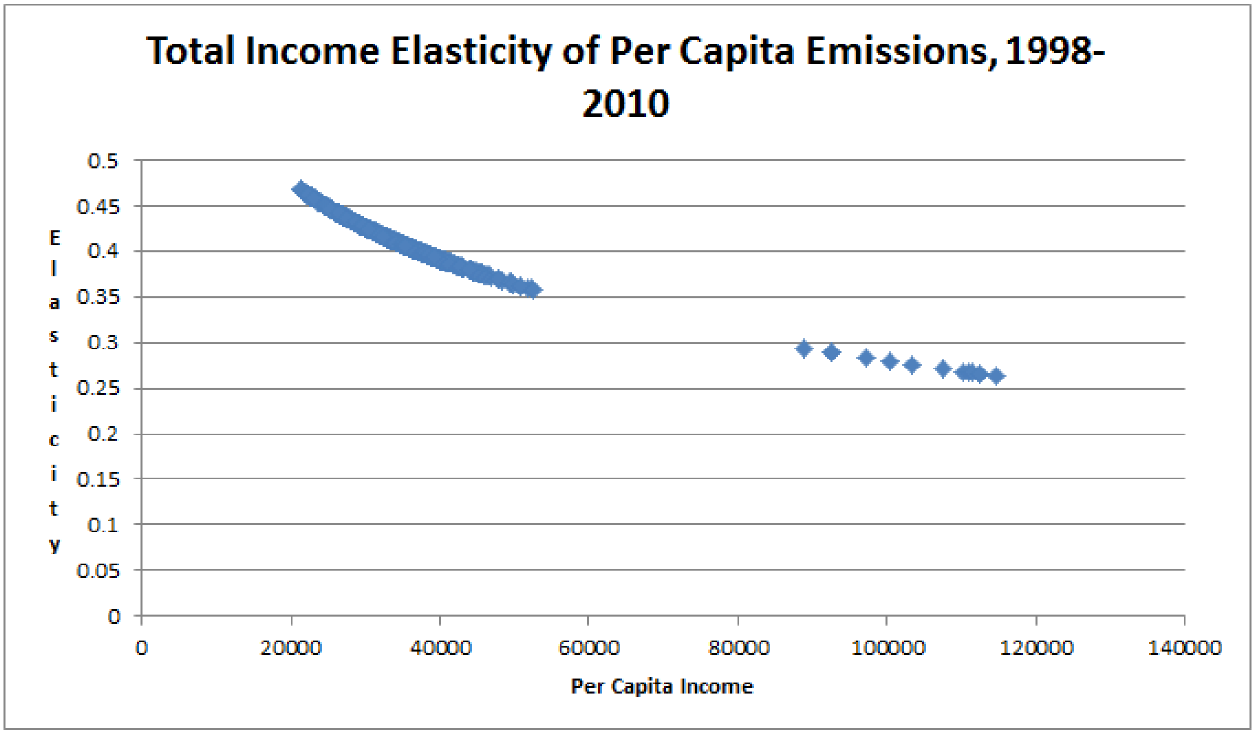


Figure 6.8: Total Income Elasticity of Emissions, Period 2



As can be seen above, total elasticity never becomes negative in either period. The closest to zero elasticity becomes in period 1 is 0.115% in the case of Washington, D.C. in 1997 with an income of over $87,500. Another state with low elasticity is Alaska in 1990 with an elasticity of 0.172% and a per capita income of roughly $52,000. In the latter period, the lowest elasticity is 0.263%, again shown by the District of Columbia, this time in 2008 with a per capita income of $114,540. Next in line for this period was Delaware in 2007, with a per capita income of $52,582. Note that both Washington, D.C. and Delaware are small, high-income areas with high population density. Alaska's appearance in the first period with one of the lowest elasticities is surprising due to its sparse population. It can be seen in the above graphs that elasticities show a positive (but diminishing) elasticity relationship between per capita income and per capita emissions, albeit with an overall downward trend as per capita incomes increase. Because these elasticities never become negative, these states all appear to be in the initial stage of an

EKC. An EKC does not appear to be present in each of its stages, in contrast to the findings by Subramaniam (2010) with her examination of similar data using this same energy intensity model.

A striking difference here puts the distinction between consumption- and production-based per capita emissions measures into context. When one removes the income elasticity of electricity trade effects from the total elasticity calculation, a transition into negative territory does emerge. This suggests that an EKC does indeed materialize in the case of *production*-based emissions, but *not* for the consumption-based measure. High income states likely prefer to import more electricity in order to report lower production-based carbon dioxide emissions, to minimize disturbances to dense populations, and to invest in the relatively cleaner service-based industry, but they do not appear to be drastically reigning in their overall carbon footprints as their incomes rise. See figures 6.9 and 6.10 below for graphical demonstration.

Figure 6.9: Total Income Elasticity of *Production-Based* Emissions, Period 1

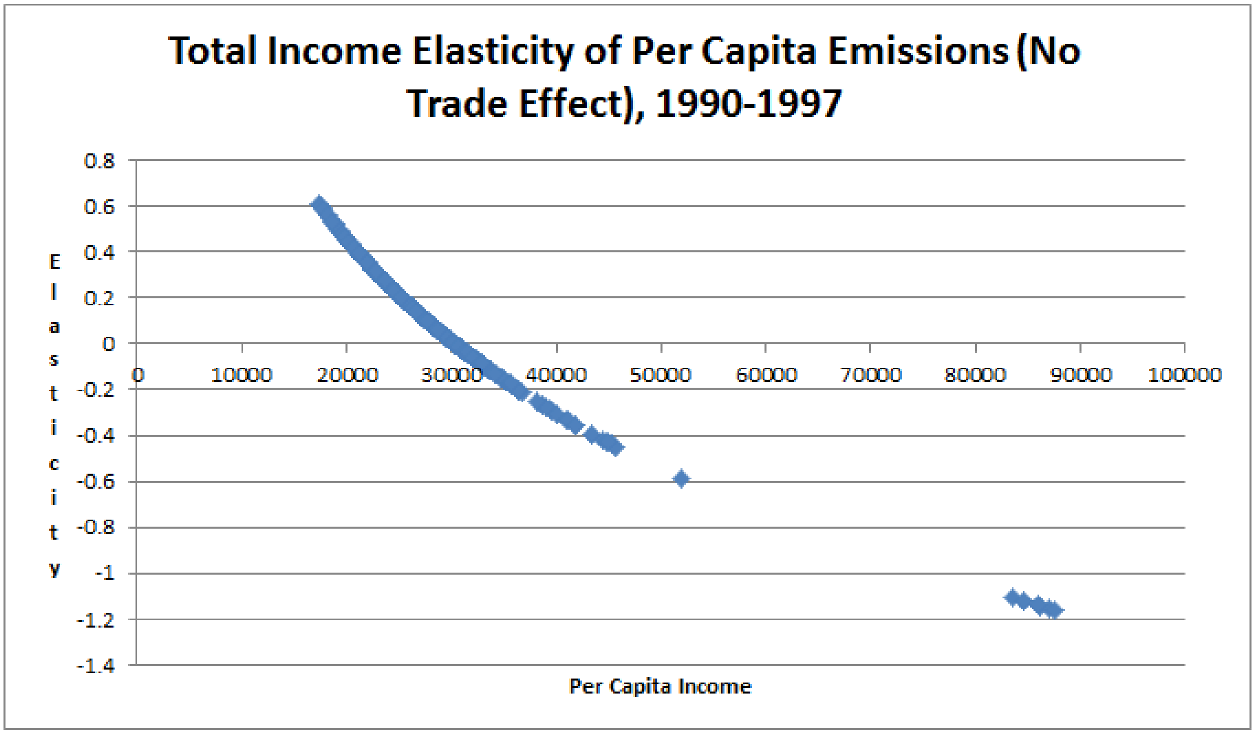
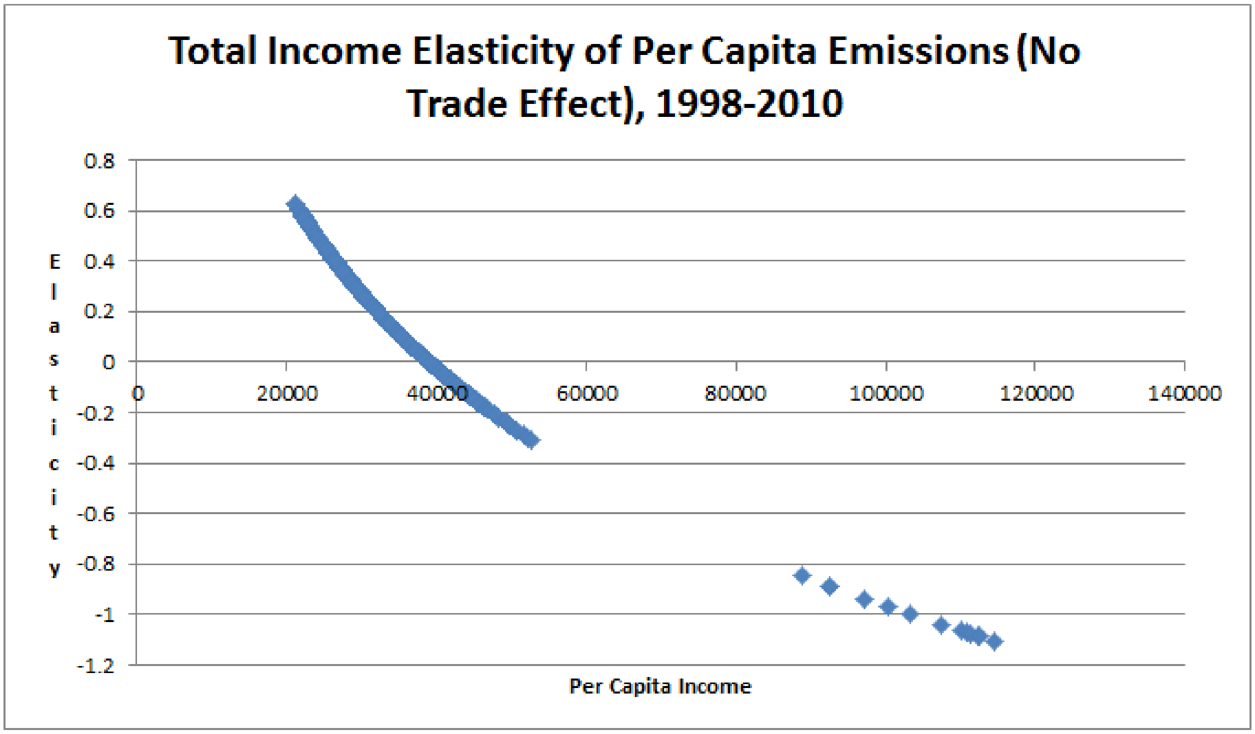


Figure 6.10: Total Income Elasticity of *Production-Based* Emissions, Period 2



Contrary to the case of consumption-based emissions, there are clear points at which *production-based* emissions dip into negative elasticity, providing evidence of the downward-sloping portion of the conventional EKC curve. In the first period, Washington in 1996 shows the lowest per capita income that ventures into negative elasticity territory, at just over $30,370. The latter period shows a higher necessary per capita income for negative elasticity. Massachusetts in 1999 displays the per capita income that, at the margin, sparks a transition to negative elasticity at just over $39,000.

These results arise when one is constrained to the energy intensity model in Subramaniam's 2010 thesis. However, there is fortunately a way to replace this flawed energy intensity model with the more reliable energy *consumption* model and apply its parameter estimates to the total elasticity calculation. It is apparent how these parameter estimates can be substituted into the total calculation with a few simple algebraic steps. Refer first to the energy intensity elasticity calculation (with Y representing per capita income and E representing total energy consumption in Btus):

Elasticity of Energy Intensity = $\partial \ln(E/GDP)/\partial \ln Y = \partial \ln[E/(Y \mathrm{x} Pop)]/ \partial \ln(Y) = \partial[\ln E - \ln Y - \ln P]/ \partial \ln Y =$

$\partial \ln E/\partial d\ln Y - 1$

Knowing this, we can simply subtract 1 from the estimated income elasticity of energy *consumption*, $\partial \ln E/\partial \ln Y$, and apply this value to the total elasticity calculation. Applying this value creates a new portrait of income elasticity of trade-adjusted per capita emissions. See Figures 6.11 and 6.12 for graphs of this alternative total elasticity calculation for each period.

Figure 6.11: Alternative Total Income Elasticity of Per Capita Emissions, 1990-1997

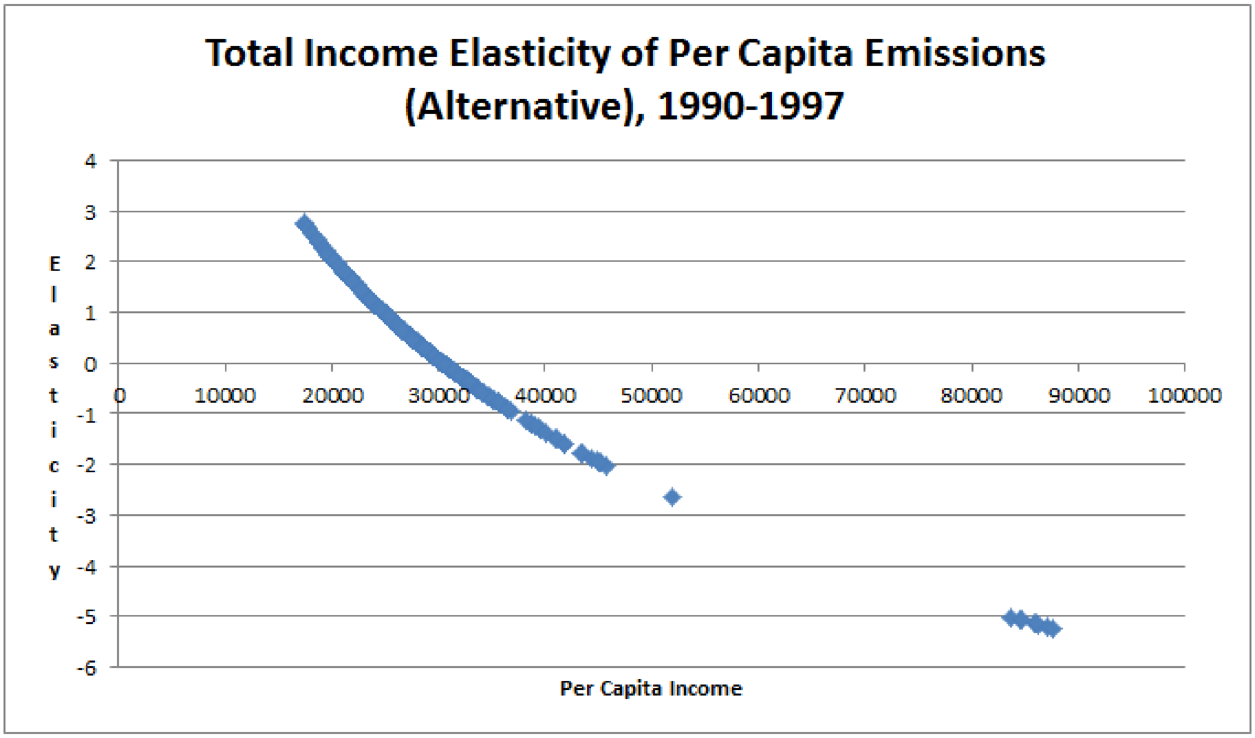
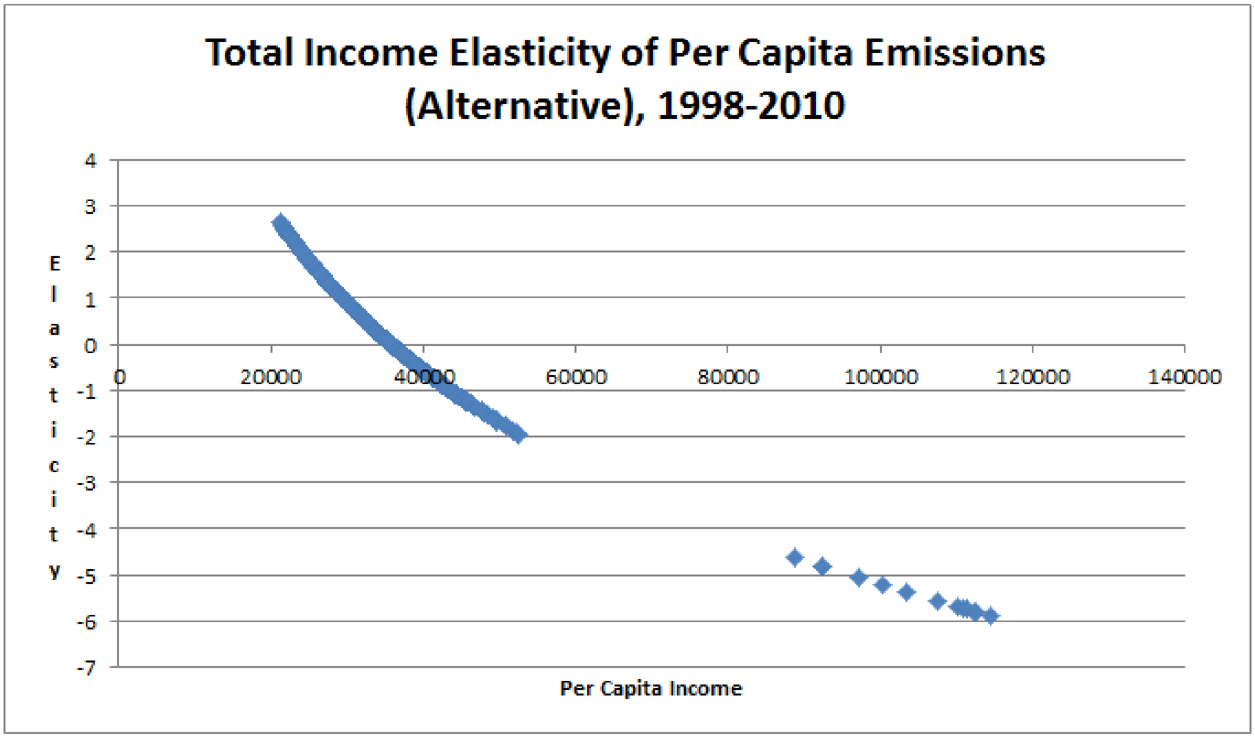


Figure 6.12: Alternative Total Income Elasticity of Per Capita Emissions, 1998-2010



Using parameter estimates from the arguably more reliable energy *consumption* model and applying it to the elasticity calculation appropriately, a large discrepancy is revealed between the two approaches. Here it appears that there *does* exist evidence for a legitimate EKC with respect to trade-adjusted per capita CO_2 emissions in the U.S. Subramaniam's 2010 paper, which relied upon the flawed energy intensity model, concluded that the necessary per capita income threshold for negative elasticity was roughly \$53,000, much higher than Aldy (2005a) had previously suggested. With the alternative total elasticity calculation presented above, the evidence suggests a turning point at lower income levels. In the first period, an income of roughly \$30,500 was necessary to turn the corner. Colorado reached this point in 1995. Other states in the negative elasticity income range included California, Massachusetts, Georgia, Illinois, Wyoming, Texas, Virginia, New Hampshire, Nevada, Minnesota, Washington, New York, New Jersey, Hawaii, Connecticut, Delaware, Alaska, and of course the District of Columbia. The threshold in the second period was roughly the same at a per capita income of just under

$36,000, with many of the same states transitioning into the negative elasticity portion of the EKC, along with a few newcomers.

6.5 Summary and Concluding Remarks

Previous studies have found evidence of an EKC with respect to carbon dioxide emissions in the years since 1990. This paper responds with more detailed resource endowment variables, more data, and close attention paid to structural change in the mid-nineties. This paper finds that regression model construction can have a dramatic impact on the conclusion arising from time-series cross-section data. Building upon the energy intensity model introduced in prior studies, this paper finds evidence that an EKC structure has yet to take hold for trade-adjusted CO_2 emissions in the U.S. When the energy model is corrected for endogeneity problems in the dependent variable, however, the conclusion differs dramatically. With this correction and the corresponding modification of the total elasticity calculation, an EKC structure materializes. The flaws in the energy intensity model seem to skew threshold incomes up, underreporting the degree to which states have moved along the EKC curve as incomes have increased. This alternative specification finds a threshold income level considerably lower than the $53,000 turning point Subramaniam found in 2010.

Should policymakers reach a consensus to make lower emissions a goal for the U.S., the issue should be treated as a *national* goal. Furthermore, national policy should focus on energy intensity and carbon intensity as modifiable components of the per capita emissions equation. More in-depth research can be conducted on how the FERC regulations of the mid-90s may have changed electricity markets, in addition to changes among the NERC regions. There could be additional variables arising from these market and regulatory changes that this paper failed to consider. Additionally, other policy variables should be more clearly built into the analysis, possibly through incorporating renewable portfolio standard policies, though these would be quite difficult to transform into numeric variables and would require a longer project timeline. Although income growth may lead to shifts toward *local* environmental improvement, the issue of carbon dioxide emissions is uniquely a global one, and not all regions of the world can expect their incomes to rise fast enough for a convenient solution. All economic and technological components of emissions will remain crucial on the state level and beyond.

REFERENCES

Aldy, J.E. 2005a, “An Environmental Kuznets Curve Analysis of U.S. State-Level Carbon Dioxide Emissions”, *The Journal of Environment Development*, vol. 14, pp. 48-72.

Aldy, J.E. 2005b, “Per Capita Carbon Dioxide Emissions: Convergence or Divergence?”, *Resources for the Future*, Discussion Paper 05-53.

Aldy, J.E. 2006, “Divergence in State-Level Per Capita Carbon Dioxide Emissions”, *Resources for the Future*, Discussion Papers, pp. 06-07.

Beck, N. and Katz, J.N. 1995, “What to do (and not to do) with Time-Series Cross-Section Data”, *The American Political Science Review*, vol. 89, no. 3, pp. 634-647.

Bureau of Economic Analysis. (2012). Gross Domestic Product by State (millions of current dollars) [Data file]. Retrieved from http://www.bea.gov/iTable/iTable.cfm?ReqID=70&step=1&isuri=1&acrdn=1

Bureau of Economic Analysis. (2012). Quantity Indexes for Real GDP by State (2005=100.0) [Data file]. Retrieved from http://www.bea.gov/iTable/iTable.cfm?ReqID=70&step=1&isuri=1&acrdn=1

Bureau of Economic Analysis. (2010). Real GDP by State (millions of chained 1997 dollars) [Data file]. Retrieved from http://www.bea.gov/iTable/iTable.cfm?ReqID=70&step=1

Bureau of Economic Analysis. (2012). SA1-3 Personal Income Summary: Population [Data file]. Retrieved from http://www.bea.gov/iTable/iTable.cfm?ReqID=70&step=1&isuri=1&acrdn=4

Crump, Richard K., V. Joseph Hotz, Guido W. Imbens, and Oscar A. Mitnik. “Nonparametric Tests for Treatment Effect Heterogeneity.” *The Review of Economics and Statistics* Vol. XC No. 3 (2008): 389-405.

Dalton, Michael, Brian O’Neill, Alexia Prskawetz, Leiwen Jiang, and John Pitkin. “Population Aging and Future Carbon Emissions in the United States.” *Energy Economics* 30 (2006): 642-675. Web.

Dinda, S. 2004, “Environmental Kuznets Curve Hypothesis: A Survey”, *Ecological Economics*, vol. 49, no. 4, pp. 431-455.

Energy Information Administration. *Annual Coal Report 2001* (DOE/EIA-0584) (2001) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842001.pdf

Energy Information Administration. *Annual Coal Report 2002* (DOE/EIA-0584) (2002) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842002.pdf

Energy Information Administration. *Annual Coal Report 2003* (DOE/EIA-0584) (2003) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842003.pdf

Energy Information Administration. *Annual Coal Report 2004* (DOE/EIA-0584) (2004) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842004.pdf

Energy Information Administration. *Annual Coal Report 2005* (DOE/EIA-0584) (2005) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842005.pdf

Energy Information Administration. *Annual Coal Report 2006* (DOE/EIA-0584) (2006) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842006.pdf

Energy Information Administration. *Annual Coal Report 2007* (DOE/EIA-0584) (2007) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842007.pdf

Energy Information Administration. *Annual Coal Report 2008* (DOE/EIA-0584) (2008) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842008.pdf

Energy Information Administration. *Annual Coal Report 2009* (DOE/EIA-0584) (2009) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842009.pdf

Energy Information Administration. *Annual Coal Report 2010* (DOE/EIA-0584) (2010) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05842010.pdf

Energy Information Administration. (2012). *Annual Energy Review, Table 3.1: Fossil Fuel Production Prices, 1949-2011* [Data file]. Retrieved from http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0301

Energy Information Administration. *Coal Industry Annual 1995* (DOE/EIA-0584) (95) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05841995.pdf

Energy Information Administration. *Coal Industry Annual 1996* (DOE/EIA-0584) (96) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05841996.pdf

Energy Information Administration. *Coal Industry Annual 1997* (DOE/EIA-0584) (97) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05841997.pdf

Energy Information Administration. *Coal Industry Annual 1998* (DOE/EIA-0584) (98) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05841998.pdf

Energy Information Administration. *Coal Industry Annual 1999* (DOE/EIA-0584) (99) [Data file and report]. Retrieved from http://www.eia.gov/coal/annual/archive/05841999.pdf

Energy Information Administration. (2012). *Crude Oil Proved Reserves, Reserves Changes, and Production* [Data file]. Retrieved from http://www.eia.gov/dnav/pet/pet_crd_pres_a_EPC0_R01_mmbbl_a.htm

Energy Information Administration. (2012). *Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860)* [Data file]. Retrieved from http://www.eia.gov/electricity/data/state/

Energy Information Administration. (2012). *Natural Gas Plant Liquids Proved Reserves* [Data file]. Retrieved from http://www.eia.gov/dnav/ng/ng_enr_ngpl_s1_a.htm

Energy Information Administration. (2012). *Natural Gas Reserves Summary as of Dec. 31* [Data file]. Retrieved from http://www.eia.gov/dnav/ng/ng_enr_sum_a_epg0_r11_bcf_a.htm

Energy Information Administration. (2013). State CO_2 Emissions - Summary [Data file]. Retrieved from http://www.eia.gov/environment/emissions/state/state_emissions.cfm

Energy Information Administration. (2012). State Energy Data System (SEDS): 1960-2010 (Complete) [Data file]. Retrieved from http://www.eia.gov/beta/state/seds/seds-data-complete.cfm#Consumption

Energy Information Administration. (2012). State Energy Data System (SEDS): 1960-2010 (Complete) [Data file] Retrieved from http://www.eia.gov/beta/state/seds/seds-data-complete.cfm?sid=US

Energy Information Administration. (2012). U.S. Electric Power Industry Estimated Emissions by State (EIA-767, EIA-906, EIA-920, and EIA-923) [Data file]. Retrieved from http://www.eia.gov/electricity/data/state/

Federal Facilities Council (FFC) Standing Committee on Operations and Maintenance. “Competition in the Electric Industry: Emerging Issues, Opportunities, and Risks for Facility Operators." *National Academy Press* 132 (1996): Web.

Hardee, Karen and Leiwen Jiang. "How do Recent Population Trends Matter to Climate Change?" *Population Research and Policy Review* 30 (2010): 287-312. Web.

Holtz-Eakin, D. and Selden, T.M. 1995, "Stoking the Fires? CO_2 Emissions and Economic Growth", *Journal of Public Economics*, vol. 57, no. 1, pp. 85-101.

Jancovici, Jean-Marc. "The Kaya Equation." *Manicore* October 2011. 14 April 2013. < http://www.manicore.com/anglais/documentation_a/greenhouse/kaya_equation.html>.

Kimball, Miles. "The Logarithmic Harmony of Percent Changes and Growth Rates." *Confessions of a Supply-Side Liberal* 9 September 2012. Web. 4 April 2013.

Lindstrom, Perry. Personal interview. Long-Term (AEO) Analysis and Forecasting Expert. Energy Information Administration. 29 January 2013.

Metcalf, G.E. 2008, "An Empirical Analysis of Energy Intensity and Its Determinants at the State Level", *The Energy Journal*, vol. 29:3, pp. 1-26.

National Climatic Data Center, NOAA. (2013). *Heating & Cooling Degree Day Data – Divisional/Regional Data* [Data files]. Retrieved from http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp#

North American Electric Reliability Corporation. (2013). *NERC Regions* [map]. Retrieved from http://www.nerc.com/fileUploads/File/AboutNERC/maps/NERC_Regions_Color_072512.jpg

O'Neill, Brian C. and Belinda S. Chen. "Demographic Determinants of Household Energy Use in the United States." *Methods of Population-Environment Analysis, A Supplement to Population and Development Review* 28 (2002): 53-88. Web.

Subramaniam, Brintha. "Per Capita Energy Consumption and CO_2 Emissions: How and Why Do States Differ?" (2010): 1-83. Print.

Tucker, M. 1995, "Carbon Dioxide Emissions and Global GDP", *Ecological Economics*, vol. 15, no. 3, pp. 215-223.

United States Census Bureau. *1990 to 1999 Annual Time Series of State Population Estimates by Age and Sex: 5-Year Age Groups by Sex* [Data file]. Retrieved from http://www.census.gov/popest/data/historical/1990s/state.html

United States Census Bureau. *Intercensal Estimates of the Resident Population by Five-Year Age Groups, Sex, Race and Hispanic Origin for States and the United States: April 1, 2000 to July 1, 2010* [Data file]. Retrieved from http://www.census.gov/popest/data/intercensal/state/state2010.html

U.S. Census Bureau. (2013). *United States Summary: 2000 – Population and Housing Unit Counts* (Part I) [Table 17 in online document]. Retrieved from http://www.census.gov/prod/cen2000/phc3-us-pt1.pdf

Vinuya, F., DiFurio, F. and Sandoval, E. 2009, "A Decomposition Analysis of CO_2 Emissions in the United States", *Applied Economics Letters*, vol. 17, no. 10, pp. 925-931.

APPENDIX

Appendix 1: Detailed Variable Construction Information

1. State-Level Carbon Emission Data

State-level electricity sector carbon dioxide emissions data were downloaded on November 27, 2012 from the Energy Information Administration's website at: http://www.eia.gov/electricity/data/state/. Data for total (energy-related) state-level carbon dioxide emissions from all sectors were downloaded on January 31, 2013 from the Energy Information Administration's website at: http://www.eia.gov/environment/emissions/state/state_emissions.cfm.

2. Procedure for Calculation of Carbon Emissions

In order to calculate energy-related carbon dioxide emissions for all sectors, the EIA first summed up the consumption of each fuel type for each sector, measured in billions of Btu, for each state and year. These Btu values are then multiplied by carbon coefficients to convert them to million metric tons of carbon dioxide. At the time of this writing, the EIA was currently engaged in updating data documentation to publish the specific coefficients. After conversion to million metric tons, the values are adjusted by subtracting "adjustment values" to account for nonfuel use of fossil fuels that result in carbon storage rather than release into the atmosphere (credit to Perry Lindstrom 2013). Adding all adjusted emissions for each fuel and sector produced a "grand total," and the resulting values reflected millions of metric tons of carbon dioxide emissions for each state and year.

Energy-related carbon dioxide constitutes over 80 percent of total emissions, so the EIA believes the state energy-related emission levels can be treated as a reliable indicator of individual states' contributions to total national emissions. State-level estimates are generated from energy consumption data for a diverse array of fuel categories, including coal, natural gas, and ten different petroleum products. The estimates net out carbon and carbon dioxide emissions that are sequestered due to the fact that a small amount of energy consumption is used for nonfuel purposes rather than undergoing combustion. The EIA uses a simplified process to allocate national-level nonfuel sequestration values to individual states, using distinct methods based on which nonfuel source is being calculated (the adjustment calculation step).

In the case of state-level electricity sector carbon dioxide emissions data, which are part of the Electric Power Annual data series, CO_2 emissions are estimated by the EIA using information collected on Form EIA-923 and prior versions describing fuel heat content and consumption in physical units. Physical units are converted to millions of Btu (MMBtu) consumed, using appropriate heat content information. Next, each fuel-specific emission factor is multiplied by the fuel consumption in MMBtu to estimate CO_2 emissions. This procedure results in figures for uncontrolled CO_2 emissions; no commercial CO_2 control systems are currently installed, according to the EIA, and such control technologies are only in the early stages of research. Therefore, no estimates of controlled carbon dioxide emissions are available.

3. Gross Domestic Product (GDP) Data

The GDP data used in this study were constructed from a variety of different datasets. Two main documents were used to construct a dataset with state-level GDP data for the 1998-2010 period, both retrieved from the Bureau of Economic Analysis (BEA) website in the “Regional Data - GDP & Personal Income” section. The quantity indexes for 1997-2011 were downloaded after selecting “Quantity indexes real GDP,” for NAICS (1997 forward) for the “All industry total” measure. Next, this dataset was used in the first step for adjusting the GDP-by-state data for this period. During this step, each state’s annual quantity indexes were divided by the corresponding 1997 quantity index. This adjusted the quantity indexes such that the index for 1997 took a value of 1.

Next, the current-dollar GDP for 1997 was retrieved. The data were gathered from the "Gross domestic product" section, for NAICS (1997 forward) for the "All industry total" measure, for all states. This current-dollar GDP file was multiplied with all the corresponding state values for each year in the re-based quantity indexes dataset. This resulted in a new dataset containing state-level real GDP in millions of chained 1997 dollars for the period of interest.

For the 1990-1997 period, state-level real GDP data were downloaded from the BEA website. The data were presented in the SIC classification, using the "All industry total" measure. These figures were reported in millions of chained 1997 dollars, so they did not need to be deflated for consistency with the other GDP dataset. Due to an industrial classification methodology change, there is a discontinuity problem with the 1990-2010 period for the state-level real GDP data included in this study. The Bureau of Economic Analysis currently reports state-level GDP data using two different classification systems; 1963 to 1997 data are reported using the Standard Industrial Classification (SIC) system, while 1997 to 2011 data are reported on the basis of the North American Industry Classification System (NAICS) methodology. Prepared by the Office of Management and Budget, the SIC has typically been used to present industry-level state and local estimates of earnings and employment. The SIC classifies establishments by their primary activities, assigning an industry code to each. NAICS eventually replaced the SIC system, after being jointly developed by the U.S., Canada and Mexico. NAICS was designed to ease comparison of business statistics across North America. State-level GDP estimates currently use the 2002 NAICS.

The detail industries are different between the SIC and NAICS classification systems, and bridging the two for time-series analysis is an ongoing research project. Given that the "All industry total" figures are the only ones used for GDP throughout the 1990 to 2010 period in this study, one might expect that these two systems could be used continuously regardless. Unfortunately, this is not necessarily the case. A BEA contact warned that, although the industry differences are not apparent when using the “All industry total” figures, differences may cause a discontinuity between SIC and NAICS years. Discontinuity arises from differences in source data and estimation methodologies between the two systems. Furthermore, NAICS-based state-level GDP estimates are consistent with U.S. GDP while SIC-based estimates are consistent with U.S. gross domestic income (GDI). The BEA warns against appending these two data series into a single time series and no convention is suggested for combining them; a BEA contact suggested building something into the model itself to account for the discontinuity.

In spite of this discontinuity, it has nevertheless been worthwhile to convert these two different data series into U.S. dollars from the same year to make the data as comparable as possible. There is no way to convert pre-1997 (SIC) data to chained dollars of a later year due to a lack of SIC-based data for 1997 or later, so all state-level GDP figures were converted to 1997 dollars. Data for 1990 to 1997 were already reported in millions of chained 1997 dollars, so that left only the task of converting the post-1997 (NAICS) portion to millions of chained 1997 dollars. As briefly described earlier, two different data files were necessary to accomplish this task.

BEA’s set of annual quantity indexes (by state) were downloaded for 1997 and later. The quantity index for each state and each year were all divided by the corresponding quantity index for the year 1997. This adjusted the quantity indexes such that each value for 1997 took on a value of 1. Next, current-dollar state-level GDP was obtained for the year 1997. Then, the previously calculated adjusted quantity indexes for each state and year were all multiplied by the corresponding 1997 current-dollar GDP values. The procedure generated real GDP for the 1997 to 2010 period in millions of chained 1997 dollars.

Several individual BEA staff contacts provided advice for this calculation and other issues during the research process. Clifford Woodruff explained the detailed systematic process for converting GDP data to adjusted values appropriate for a particular year. Both Clifford Woodruff and Catherine Wang confirmed the status of the NAICS and SIC discontinuity problem. Their contact information is provided below.

Clifford Woodruff

(202) 606-9234

gdpbystate@bea.gov

Catherine Wang

(202) 606-9670

gdpbystate@bea.gov

4. Energy Generation Data

This study also utilizes data on state-level total energy production, in billion Btu. These data are part of the State Energy Data System (SEDS) and were compiled by the Office of Survey Development and Statistical Integration, U.S. Energy Information Administration, from data collected by the EIA and other public information. The energy sources included in the total energy production calculation are coal, crude oil, natural gas (marketed production), and renewable energy and nuclear-generated electricity. Energy data from these sources was converted from physical units (such as short tons, barrels, and cubic feet) to British thermal units (Btu) using estimated heat content.

5. Population Data and GDP Per Capita

Annual state-level population data were collected for use in this study, the primary purpose of which was to calculate real GDP per capita. GDP per capita was calculated by dividing the real GDP data by population data for each state and year, the result of which represented per capita income (and its squared term) in the regressions. Population data were available in the “Regional Data - GDP & Personal Income” section of the BEA’s website, as part of the state personal income data. Population is reported as number of persons in each state; the figures represent midyear population estimates of the Census Bureau.

6. Interstate Electricity Trade Data

Interstate electricity trade data were also necessary to include in this study. These annual data were available on the state level on the Energy Information Administration’s (EIA) website as part of the “Consumption” section in the State Energy Data System (SEDS). The figures represent state-level net interstate sales of electricity and associated losses, reported in billion Btu. The data are estimates of the energy used to produce the electricity coming from other states or going to other states, excluding imports or exports associated with Canada and Mexico. The estimates include associated energy losses from generation, transmission, and distribution. Origins and destinations of electricity flow were not tracked, so for states with net electricity inflow, the EIA has applied an average Btu-to-kWh ratio to estimate the heat content of the electricity flowed in. This average ratio was calculated by dividing total electricity outflow (in Btu) with total electricity outflow (in kWh) for all states with net electricity outflow. If the net interstate flow of electricity is negative, the state is a net exporter of electricity to other states; a positive number conversely represents a net importer.

7. Electricity Production Data

Included as a measure of state-level electricity production is the total energy consumed by the electric power sector in a state (TEEIBZZ, where ZZ denotes the two-letter abbreviation for a particular state). This measure was also taken from EIA’s SEDS. This amount, expressed in billion Btu, is the sum of all primary energy used to generate electricity, and it includes net imports of electricity across U.S. borders in billion Btu, or ELNIBZZ. The calculation methodology for TEEIBZZ is as follows:

$$\mathrm{TEEIBZZ} = \mathrm{CLEIBZZ} + \mathrm{NGEIBZZ} + \mathrm{PAEIBZZ} + \mathrm{NUEGBZZ} + \mathrm{GEEGBZZ} + \mathrm{HYEGBZZ} + \mathrm{SOEGBZZ} + \mathrm{WWEIBZZ} + \mathrm{WYEGBZZ} + \mathrm{ELNIBZZ} - \mathrm{SFEIBZZ}$$

Where CLEIBZZ is coal consumed by the electric power sector, NGEIBZZ is natural gas consumed by the electric power sector including supplemental gaseous fuels, PAEIBZZ is all petroleum products consumed by the electric power sector, NUEGBZZ is electricity produced from nuclear power by the electric power sector, GEEGBZZ is electricity produced from geothermal energy by the electric power sector, HYEGBZZ is hydroelectricity produced by the electric power sector, SOEGBZZ is electricity produced from photovoltaic and solar thermal energy by the electric power sector, WWEIBZZ is wood and waste consumed by the electric power sector, WYEGBZZ is electricity produced from wind energy by the electric power sector, and SFEIBZZ is supplemental gaseous fuels consumed by the electric power sector (all expressed in billion Btu).

Supplemental gaseous fuels are already accounted for in the fossil fuels from which they are derived, which is why they are subtracted out in the preceding equation to obtain TEEIBZZ (to avoid double counting). The components of the equation were summed together by the EIA specifically to add up all the energy used to produce electricity in a state. Before adding, the EIA converted each of these energy sources to the common unit of Btu. Coal, natural gas, petroleum, renewable energy sources, and nuclear electric power each used distinct conversion methods. The electric power sector also produces heat for use as energy, but the SEDS variable does not capture that. Year-to-year stock changes are also not captured; furthermore, the dataset did not include energy sources used in commercial and industrial combined heat-and-power plants and electricity-only plants, but these are relatively small amounts. The

EIA believes it is generally safe to assume that these fuel amounts consumed by the electric power sector are used to generate electricity for that year. Below is the contact information for Yvonne Taylor, the EIA SEDS expert who helped interpret the meaning of the data and confirm that it could be used to represent electricity production.

Yvonne Taylor

(202) 586-1455

Yvonne.taylor@eia.gov

8. Energy Intensity Data

Annual energy intensity data by state was an important variable included in the analysis. Energy intensity is defined as the total energy consumed per dollar of real gross domestic product in that state, and the measure is reported in thousand Btu per chained 2005 dollar. This variable was obtained directly from the EIA as a component of SEDS. EIA recognizes the discontinuity after 1997 in state-level real GDP calculation methodology due to the BEA releasing figures for real GDP calculated with the SIC system prior to 1997 and the NAICS system after 1997. Nevertheless, the EIA compares energy intensity over time and, for data from 1977 to 1996, applies the quantity indexes to the 1997 real GDP to calculate real GDP in SEDS. The EIA employs the following calculation to obtain state-level energy intensity data (called “TETGR”):

$$\mathrm{TETGR} = \mathrm{TETCB}/\mathrm{GDPRX}$$

In the above equation, TETCB indicates total energy consumption in billion Btu and GDPRX indicates real GDP by state (SIC classification for years prior to 1997 and NAICS for 1997 forward).

9. Energy Consumption Data and Carbon Intensity Calculation

State-level total energy consumption was incorporated into this study. Measured in billion Btu, these data were also gathered from the EIA’s website in the “Consumption” section of SEDS. Appendix A in the Consumption section of EIA’s Technical Notes & Documentation section, available online, describes the calculation of total energy consumption (TETCB) as the following:

$$\text{TETCBZZ} = \text{FFTCBZZ} + \text{NUETBZZ} + \text{RETCBZZ} + \text{ELNIBZZ} + \text{ELISBZZ}$$

Where FFTCB represents total consumption of fossil fuels (in billion Btu), NUETB is electricity produced from nuclear power (billion Btu), RETCB is total consumption of renewable energy (billion Btu), ELNIB is net imports of electricity into the United States (billion Btu), and ELISB is net interstate sales of electricity and associated losses – the measure of interstate electricity trade (billion Btu). The “ZZ” at the end of each of these variable names represents the two-letter U.S. Postal Service codes for each of the fifty states and the District of Columbia; each state (and DC) has its own annual value for each variable. State-level carbon dioxide emissions were divided by energy consumption to produce the carbon intensity variable (metric tons of carbon dioxide per billion Btu consumed), which was a dependent variable in regression analysis.

10. Population Density

Population density was incorporated into regression analysis. To obtain a measure of population density, the aforementioned annual population measures were divided by each state’s land area. The land area data reflected square miles of land in the year 2000 for each state – that is, the measure was time invariant. It is possible that some land area change – due to shrinking wetlands, for example – could have occurred between 1990 and 2000, but such change is likely to be effectively negligible. The land area data were gathered online from the U.S. Census Bureau.

11. Heating Degree Days (HDD) and Cooling Degree Days (CDD)

Heating Degree Days (HDD) and Cooling Degree Days (CDD) were included on an annual basis for each state to represent energy demanded for heating and cooling buildings. Base temperatures are chosen to represent an indoor temperature that is suitable for humans to feel comfortable. If a day's average temperature is less than the base temperature, the average temperature is subtracted from the base temperature to calculate HDD for particular day. If the average temperature does not fall below the base temperature, there are zero HDD for that day. The National Climatic Data Center (NCDC), from which these data were obtained, generally uses sixty-five degrees Fahrenheit as a base temperature for HDD and CDD.

HDD were calculated on a monthly basis by NCDC and were then summed together to produce annual values for this study. NCDC obtained monthly figures by weighting each division within a state according to its share of the state population, assuring that overall state values were more indicative of the conditions in especially populous regions of each state. Each new series of monthly data used the most recently completed census to determine population weights for each division during the calculation of state HDD. CDD used essentially the same weighted calculation procedure. Both HDD and CDD are available for the 48 conterminous states, treating Washington, DC as part of the state of Maryland; because of this designation, this study uses the same HDD and CDD figures for Maryland and DC. Monthly values for 1990-2010 were downloaded and summed up separately for each state using an online tool.

12. Hydroelectric and Nuclear Nameplate Capacity

Annual state-level hydroelectric and nuclear nameplate capacity were summed together to construct a variable that would reflect endowment of relatively cleaner energy sources. The nameplate capacity (in Megawatts) for each of these energy types were summed together and then divided by the population data to produce a per capita clean energy endowment variable. These data were obtained online from the Energy Information Administration, in the Electricity section of the EIA's website. In the Electricity section of their online glossary, the EIA defines generator nameplate capacity as "the maximum rated output of a generator, prime mover, or other electric power production equipment under specific conditions designated by the manufacturer."

13. Fossil Fuel Endowment Per Capita: Liquid and Dry Natural Gas, Coal, and Crude Oil

Conventional fossil fuel endowment is likely to have a significant impact on a state's carbon intensity as well as the carbon dioxide embodied in its electricity trade. In recognition, a variable was constructed to represent this endowment. The fossil fuel endowment variable is the sum of four different types of fossil fuels present in each state on an annual basis. Included were reserves of coal, dry natural gas, liquid natural gas, and crude oil. In order to sum these reserves together into one variable with a common unit of measurement, the reserves of each type were converted into carbon dioxide emissions that would result from consumption of the quantity of fuel – producing, in effect, carbon dioxide emissions embodied in state fossil fuel reserves.

Annual state-level dry natural gas reserve data were downloaded from the EIA's website in the Natural Gas section, measured in billion cubic feet. Some states had separate amounts reported for dry natural gas proved reserves and federal offshore dry natural gas proved reserves; in these cases, the two measures were summed together to produce a total measure of each state's reserves. On occasion, states' collective federal offshore reserves were bundled together and reported as such – this occurred in the case of Alabama's and Louisiana's collective reserves. To estimate the disaggregated individual state federal offshore totals, a simple ratio was employed. Each state's share in the collective total of state onshore reserves was used as a proportion to estimate its share in federal offshore reserves. This example shows the formula used to estimate Alabama's individual federal offshore reserves, which could then be added to its on shore total:

Estimated AL federal offshore reserves = [(AL onshore reserves) / (AL onshore reserves + LA onshore reserves)] x (Combined federal offshore reserves of AL and LA)

In addition, a "Miscellaneous" category reported the combined reserves of several states with small amounts of dry natural gas reserves. These states included Arizona, Illinois, Indiana, Maryland, Missouri, Nebraska, Nevada, Oregon, South Dakota, and Tennessee. Because there were ten states in this category, each state was allocated one-tenth of reserves in the category – an equal allocation. Although this estimation is a rough one, it accomplishes the task of signaling that each state has nonzero, but scarce, reserves of dry natural gas. States that were not mentioned at all in this data set were assigned a value of zero for dry natural gas reserves.

To convert these data to units of carbon dioxide, it was necessary to consult the EIA's Carbon Dioxide Emissions Coefficients web page in their Environment section. The web page gives common ratios that allow relatively convenient conversion to carbon dioxide from various fuel types. The ratio provided for natural gas is 117.1 pounds of CO_2 per thousand cubic feet. The dry natural gas proved reserves totals, which were initially measured in billion cubic feet, were each multiplied by one billion to produce measures in terms of single cubic feet, then divided by one thousand and multiplied by 117.1 to produce a measure of pounds of CO_2. Finally, the weight in pounds was divided by 2,204.62 (to convert the weight to tons) and then divided by one million to convert the units into million metric tons of carbon dioxide.

Liquid natural gas was also incorporated into the fossil fuel reserve endowment variable. Some states reported two measures of reserves in the case of liquid natural gas as well; in the same vein, the separate reserves (proved reserves of natural gas plant liquids and federal offshore reserves) were added together in such cases to reflect a state's total reserves. These data were reported in terms of million barrels, and thus needed a slightly different treatment to be converted into million metric tons of carbon dioxide. First, the liquid reserves were converted to cubic feet equivalent so that the previously discussed ratio could be used for the final conversion to metric tons of carbon dioxide. The ratio employed at this intermediate step was the following:

1 million barrels oil equivalent = 5.61 billion cubic feet of natural gas

This ratio was obtained from the Natural Gas and Coal Measurements and Conversions page in the Extension and Outreach section on Iowa State University's website. The ratio of 117.1 pounds of CO_2 to every one thousand cubic feet was again used to convert to metric tons of carbon dioxide, which was then divided by one million to be transformed into million metric tons of carbon dioxide.

Again, states that were not mentioned in the data set were assumed to have zero reserves. The liquid natural gas data gathering process did include additional complexities, though. The liquid natural gas reserves data file also included a "Miscellaneous" category that reported collective reserves for a few states that contained small amounts of reserves. These states included Arizona, Illinois, Indiana, Maryland, Missouri, Nebraska, Nevada, New York, Ohio, Oregon, Pennsylvania, South Dakota, Tennessee, and Virginia. Because there were fourteen states in the category, each received one fourteenth of the total reserves reported as "Miscellaneous."

In addition, there were cases where federal offshore reserves were reported as a collective total for multiple states at once, rather than for individual ones. In such a case, federal offshore reserves were allocated to individual states in the same proportion each state had in the total onshore reserves. In this data file, there was again a column for combined Louisiana and Alabama federal offshore reserves. To estimate the offshore reserves for Louisiana and Alabama individually, the same formula as previously mentioned was used for each state:

Estimated AL offshore reserves = [(AL onshore) / (LA onshore + AL onshore)]*(LA offshore + AL offshore)

These estimated individual offshore values were then added to the reported individual onshore values to approximate total state reserves.

Utah and Wyoming exhibited unique problems in the original data set. They reported individual reserves for 2007 – 2010 only, so their reserves from 1990 to 2006 had to be approximated. Before 2007, Utah and Wyoming's reserves were reported as a combined total between the two states. Utah and Wyoming's individual reserves before 2007 were also approximated with proportions; this time, though, the proportions of reserves each state held in the total from 2007 to 2010 were used to approximate prior data. This formula for Wyoming's reserves (in a year prior to 2007) shows the method mathematically:

WY estimated reserves in year X = [(sum of WY reserves 2007 - 2010) / (combined sum WY and UT reserves 2007 - 2010)] x (combined sum of WY and UT reserves in year X)

Coal reserves were taken into account as another component of the fossil fuel endowment variable. Recoverable coal reserves (in million short tons) were obtained from various Annual Coal Reports, some of which were past issues. In general, annual figures for a particular year were taken from the most recent Annual Report that contained data for that year. Some data manipulation was necessary to fill in gaps with reasonable estimates for states with missing coal reserve data. Several states in each Annual Report displayed a "W" in place of reserve data, which indicated numbers "withheld to avoid disclosing private company data."

Reserves of the "W" states were approximated in the following manner. Total U.S. reserves were obtained from each corresponding Annual Report; then, coal reserves for states that *did* report their figures were summed up as the total *reported* reserves by individual states. This figure was then subtracted from the total U.S. coal reserves, producing a figure that reflected the total coal reserves collectively attributable to the remaining “W” states. These remaining reserves were then allocated proportionately. Annual Reports did release production data, even for the “W” states. Production quantities were totaled collectively for the “W” states, and each “W” state’s share in this total production quantity, as a proportion, was calculated. Finally, the sum of “W” state reserves was multiplied by each state’s production share to approximate each state’s coal reserves in a given year. Some states, such as Arkansas, occasionally had a “-“ instead of a “W” where their reported coal reserves would be in the table. These states were treated the same as the “W” states, unless they also had no reported production. States that had no reported reserves *and* no reported production in a given year were assumed to have zero coal reserves in that year.

When all the approximation and data manipulation was complete, overall annual state-level coal reserve figures were obtained in million short tons. Next, the EIA’s Carbon Dioxide Emissions Coefficients web page was again consulted for the conversion factor from short tons of coal to carbon dioxide. The ratio provided was 4,631.5 pounds of CO_2 per short ton. Therefore, the final recoverable coal reserves figure, in million short tons, was multiplied by 4,631.5 to obtain CO_2 in million pounds, which was then divided by 2,204.62 to convert the figure to million metric tons of CO_2.

The fourth and final component of the fossil fuel endowment variable was crude oil. Also obtained from the EIA, these data were reported and compiled in a manner similar to the reserves of dry and liquid natural gas. State totals were reported in million barrels of crude oil proved reserves. In some cases, such as for California and Texas, state totals and federal offshore reserves were reported as separate figures. In these cases, the federal offshore reserves were again added to the state totals to produce the overall figures for use in this study. Some states provided separate state-owned offshore reserves, but these were not added to the regular state totals because they had already been counted in those totals. This method applies to natural gas and liquid natural gas data compilation as well.

If a particular state was not included in this crude oil data set, it was assumed to have zero reserves in all years. Finally, like the natural gas data files, the crude oil data file also reported a "Miscellaneous" category. In this case, the states in that category were Arizona, Missouri, Nevada, New York, South Dakota, Tennessee, and Virginia. However, research showed that Arizona and Virginia truly possessed no such reserves. This is apparent in EIA's Figure 9 on their "U.S. Crude Oil, Natural Gas, and NG Liquids Proved Reserves" web page: http://www.eia.gov/naturalgas/crudeoilreserves/. Therefore, in this data set, the miscellaneous disaggregation was slightly different than in previous data sets. Instead of allocating the total miscellaneous reserves equally among all seven states, Arizona and Virginia were removed and assigned a value of zero for all years. The five states that remained in that category each received one fifth of the total miscellaneous reserves in each particular year. Once all four fossil fuel types had been compiled and converted to million metric tons of CO_2, they were summed together to produce a variable that reflected the total CO_2 embodied in a state's fossil fuel reserves in a given year.

14. NERC Regional Dummy Variables

In order to account for effects that may be associated with the inherent identity of a particular state or group of states, regional dummy variables were employed in regressions. These regional dummy variables came from the eight regional entities that work with the North American Electric Reliability Corporation (NERC) to ensure a reliable bulk power system in North America. The different NERC regions include the Florida Reliability Coordinating Council (FRCC), Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability*First* Corporation (RFC), SERC Reliability Corporation (SERC), Southwest Power Pool Regional Entity (SPP), Texas Reliability Entity (TRE), and the Western Electricity Coordinating Council (WECC). Because of the apparent lack of an easily-accessible data file of which states were included in each region, a dataset was constructed from simply viewing a regional entity map available online from NERC.

These dummy variables do not reflect a perfect identification through time for which states belonged to which regions in each year. Due to past structural changes within the industry, there is much ambiguity as to how these variables should be treated over time. The clearest change over time associated with these regional identifications involves a relationship between the FRCC and SERC regions. The state of Florida was included in SERC until 1996, when the Florida peninsula became a separate region (FRCC). Because of this clear change, Florida is treated purely as part of SERC until the year 1996 in the dataset, at which point it is treated as part of both FRCC and SERC. This is because, as one can see in the previously mentioned map, part of Florida became the FRCC while part of the state remained a portion of SERC.

The other NERC dummy variables are treated as time-invariant, based upon the appearance of the current NERC map, for the simple reason that regional and structural shifts since 1990 have been too complex to lend themselves to the construction of a dataset that perfectly incorporates these changes. While certain regions may not even have been in effect until after 1990, it is assumed that particular current NERC regions contain clusters of states that have gone through similar regulation experiences and it is thus deemed appropriate to treat them as such for the purposes of the regression analysis in this study. The various regions, sub-regions, and their associated predecessors have gone through enough restructuring over the past forty or more years to warrant their own standalone paper on the history of NERC and electricity supply reliability in the United States. This complex history is outside the scope of this analysis. It must also be noted that, in the NERC dummy dataset employed in this analysis, it is not remotely unusual for a state to be considered part of multiple NERC regions (individual states frequently take a value of one for more than just one NERC dummy variable). This allows inclusion of all dummy variables in a model without succumbing to the dummy variable trap.

15. Real Fossil Fuel Composite Price

Included in some regressions was a variable accounting for national fossil fuel prices. Annual real fossil fuel composite prices were obtained from the EIA for this purpose. The EIA derived these data by multiplying each fossil fuel's price per Btu by the total Btu content of the production of each fossil fuel, then dividing this accumulated value of total fossil fuel production by the accumulated Btu content of total production of fossil fuel. The composite price was reported in chained (2005) dollars, calculated by using gross domestic product implicit price deflators. This variable took three potential forms throughout regression analysis. The first was the natural logarithm of the price itself for each year. The second was the natural logarithm of the five-year lagged moving average of the real fossil fuel composite price; that is, for example, the 1990 five-year moving average was calculated as the average real fossil fuel composite price among the years 1985, 1986, 1987, 1988, and 1989.

Real fossil fuel composite price was obtained for regression analysis because of the idea that some states may choose to utilize less fossil fuel to react to increases in price. The five-year lagged moving average is included because such shifts might take time, rather than occurring immediately. A third form of this variable - the difference between the particular year's real composite price and the moving average - was also included in some regressions. The difference could be included in a regression together with the moving average to account for current prices and lagged effects simultaneously, while avoiding the collinearity problems that would likely occur if the regular current price were included in the same regression with the moving average.

16. (1+S)

One of the dependent variables in regression analysis is the quantity (1+S), which can be thought of as a proxy for trade balance of carbon dioxide emissions – that is, whether a given state is a net exporter or net importer of carbon dioxide, and to what degree. With subscript *i* standing for a particular state and *t* for a particular year, the expression S can be thought of as the *share* of total state carbon emissions from all sources (C_{it}) that comes from carbon emissions embodied in electricity imports. (1+S) equals $1 - (C^{X}_{it} / C_{it})$ for net exporters. On the other hand, because a trade balance indicating net imports is treated as a positive quantity, the formula is a bit different for net importing states. In the case of net importers, (1+S) equals $1 + (C^{I}_{it} / C_{it})$, where C^{I}_{it} represents carbon emissions embodied in electricity imports. Because of this particular construction, (1+S) is less than one for net exporters and is greater than one for net importers.

Of course, in order to construct this (1+S) expression, it was first necessary to calculate the carbon emissions embodied in net exports and in net imports for exporters and importers, respectively. For net exporters, carbon dioxide exports C^{X}_{it} equals $X^{e}_{it} \times [C^{e}_{it} / E^{e}_{it}]$, where X^{e}_{it} is net exports of electricity in Btus, C^{e}_{it} is carbon emissions from total electricity generation, and E^{e}_{it} represents the electric power sector's energy consumption in Btus. For net importing states, the procedure was slightly different. Because the origin of electricity imported to these states (that is, the state which originally produced the energy) was not tracked for the original data set, the specific ratio of emissions per Btu was not known for individual importers. Therefore, this ratio needed to be substituted with the collective average emissions per Btu embodied in electricity exports $\sum_i C^{X}_{it} / \sum_i X^{e}_{it}$ as a method of approximation. This is because, for exporting states, emissions quantities from the electricity sector and total electricity generation were both tracked. So, for net importers, the carbon dioxide emissions embodied in net imports C^I_{it} equals $\{\sum_i C^X_{it} / \sum_i X^e_{it}\} \times I^e_{it}$ where I^e_{it} denotes net imports of electricity in Btus.

Now, with these carbon dioxide exports and imports calculated, the (1+S) variable can be constructed. For exporters, (1+S) equals $1 - (C^X_{it} / C_{it})$ and for importers, (1+S) equals $1 + (C^I_{it} / C_{it})$. It is visible from this methodology that a carbon dioxide trade ratio is treated as positive in the case of net imports and negative in the case of net exports. It is also apparent now that (1+S) can represent a proxy for carbon dioxide trade balance; when (1+S) rises for a particular state, that indicates an increase in electricity imported (and thus an increase in carbon dioxide emissions *exported to other states* that generate this electricity), relative to total statewide production of carbon dioxide. It can also reflect a decrease in electricity exported (and thus a decrease in carbon dioxide effectively *imported* from other states that are importing the electricity).

Conversely, when (1+S) falls, it indicates a decrease in imports or an increase in exports of electricity, relative to total statewide production. In the case of an increase in electricity exports, this means a higher proportion of statewide carbon dioxide emissions generated at home that can be attributed to the consumption of other states (in other words, an effective increase in *carbon dioxide imports*). On the other hand, in the case of a decrease in electricity imports, this indicates a lower ratio of carbon dioxide from imported electricity to total CO_2 emissions produced at home (in other words, a relative decrease in carbon dioxide *exports* that cause additional emissions in other states from which this electricity is imported). The interpretation of this variable may seem unnecessarily complex, but the peculiar construction is due to a mathematical necessity to avoid attempts to calculate the natural logarithm of zero in the event of zero exports *and* zero imports.

17. Age Distribution

The age variables measure the percentage of each state's population that falls within a particular age range. Four age range variables are constructed in this panel data set from data files available from the U.S. Census Bureau. The ranges correspond to percentages falling between the ages of zero and 19, 20 and 39, 40 and 54, and 55 and over. The 40 to 54 age range was dropped in the regression equation to avoid problems resulting from perfect collinearity occurring with the inclusion of all four variables.

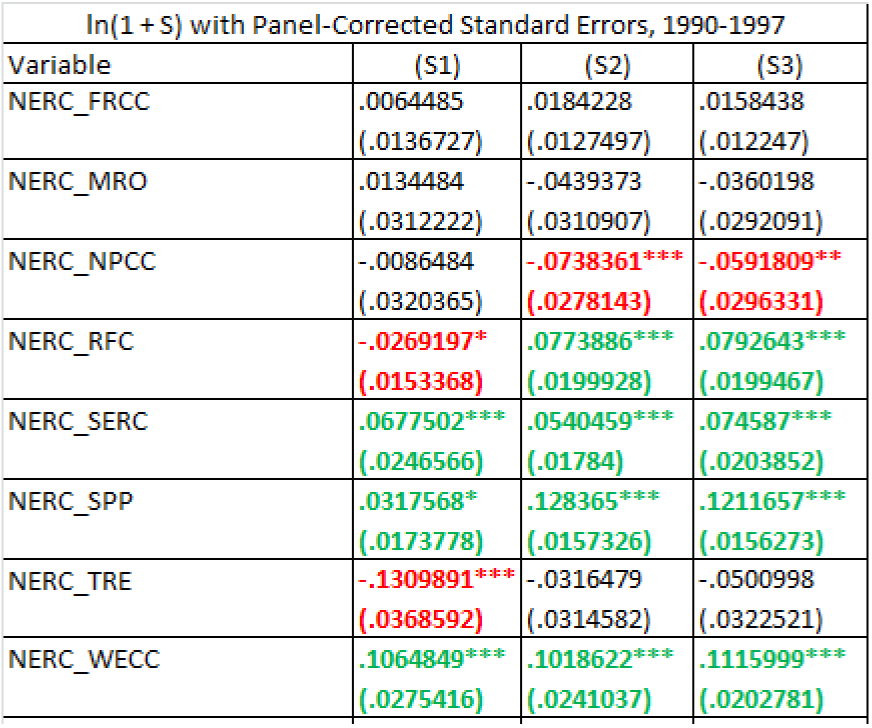
The age range variables in this paper's panel data set were aggregated from two different data files. One was used for age distribution from the year 1990 to 1999, while the other corresponded to the year 2000 through 2010. The 1990-1999 data set reported the numbers of individuals falling into age ranges in increments of five years; ranges corresponded to under 5 years, 5 to 9 years, 10 to 14, 15 to 19, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 to 44, 45 to 49, 50 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 years and over. From this raw data set, individuals falling within certain five-year age ranges were summed together to create each new bin. For example, the "under 5 years" count was added to 5 to 9, 10 to 14, and 15 to 19 to create the new value for the "zero to 19 years" variable. This continued until values were obtained for all four of the new bins. Then, each of these values were divided by the population values previously discussed. Simple addition showed that these percentages all added up to one hundred percent (or extremely close), indicating no major human errors during the data manipulation process.

Age distribution data for 2000 to 2010 were collected in a similar manner. These data were reported in the exact same five-year increments as in the case for 1990 through 1999, with one very small difference. According to the "file layout" PDF file that accompanied the data file on the U.S. Census Bureau's website, a value of zero for "AGEGRP" in the original data file indicated the number of individuals with an age of zero, while a value of 1 for “AGEGRP” indicated total individuals within the age range of 1 to 4 years. However, this did not seem accurate once the data were closely examined.

As in the case of the 1990 to 1999 data, all ages were added together to obtain totals for the new bins previously discussed, then divided by state population to convert these numbers to percentages. However, once all percentages were added together, the totals were equal to 200 percent instead of 100 percent. Upon closer inspection, it was apparent that the totals for the zero value in “AGEGRP” – that is, the population of individuals with an age of zero, according to the companion document – were all equal to the total state population. These values matched the values in the population data file used in this study. It was thus concluded that the U.S. Census Bureau likely made an error with labeling in their metadata document. Once these totals for each zero in “AGEGRP” were dropped, the sum of the percentages were again equal to 100 percent (or extremely close), making it very likely that the metadata document had made a slight error. It is likely that the “1 to 4” age group includes all ages under 5 years, including individuals with an age of zero, and was treated as such in this study during variable construction. All of the age group populations in this file and in the 1990 to 1999 data file reflect numbers of correspondingly aged individuals residing in the state as of July 1st of each particular year.

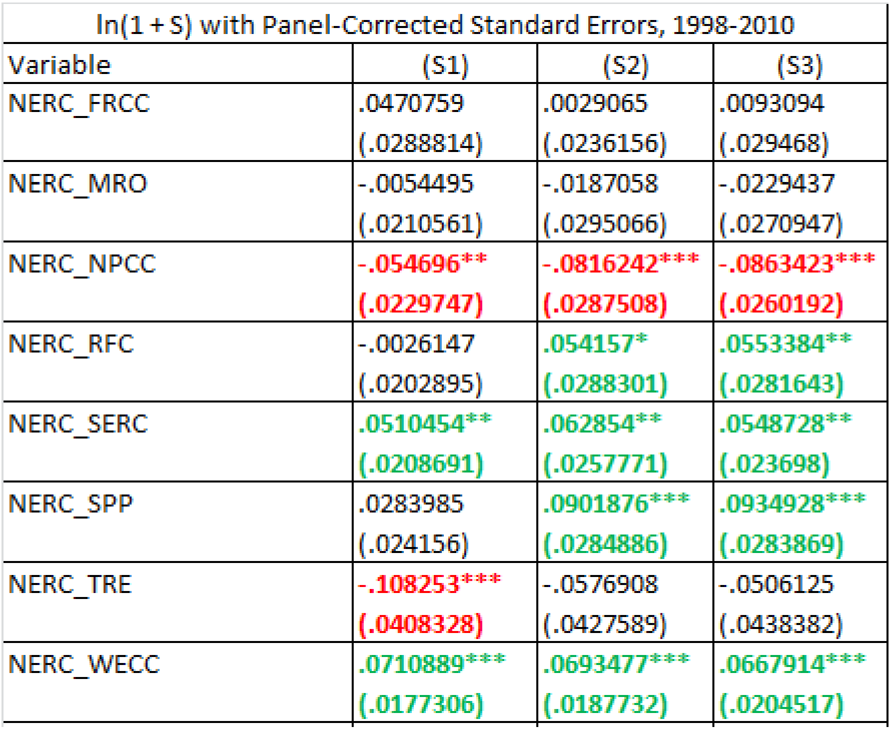
Appendix 2: NERC Dummy Variable Coefficients for Selected Regressions

Table A2.1: NERC Dummy Coefficients for Electricity Trade Effect, Period 1



ln(1 + S) with Panel-Corrected Standard Errors, 1990-1997			
Variable	(S1)	(S2)	(S3)
NERC_FRCC	.0064485 (.0136727)	.0184228 (.0127497)	.0158438 (.012247)
NERC_MRO	.0134484 (.0312222)	-.0439373 (.0310907)	-.0360198 (.0292091)
NERC_NPCC	-.0086484 (.0320365)	-.0738361*** (.0278143)	-.0591809** (.0296331)
NERC_RFC	-.0269197* (.0153368)	.0773886*** (.0199928)	.0792643*** (.0199467)
NERC_SERC	.0677502*** (.0246566)	.0540459*** (.01784)	.074587*** (.0203852)
NERC_SPP	.0317568* (.0173778)	.128365*** (.0157326)	.1211657*** (.0156273)
NERC_TRE	-.1309891*** (.0368592)	-.0316479 (.0314582)	-.0500998 (.0322521)
NERC_WECC	.1064849*** (.0275416)	.1018622*** (.0241037)	.1115999*** (.0202781)

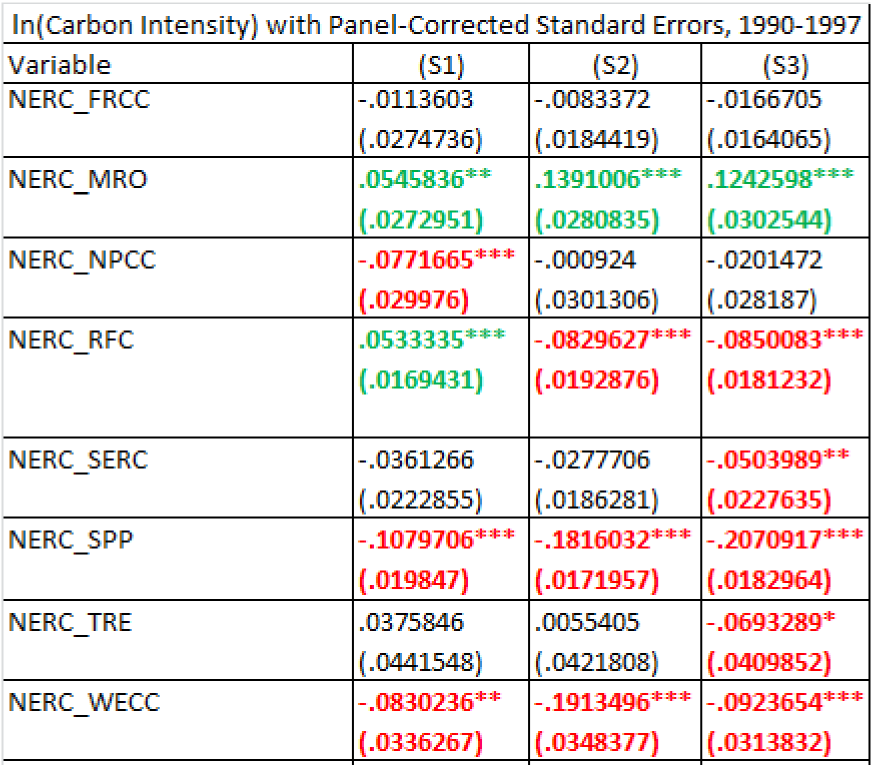
Table A2.2: NERC Dummy Coefficients for Electricity Trade Effect, Period 2



ln(1 + S) with Panel-Corrected Standard Errors, 1998-2010

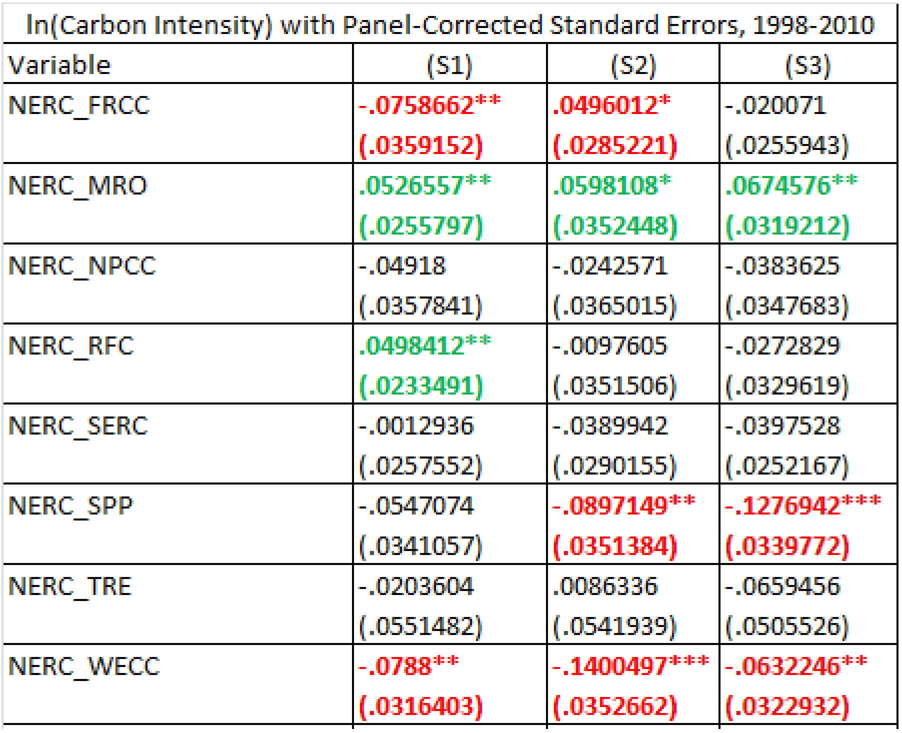
Variable	(S1)	(S2)	(S3)
NERC_FRCC	.0470759 (.0288814)	.0029065 (.0236156)	.0093094 (.029468)
NERC_MRO	-.0054495 (.0210561)	-.0187058 (.0295066)	-.0229437 (.0270947)
NERC_NPCC	-.054696** (.0229747)	-.0816242*** (.0287508)	-.0863423*** (.0260192)
NERC_RFC	-.0026147 (.0202895)	.054157* (.0288301)	.0553384** (.0281643)
NERC_SERC	.0510454** (.0208691)	.062854** (.0257771)	.0548728** (.023698)
NERC_SPP	.0283985 (.024156)	.0901876*** (.0284886)	.0934928*** (.0283869)
NERC_TRE	-.108253*** (.0408328)	-.0576908 (.0427589)	-.0506125 (.0438382)
NERC_WECC	.0710889*** (.0177306)	.0693477*** (.0187732)	.0667914*** (.0204517)

Table A2.3: NERC Dummy Coefficients for Carbon Intensity, Period 1



ln(Carbon Intensity) with Panel-Corrected Standard Errors, 1990-1997			
Variable	(S1)	(S2)	(S3)
NERC_FRCC	-.0113603 (.0274736)	-.0083372 (.0184419)	-.0166705 (.0164065)
NERC_MRO	**.0545836**** **(.0272951)**	**.1391006***** **(.0280835)**	**.1242598***** **(.0302544)**
NERC_NPCC	**-.0771665***** **(.029976)**	-.000924 (.0301306)	-.0201472 (.028187)
NERC_RFC	**.0533335***** **(.0169431)**	**-.0829627***** **(.0192876)**	**-.0850083***** **(.0181232)**
NERC_SERC	-.0361266 (.0222855)	-.0277706 (.0186281)	**-.0503989**** **(.0227635)**
NERC_SPP	**-.1079706***** **(.019847)**	**-.1816032***** **(.0171957)**	**-.2070917***** **(.0182964)**
NERC_TRE	.0375846 (.0441548)	.0055405 (.0421808)	**-.0693289*** **(.0409852)**
NERC_WECC	**-.0830236**** **(.0336267)**	**-.1913496***** **(.0348377)**	**-.0923654***** **(.0313832)**

Table A2.4: NERC Dummy Coefficients for Carbon Intensity, Period 2



ln(Carbon Intensity) with Panel-Corrected Standard Errors, 1998-2010

Variable	(S1)	(S2)	(S3)
NERC_FRCC	-.0758662** (.0359152)	.0496012* (.0285221)	-.020071 (.0255943)
NERC_MRO	.0526557** (.0255797)	.0598108* (.0352448)	.0674576** (.0319212)
NERC_NPCC	-.04918 (.0357841)	-.0242571 (.0365015)	-.0383625 (.0347683)
NERC_RFC	.0498412** (.0233491)	-.0097605 (.0351506)	-.0272829 (.0329619)
NERC_SERC	-.0012936 (.0257552)	-.0389942 (.0290155)	-.0397528 (.0252167)
NERC_SPP	-.0547074 (.0341057)	-.0897149** (.0351384)	-.1276942*** (.0339772)
NERC_TRE	-.0203604 (.0551482)	.0086336 (.0541939)	-.0659456 (.0505526)
NERC_WECC	-.0788** (.0316403)	-.1400497*** (.0352662)	-.0632246** (.0322932)

Table A2.5: NERC Dummy Coefficients for Energy Intensity, Period 1

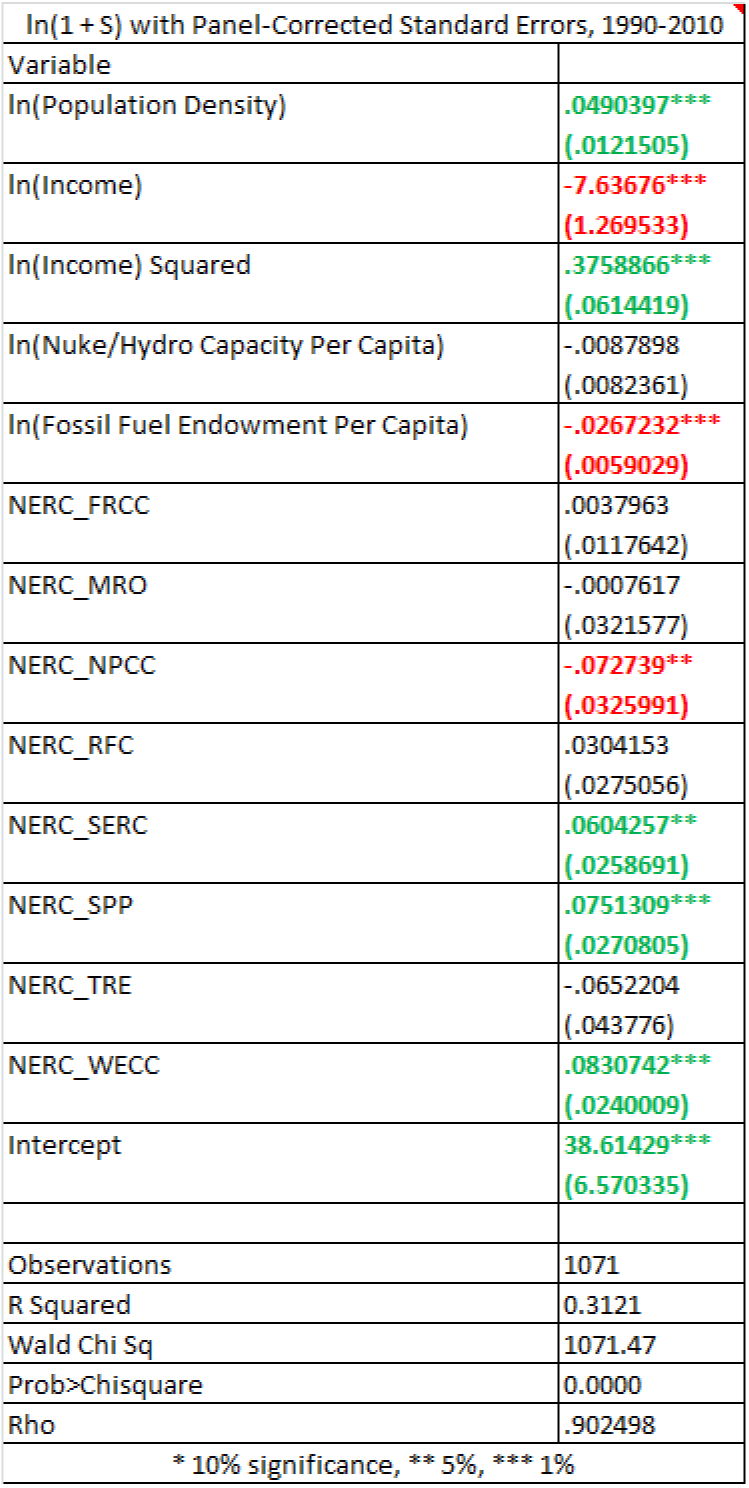
ln(Energy Intensity) with Panel-Corrected Standard Errors, 1990-1997					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
NERC_FRCC	-.0561128 (.0502617)	-.0829214 (.0656823)	-.0580753 (.0473388)	-.084942 (.0634635)	-.0400778 (.0380704)
NERC_MRO	-.1442586*** (.0147324)	-.1701786*** (.0151535)	-.1689674*** (.0158762)	-.1567663*** (.0128695)	-.164398*** (.0141984)
NERC_NPCC	-.2484559*** (.024655)	-.2539597*** (.0235961)	-.2557971*** (.0239771)	-.2500068*** (.0232303)	-.2514105*** (.0290024)
NERC_RFC	.0436051*** (.0114775)	-.0352949** (.015141)	-.0197169 (.015798)	-.0369908*** (.013755)	-.0092217 (.0185838)
NERC_SERC	.0422255** (.0171947)	.070016*** (.0146648)	.040895** (.0181443)	.0693313*** (.0145281)	.0422544** (.0195356)
NERC_SPP	.127928*** (.0158562)	.0352287** (.0177435)	.0666159*** (.0173425)	.0328152* (.0173521)	.0776715*** (.0199504)
NERC_TRE	.6254546*** (.0188068)	.5754626*** (.0188757)	.6007251*** (.0179779)	.5709019*** (.019777)	.5808668*** (.0198654)
NERC_WECC	-.3228324*** (.0196214)	-.254591*** (.0198898)	-.2935379*** (.0196454)	-.2593548*** (.0206354)	-.2805342*** (.0205576)

Table A2.6: NERC Dummy Coefficients for Energy Intensity, Period 2

ln(Energy Intensity) with Panel-Corrected Standard Errors, 1998-2010					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
NERC_FRCC	-.2668275*** (.035014)	-.2838588*** (.0341578)	-.2405417*** (.0348592)	-.2875939*** (.0365966)	-.1996809*** (.0273374)
NERC_MRO	-.0449875 (.0296617)	-.046637 (.0324185)	-.0543504* (.0324362)	-.044611 (.0324728)	-.0446744 (.0337575)
NERC_NPCC	-.2339955*** (.0263741)	-.2497877*** (.0274507)	-.2479876*** (.0275735)	-.2482276*** (.0276119)	-.2264113*** (.0256348)
NERC_RFC	.0841008*** (.0211631)	.0199409 (.0258607)	.0331411 (.0258418)	.0214745 (.0258451)	.051342** (.0257423)
NERC_SERC	.1448847*** (.0142507)	.1487313*** (.0131573)	.1242702*** (.0144075)	.1494124*** (.0135133)	.1169518*** (.0134244)
NERC_SPP	.1073266*** (.0189043)	.0385263** (.018728)	.059836*** (.0191715)	.0402757** (.0190704)	.0743578*** (.0214357)
NERC_TRE	.4444365*** (.0470013)	.4077646*** (.0499992)	.4328465*** (.048616)	.4044115*** (.0501381)	.410848*** (.0539881)
NERC_WECC	-.2988483*** (.0178319)	-.2493899*** (.0233552)	-.2790003*** (.0204675)	-.2472159*** (.0238528)	-.2822367*** (.0211546)

Appendix 3: Regression Results for “All Years” Time Period: 1990-2010

Table A3.1: Electricity Trade Effect Parameter Estimates, 1990-2010



ln(1 + S) with Panel-Corrected Standard Errors, 1990-2010	
Variable	
ln(Population Density)	.0490397*** (.0121505)
ln(Income)	-7.63676*** (1.269533)
ln(Income) Squared	.3758866*** (.0614419)
ln(Nuke/Hydro Capacity Per Capita)	-.0087898 (.0082361)
ln(Fossil Fuel Endowment Per Capita)	-.0267232*** (.0059029)
NERC_FRCC	.0037963 (.0117642)
NERC_MRO	-.0007617 (.0321577)
NERC_NPCC	-.072739** (.0325991)
NERC_RFC	.0304153 (.0275056)
NERC_SERC	.0604257** (.0258691)
NERC_SPP	.0751309*** (.0270805)
NERC_TRE	-.0652204 (.043776)
NERC_WECC	.0830742*** (.0240009)
Intercept	38.61429*** (6.570335)
Observations	1071
R Squared	0.3121
Wald Chi Sq	1071.47
Prob>Chisquare	0.0000
Rho	.902498
* 10% significance, ** 5%, *** 1%	

Table A3.2: Carbon Intensity Parameter Estimates, 1990-2010

ln(Carbon Intensity) with Panel-Corrected Standard Errors, 1990-2010		
Variable		
ln(Population Density)	-.0686125*** (.0137784)	-.074981*** (.0142508)
ln(Income)	6.8794*** (1.165292)	9.864207*** (1.303503)
ln(Income) Squared	-.3403138*** (.0558801)	-.4839063*** (.06279)
ln(Nuke/Hydro Capacity Per Capita)		-.0578569*** (.0058631)
Nuke/Hydro Capacity Per Capita	-154.9195*** (15.61405)	
ln(Fossil Fuel Endowment Per Capita)	.029644*** (.0068112)	.0344129*** (.0073913)
NERC_FRCC	-.0017594 (.0153411)	.0077575 (.0168795)
NERC_MRO	.0439282 (.0332913)	.0430613 (.0332907)
NERC_NPCC	-.043757 (.0361019)	-.0363364 (.0367837)
NERC_RFC	.004773 (.0291996)	.0121807 (.0304003)
NERC_SERC	-.0369744 (.0278598)	-.034698 (.0281254)
NERC_SPP	-.1236162*** (.0332705)	-.0941261*** (.0322058)
NERC_TRE	-.0409366 (.0572401)	.04008 (.0574638)
NERC_WECC	-.068943* (.039768)	-.1533843*** (.0408818)
ln(Moving Average of Fossil Fuel Price)	-.0292157 (.0261054)	-.021806 (.0264077)
Intercept	-30.23335*** (6.105903)	-45.49702*** (6.789456)
Observations	1071	1071
R Squared	0.9774	0.9765
Wald Chi Sq	885.28	877.75
Prob>Chisquare	0.0000	0.0000
Rho	.9076813	.902784
* 10% significance, ** 5%, *** 1%		

Table A3.3: Energy Intensity Parameter Estimates, 1990-2010

ln(Energy Intensity) with Panel-Corrected Standard Errors, 1990-2010	
Variable	
ln(Population Density)	-.1545012*** (.0108166)
ln(Income)	-2.354832** (1.013595)
ln(Income) Squared	.0816636* (.0478065)
ln(Nuke/Hydro Capacity Per Capita)	
Nuke/Hydro Capacity Per Capita	58.77597*** (9.885383)
Nuke/Hydro Capacity Per Capita, Squared	
ln(Fossil Fuel Endowment Per Capita)	.01779*** (.0033633)
Fossil Fuel Endowment Per Capita	
NERC_FRCC	-.0418988* (.0243644)
NERC_MRO	-.0866181*** (.0319567)
NERC_NPCC	-.2104867*** (.0281067)
NERC_RFC	.0718879*** (.0248899)
NERC_SERC	.0767148*** (.0175527)
NERC_SPP	.1020735*** (.020378)
NERC_TRE	.4594202*** (.0427555)
NERC_WECC	-.2704689*** (.0232801)
ln(Moving Average of Fossil Fuel Price)	-.1072312*** (.0377542)
ln(% Age 0-19)	-.0010751 (.0219076)
ln(% Age 20-39)	.1390222 (.1191269)
ln(% Age 55 and Over)	.0246235 (.1097218)
HDD	.0000255*** (4.65e-06)
CDD	.0000286*** (9.95e-06)
Intercept	18.6481*** (5.313699)
Observations	1071
R Squared	0.9599
Wald Chi Sq	6559.88
Prob>Chisquare	0.0000
Rho	.8813485
* 10% significance, ** 5%, *** 1%	

Table A3.4: Energy *Consumption* Parameter Estimates, 1990-2010

ln(Energy *Consumption*) with Panel-Corrected Standard Errors, 1990-2010	
Variable	
ln(Population Density)	.4790553*** (.0203313)
ln(Income)	38.38833*** (3.101152)
ln(Income) Squared	-1.842104*** (.1494381)
ln(Nuke/Hydro Capacity Per Capita)	.2397891*** (.0064456)
ln(Fossil Fuel Endowment Per Capita)	.0592557*** (.007521)
NERC_FRCC	.2514675** (.1212151)
NERC_MRO	-.0887235** (.0376808)
NERC_NPCC	-1.195168*** (.0392261)
NERC_RFC	-.0345023 (.0332163)
NERC_SERC	.1845782*** (.0193819)
NERC_SPP	.1998567*** (.0248213)
NERC_TRE	1.696992*** (.0582575)
NERC_WECC	-.1066964*** (.0316798)
ln(Moving Average of Fossil Fuel Price)	.1462864*** (.0554577)
% Age 0-19	-.1818648* (.1019674)
% Age 20-39	-.4001245 (.6760128)
% Age 55 and Over	-3.707821*** (.8759823)
HDD	.0000319*** (7.83e-06)
CDD	.0000255* (.0000146)
Intercept	-188.8847*** (16.16223)
Observations	1071
R Squared	0.9904
Wald Chi Sq	34020.17
Prob>Chisquare	0.0000
Rho	.8567612
* 10% significance, ** 5%, *** 1%	

Appendix 4: Elasticity Graphs for "All Years" Time Period: 1990-2010

Figure A4.1: Income Elasticity of Electricity Trade Effect, 1990-2010

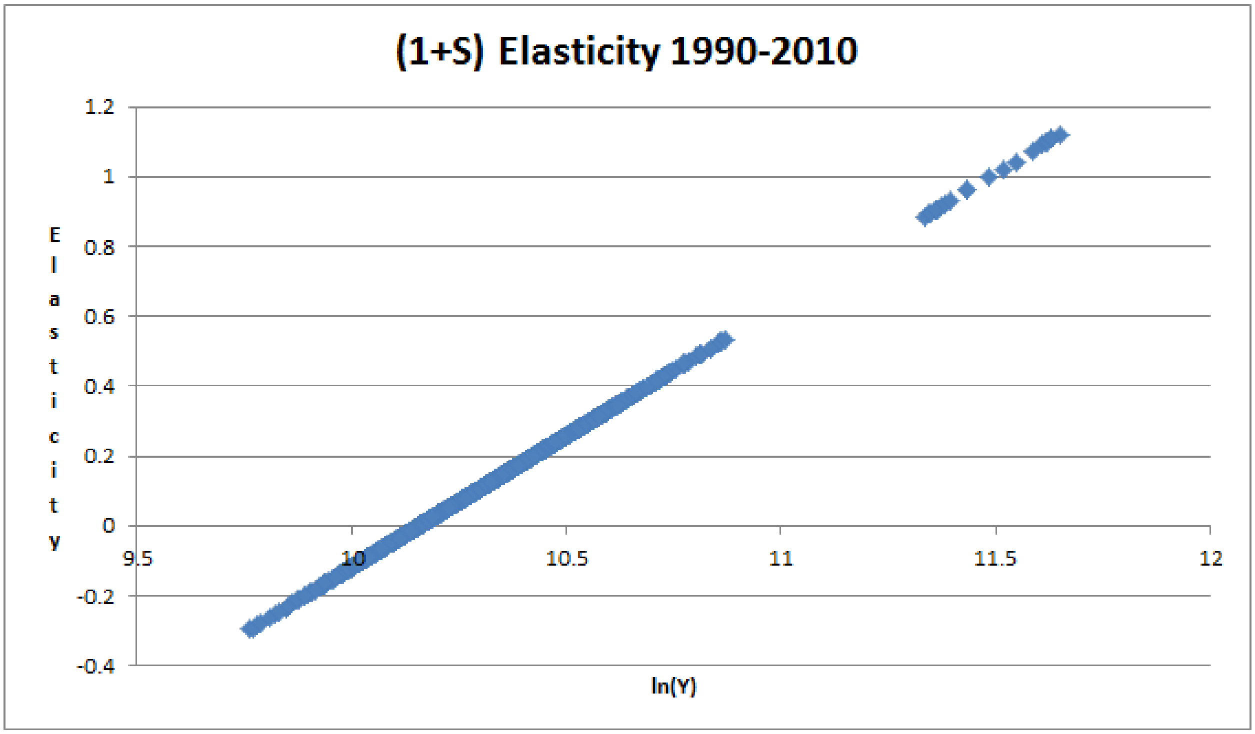


Figure A4.2: Income Elasticity of Carbon Intensity, 1990-2010

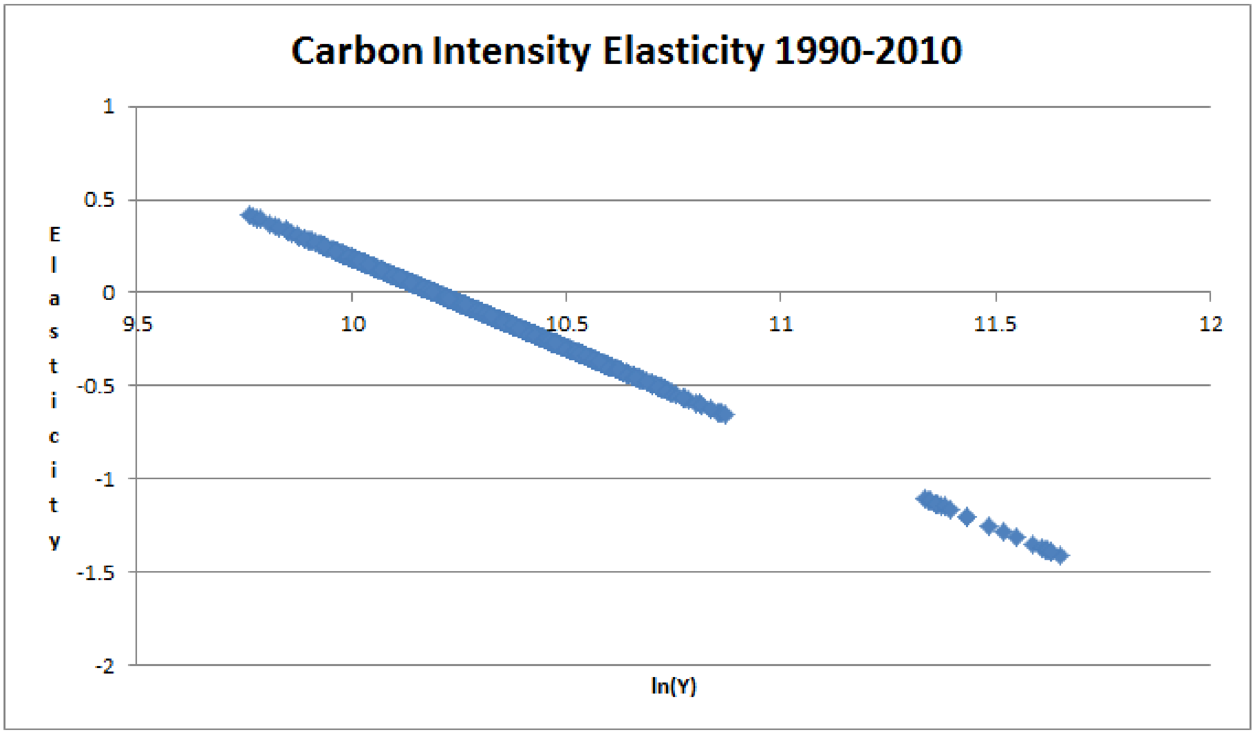


Figure A4.3: Income Elasticity of Energy Intensity, 1990-2010

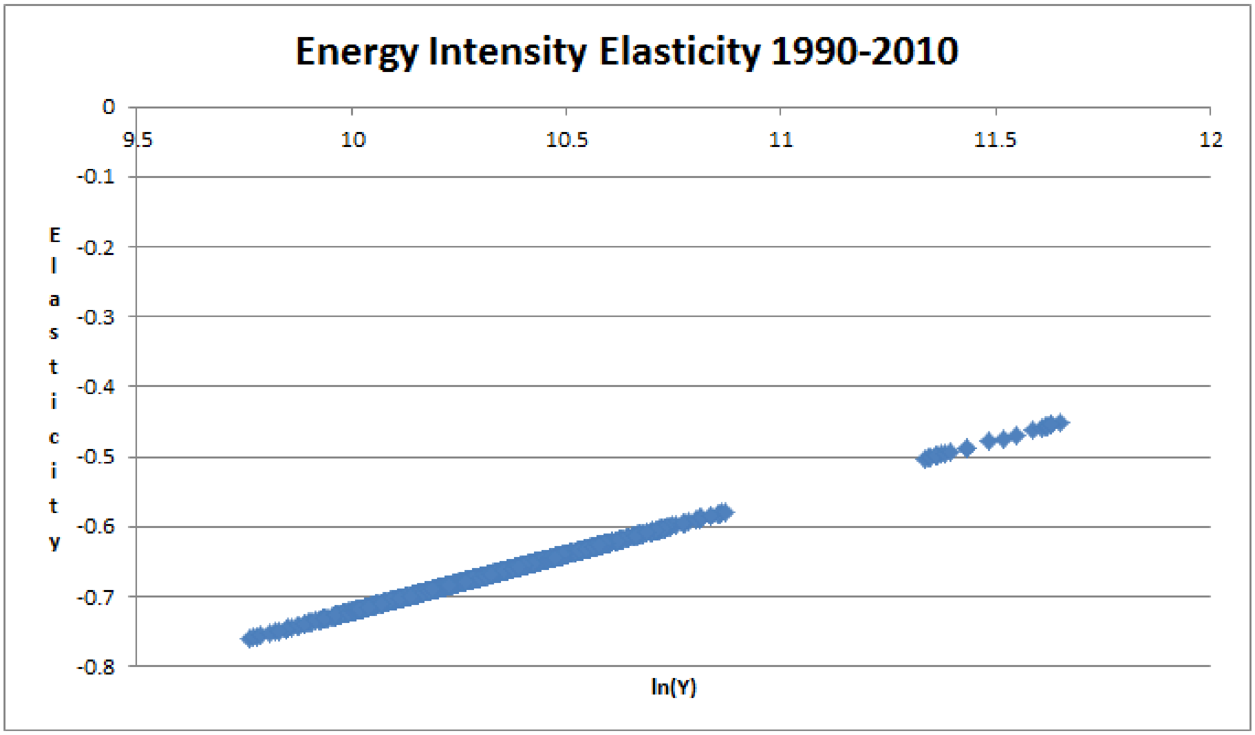


Figure A4.4: Total Income Elasticity of Per Capita Emissions, 1990-2010

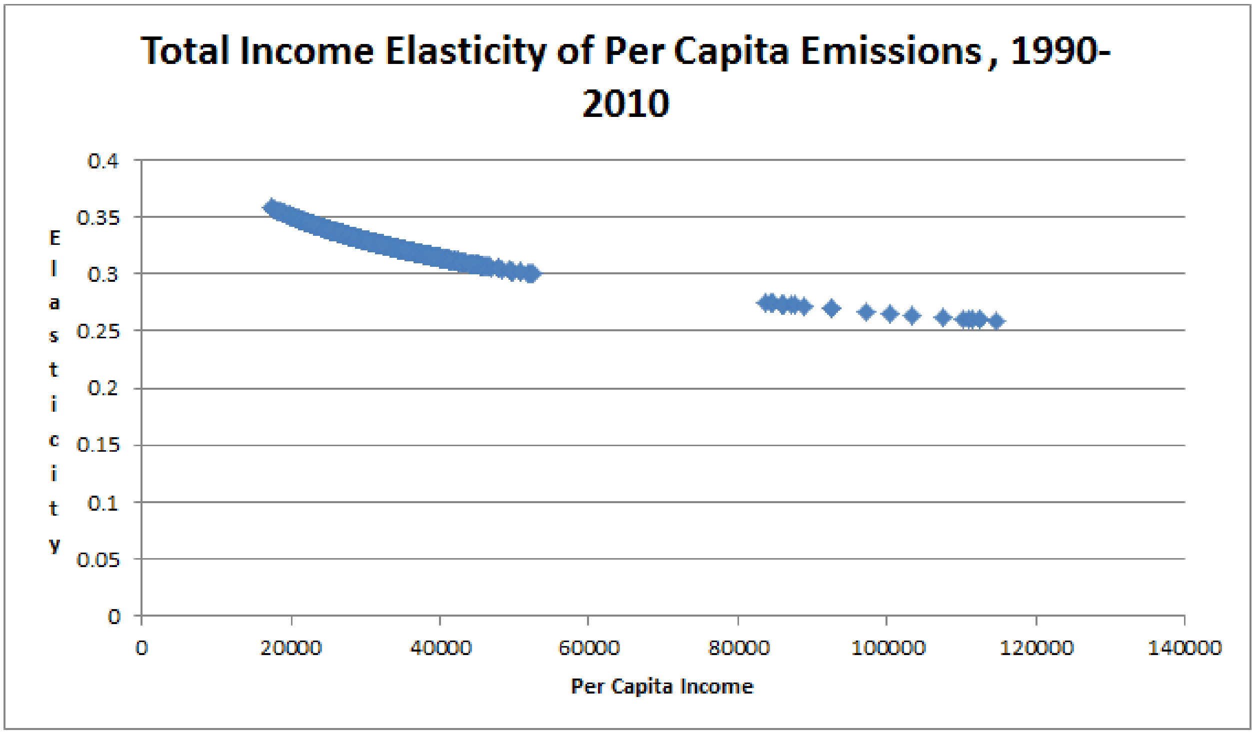
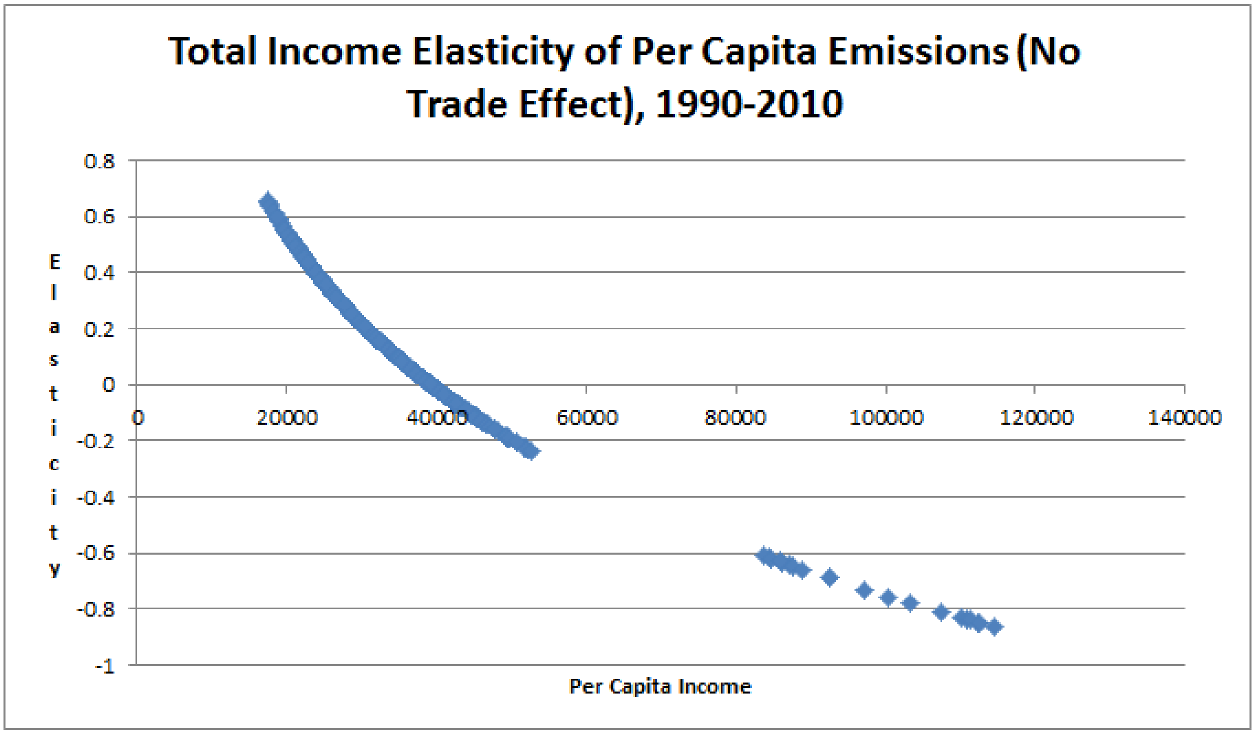


Figure A4.5: Total Income Elasticity of Per Capita Emissions (No Trade Effect): 1990-2010



Appendix 5: Tests of Structural Change

Chow Test Calculations[3]

Total observations equals 1071 in each case.

S_c = Sum of squared residuals from combined data

S_1 = Sum of squared residuals from first group

S_2 = Sum of squared residuals from second group

k = Total number of parameters, including intercept

Electricity Trade Effect (S2) Chow Test Results

$S_c = 22.614$

$S_1 = 13.249$

$S_2 = 8.4347$

$k = 14$

Chow statistic = 3.196287995; with 14 numerator degrees of freedom and 1045 denominator degrees of freedom, table value = 1.7522. REJECT null hypothesis of equal coefficients across periods at 5% significance.

Carbon Intensity (S2) Chow Test Results

$S_c = 36.150$

$S_1 = 20.969$

$S_2 = 14.143$

$k = 15$

Chow statistic = 2.051640465; with 15 numerator degrees of freedom and 1041 denominator degrees of freedom, table value = 1.6664. REJECT null hypothesis of equal coefficients across periods at 5% significance.

---

[3] These Chow tests were conducted using pooled OLS regressions.

Energy Intensity Effect (S5) Chow Test Results – No Age Variables

$S_c = 30.426$

$S_1 = 16.852$

$S_2 = 12.512$

$k = 17$

Chow statistic = 2.206170821; with 17 numerator degrees of freedom and 1037 denominator degrees of freedom, table value = 1.6664. REJECT null hypothesis of equal coefficients across periods at 5% significance.

Energy Intensity Effect (S4) Chow Test Results – With Age Variables

$S_c = 30.196$

$S_1 = 15.989$

$S_2 = 11.780$

$k = 20$

Chow statistic = 4.505450322; with 20 numerator degrees of freedom and 1031 denominator degrees of freedom, table value = 1.5705. REJECT null hypothesis of equal coefficients across periods at 5% significance.

Crump, et al Nonparametric Subpopulation Test Calculations: Alternative Tests of Structural Change

The test statistic is the following:

$T' = (\beta_0-\beta_1)'(\Omega_{0,11}/N_0+\Omega_{1,11}/N_1)^{-1}(\beta_0-\beta_1)$

where N_0 and N_1 are the sample sizes for each time period, Ω_0 and Ω_1 are corresponding consistent estimators for normalized asymptotic covariance matrices, the subscripts $_{11}$ denote the second row, second column elements from Ω matrices for each subpopulation partitioned into parts corresponding to variance of the intercept and of the slope coefficients, respectively, like so:

$$\Omega_w = \begin{pmatrix} \Omega_{w,00} & \Omega_{w,01} \\ \Omega_{w,10} & \Omega_{w,11} \end{pmatrix},$$

This nonparametric test serves in this context as an alternative test of structural change between subpopulations or periods in panel data models (Crump et al, 2008). The results follow below.

Electricity Trade Effect (S2) Subpopulation Test Result

Test statistic = 15475.902; with k-1 (including intercept) degrees of freedom, the Chi square table value = 22.36. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Carbon Intensity (S2) Subpopulation Test Result

Test statistic = 25747.574; with k-1 = 15 degrees of freedom, the Chi square table value = 25.00. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Energy Intensity Effect (S5) Subpopulation Test Result – No Age Variables

Test statistic = 41419.54; with k-1 = 16 degrees of freedom, the Chi square table value = 26.30. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Energy Intensity Effect (S4) Subpopulation Test Result – With Age Variables

Test statistic = 44230.87; with k-1 = 19 degrees of freedom, the Chi square table value = 30.14. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Energy *Consumption* Subpopulation Test Result – No Age Variables

Test statistic = 50721.033; with k-1 = 16 degrees of freedom, the Chi square table value = 26.30. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Energy *Consumption* Subpopulation Test Result – With Age Variables

Test statistic = 55292.95; with k-1 = 19 degrees of freedom, the Chi square table value = 30.14. REJECT the null hypothesis of equal coefficients across periods at 5% significance.

Appendix 6: Tests for Heteroscedasticity, Autocorrelation, and Contemporaneous Correlation[4]

Electricity Trade Effect (S2) Test Results

Cross-section heteroskedasticity: LM test statistic = 1593.9; Chi square table value with 50 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no heteroskedasticity.

Contemporaneous correlation: Breusch-Pagan LM test statistic = 12181; Chi square table value with 1275 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no contemporaneous correlation.

Autocorrelation: Durbin-Watson test statistic = 0.0707; with 51 and 13 degrees of freedom, REJECT null hypothesis of no autocorrelation at 5% significance.

Carbon Intensity (S2) Test Results

Cross-section heteroskedasticity: LM test statistic = 1189.9; Chi square table value with 50 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no heteroskedasticity.

Contemporaneous correlation: Breusch-Pagan LM test statistic = 13381; Chi square table value with 1275 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no contemporaneous correlation.

Autocorrelation: Durbin-Watson test statistic = 0.0592; with 51 and 14 degrees of freedom, REJECT null hypothesis of no autocorrelation at 5% significance.

Energy Intensity Effect (S5) Test Results – No Age Variables

Cross-section heteroskedasticity: LM test statistic = 3210.3; Chi square table value with 50 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no heteroskedasticity.

Contemporaneous correlation: Breusch-Pagan LM test statistic = 12015; Chi square table value with 1275 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no contemporaneous correlation.

Autocorrelation: Durbin-Watson test statistic = 0.0614; with 51 and 16 degrees of freedom, REJECT null hypothesis of no autocorrelation at 5% significance.

Energy Intensity Effect (S4) Test Results – With Age Variables

Cross-section heteroskedasticity: LM test statistic = 3360.4; Chi square table value with 50 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no heteroskedasticity.

---

[4] Test results shown are for "all years" (1990-2010) regressions. Test results had the same conclusions for both subperiods and for the "all years" regressions.

Contemporaneous correlation: Breusch-Pagan LM test statistic = 11539; Chi square table value with 1275 degrees of freedom yields a p-value of 0.00000. REJECT null hypothesis of no contemporaneous correlation.

Autocorrelation: Durbin-Watson test statistic = 0.0628; with 51 and 19 degrees of freedom, REJECT null hypothesis of no autocorrelation at 5% significance.

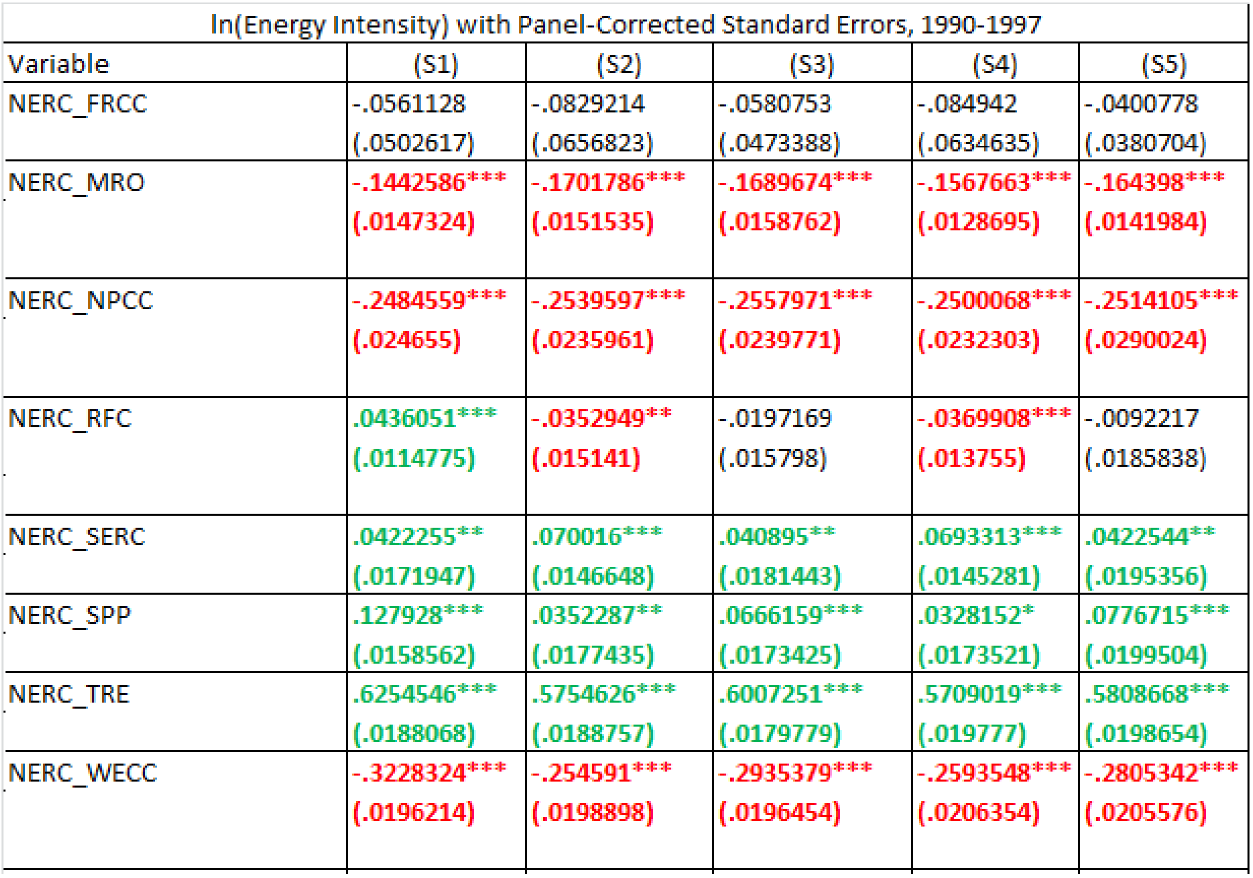
Appendix 7: Energy *Intensity* Regression Results

Table A7.1: Energy *Intensity* Parameter Estimates, Period 1

ln(Energy Intensity) with Panel-Corrected Standard Errors, 1990-1997					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
ln(Population Density)	-.1083528*** (.0082088)	-.1216315*** (.0066789)	-.1127785*** (.0075654)	-.1164612*** (.0062044)	-.1239191*** (.0069697)
ln(Income)	-5.065868*** (1.037767)	-4.525482*** (.9094143)	-3.665508*** (.8939889)	-4.931979*** (.865683)	-3.147733*** (.9370375)
ln(Income) Squared	.2008754*** (.0490674)	.1825314*** (.0432193)	.1412361*** (.0422488)	.2015861*** (.0412285)	.1166717*** (.0448761)
ln(Nuke/Hydro Capacity Per Capita		.0037303 (.0033996)		.0037545 (.0031196)	57.20742*** (5.155467)
Nuke/Hydro Capacity Per Capita	-32.15586* (17.2158)		57.44871*** (5.289803)		
Nuke/Hydro Capacity Per Capita, Squared	31862.87*** (4891.449)				
ln(Fossil Fuel Endowment Per Capita)		.0236757*** (.0019121)	.0270818*** (.0022777)	.0236665*** (.001743)	.026665*** (.0026328)
Fossil Fuel Endowment Per Capita	.0000225*** (1.57e-06)				
ln(Moving Average of Fossil Fuel Price)	.0505823 (.0623242)	.1066142 (.0698941)	.1086178* (.0642733)	.1625255** (.082294)	.0039495 (.0391285)
ln(% Age 0-19)	.0319657** (.0151796)	.0256846** (.0126282)	.0151336 (.0151071)		
ln(% Age 20-39)	-.4063308** (.1611624)	-.3835346** (.1844136)	-.3743127** (.176056)		
ln(% Age 55 and Over)	-.3335459*** (.098942)	-.0324265 (.0888298)	-.1045862 (.0971146)		
% Age 0-19				.0098971 (.0167265)	
% Age 20-39				-1.816818*** (.7055158)	
% Age 55 and Over				-.8298653* (.4488568)	
HDD	.0000177*** (5.65e-06)	.00002*** (6.43e-06)	.0000234*** (5.30e-06)	.0000186*** (6.88e-06)	.0000232*** (5.27e-06)
CDD	-1.84e-06 (.0000102)	-.0000211 (.0000141)	-5.08e-06 (.0000111)	-.0000233 (.0000147)	-1.74e-06 (.000011)
Intercept	32.56805*** (5.302217)	29.44305*** (4.643097)	24.74831*** (4.591954)	32.74559*** (4.641698)	22.74173*** (4.920845)
Observations	408	408	408	408	408
R Squared	0.9755	0.9674	0.9726	0.9639	0.9763
Wald Chi Sq	2.66e+07	1.21e+07	4.15e+07	1.30e+07	8.86e+07
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	.7579057	.7200307	.7618987	.6885959	.8110335

* 10% significance, ** 5%, *** 1%

Table A7.2: Energy *Intensity* Parameter Estimates – Regional Dummies, Period 1



ln(Energy Intensity) with Panel-Corrected Standard Errors, 1990-1997					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
NERC_FRCC	-.0561128 (.0502617)	-.0829214 (.0656823)	-.0580753 (.0473388)	-.084942 (.0634635)	-.0400778 (.0380704)
NERC_MRO	-.1442586*** (.0147324)	-.1701786*** (.0151535)	-.1689674*** (.0158762)	-.1567663*** (.0128695)	-.164398*** (.0141984)
NERC_NPCC	-.2484559*** (.024655)	-.2539597*** (.0235961)	-.2557971*** (.0239771)	-.2500068*** (.0232303)	-.2514105*** (.0290024)
NERC_RFC	.0436051*** (.0114775)	-.0352949** (.015141)	-.0197169 (.015798)	-.0369908*** (.013755)	-.0092217 (.0185838)
NERC_SERC	.0422255** (.0171947)	.070016*** (.0146648)	.040895** (.0181443)	.0693313*** (.0145281)	.0422544** (.0195356)
NERC_SPP	.127928*** (.0158562)	.0352287** (.0177435)	.0666159*** (.0173425)	.0328152* (.0173521)	.0776715*** (.0199504)
NERC_TRE	.6254546*** (.0188068)	.5754626*** (.0188757)	.6007251*** (.0179779)	.5709019*** (.019777)	.5808668*** (.0198654)
NERC_WECC	-.3228324*** (.0196214)	-.254591*** (.0198898)	-.2935379*** (.0196454)	-.2593548*** (.0206354)	-.2805342*** (.0205576)

Table A7.3: Energy *Intensity* Parameter Estimates, Period 2

ln(Energy Intensity) with Panel-Corrected Standard Errors, 1998-2010					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
ln(Population Density)	-.1555576*** (.0112194)	-.1511672*** (.0116442)	-.1486756*** (.0117375)	-.1510059*** (.0117455)	-.1508798*** (.0122789)
ln(Income)	-2.910787** (1.378067)	-3.332048** (1.413493)	-2.778146** (1.342482)	-3.372514** (1.453035)	-2.215575 (1.383792)
ln(Income) Squared	.1068935* (.0640907)	.1300323** (.0660265)	.1040786* (.062612)	.132044* (.067905)	.0770551 (.0643433)
ln(Nuke/Hydro Capacity Per Capita)		.0022716 (.0038431)		.0024307 (.0038547)	
Nuke/Hydro Capacity Per Capita	-70.5195*** (17.52339)		43.26805*** (11.31024)		50.05787*** (11.077)
Nuke/Hydro Capacity Per Capita, Squared	43676.8*** (6334.111)				
ln(Fossil Fuel Endowment Per Capita)		.0199326*** (.0039839)	.021139*** (.0039867)	.0197355*** (.0039885)	.0201476*** (.0040398)
Fossil Fuel Endowment Per Capita	.0000176*** (2.17e-06)				
ln(Moving Average of Fossil Fuel Price)	-.120993*** (.0392206)	-.1621661*** (.0399384)	-.1494515*** (.0397438)	-.1636368*** (.0409782)	-.1235718*** (.0345881)
ln(% Age 0-19)	-.0079359 (.0332924)	-.0092225 (.0280439)	-.0094728 (.0283471)		
ln(% Age 20-39)	-.1106863 (.1420451)	-.1617224 (.1601516)	-.1439062 (.1495175)		
ln(% Age 55 and Over)	-.0056013 (.1215898)	.1392622 (.1253011)	.0871436 (.1255392)		
% Age 0-19				-.0229917 (.0416062)	
% Age 20-39				-.5464011 (.5694494)	
% Age 55 and Over				.659804 (.5986107)	
HDD	.0000311*** (6.29e-06)	.000031*** (6.45e-06)	.0000312*** (6.34e-06)	.0000308*** (6.44e-06)	.0000309*** (6.48e-06)
CDD	.0000465*** (.0000137)	.0000373*** (.000014)	.000041*** (.0000135)	.0000375*** (.000014)	.0000441*** (.0000135)
Intercept	21.35144*** (7.30279)	23.37071*** (7.447553)	20.31805*** (7.08959)	23.59342*** (7.869043)	17.42965** (7.445343)
Observations	663	663	663	663	663
R Squared	0.9678	0.9662	0.9667	0.9662	0.9669
Wald Chi Sq	150301.08	103145.64	68452.05	95019.32	26692.84
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	.8160637	.8298761	.833178	.8318736	.8467816
* 10% significance, ** 5%, *** 1%					

Table A7.4: Energy *Intensity* Parameter Estimates – Regional Dummies, Period 2

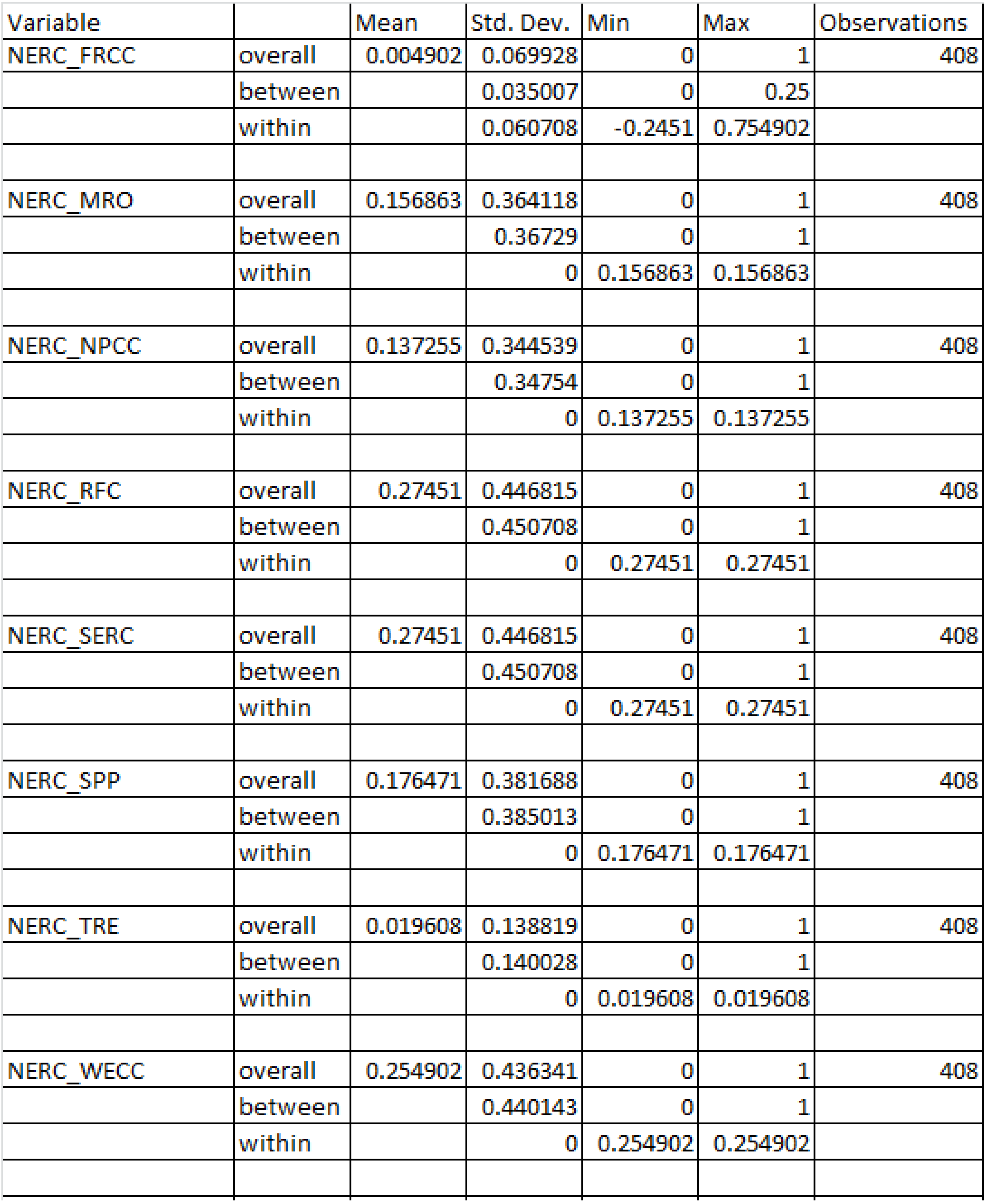
ln(Energy Intensity) with Panel-Corrected Standard Errors, 1998-2010					
Variable	(S1)	(S2)	(S3)	(S4)	(S5)
NERC_FRCC	**-.2668275***** **(.035014)**	**-.2838588***** **(.0341578)**	**-.2405417***** **(.0348592)**	**-.2875939***** **(.0365966)**	**-.1996809***** **(.0273374)**
NERC_MRO	-.0449875 (.0296617)	-.046637 (.0324185)	-.0543504* (.0324362)	-.044611 (.0324728)	-.0446744 (.0337575)
NERC_NPCC	**-.2339955***** **(.0263741)**	**-.2497877***** **(.0274507)**	**-.2479876***** **(.0275735)**	**-.2482276***** **(.0276119)**	**-.2264113***** **(.0256348)**
NERC_RFC	**.0841008***** **(.0211631)**	.0199409 (.0258607)	.0331411 (.0258418)	.0214745 (.0258451)	**.051342**** **(.0257423)**
NERC_SERC	**.1448847***** **(.0142507)**	**.1487313***** **(.0131573)**	**.1242702***** **(.0144075)**	**.1494124***** **(.0135133)**	**.1169518***** **(.0134244)**
NERC_SPP	**.1073266***** **(.0189043)**	**.0385263**** **(.018728)**	**.059836***** **(.0191715)**	**.0402757**** **(.0190704)**	**.0743578***** **(.0214357)**
NERC_TRE	**.4444365***** **(.0470013)**	**.4077646***** **(.0499992)**	**.4328465***** **(.048616)**	**.4044115***** **(.0501381)**	**.410848***** **(.0539881)**
NERC_WECC	**-.2988483***** **(.0178319)**	**-.2493899***** **(.0233552)**	**-.2790003***** **(.0204675)**	**-.2472159***** **(.0238528)**	**-.2822367***** **(.0211546)**

Appendix 8: Descriptive Statistics

Table A8.1: Summary Statistics, Period 1, Part 1

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Energy Intensity)	overall	2.384813	0.418436	0.978326	3.380314	408
	between		0.418252	1.029781	3.319206	
	within		0.056239	2.182185	2.667042	
ln(Carbon Intensity)	overall	4.087178	0.335975	3.133729	5.038715	408
	between		0.337318	3.157935	4.965828	
	within		0.032454	3.839485	4.251317	
ln(1+S)	overall	-0.0098	0.259431	-0.76306	1.100081	408
	between		0.258847	-0.71824	1.068756	
	within		0.038151	-0.18656	0.305651	
ln(Population Density)	overall	4.421607	1.558547	-0.03317	9.196104	408
	between		1.571664	0.034937	9.16788	
	within		0.037766	4.240267	4.60849	
ln(Income)	overall	10.20769	0.245216	9.763762	11.3799	408
	between		0.239489	9.862862	11.35845	
	within		0.061338	10.00459	10.40138	
ln(Income) Squared	overall	104.2568	5.134955	95.33104	129.5021	408
	between		5.024997	97.28074	129.0145	
	within		1.245573	100.2024	108.2065	
ln(Nuke/Hydro Capacity Per Capita)	overall	0.000841	0.000854	0	0.004247	408
	between		0.000859	0	0.004008	
	within		6.89E-05	0.000189	0.001307	
Fossil Fuel Endowment Per Capita	overall	1093.608	4490.681	0	32695.44	408
	between		4525.612	0	31678.6	
	within		193.1498	-435.751	2652.006	
Nuke/Hydro Capacity Per Capita, Squared	overall	1.44E-06	2.83E-06	0	0.000018	408
	between		2.84E-06	0	1.61E-05	
	within		3.23E-07	-4.38E-07	4.19E-06	

Table A8.2: Summary Statistics, Period 1, Part 2



Variable		Mean	Std. Dev.	Min	Max	Observations
NERC_FRCC	overall	0.004902	0.069928	0	1	408
	between		0.035007	0	0.25	
	within		0.060708	-0.2451	0.754902	
NERC_MRO	overall	0.156863	0.364118	0	1	408
	between		0.36729	0	1	
	within		0	0.156863	0.156863	
NERC_NPCC	overall	0.137255	0.344539	0	1	408
	between		0.34754	0	1	
	within		0	0.137255	0.137255	
NERC_RFC	overall	0.27451	0.446815	0	1	408
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SERC	overall	0.27451	0.446815	0	1	408
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SPP	overall	0.176471	0.381688	0	1	408
	between		0.385013	0	1	
	within		0	0.176471	0.176471	
NERC_TRE	overall	0.019608	0.138819	0	1	408
	between		0.140028	0	1	
	within		0	0.019608	0.019608	
NERC_WECC	overall	0.254902	0.436341	0	1	408
	between		0.440143	0	1	
	within		0	0.254902	0.254902	

Table A8.3: Summary Statistics, Period 1, Part 3

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Fossil Fuel Composite Price)	overall	0.754905	0.097377	0.587787	0.936093	408
	between		0	0.754905	0.754905	
	within		0.097377	0.587787	0.936093	
ln(% Age 0-19)	overall	-1.22318	0.22791	-1.5761	0.273761	408
	between		0.229502	-1.5429	0.26381	
	within		0.013324	-1.26808	-1.18183	
ln(% Age 20-39)	overall	-1.18018	0.070268	-1.37319	-0.94675	408
	between		0.055472	-1.29699	-1.02774	
	within		0.043742	-1.31028	-1.05926	
ln(% Age 55 and Over)	overall	-1.5854	0.139372	-2.36923	-1.27892	408
	between		0.139691	-2.24301	-1.30643	
	within		0.015703	-1.71161	-1.45086	
HDD	overall	5216.544	2280.53	0	11067	408
	between		2272.395	0.5	10344.25	
	within		354.7556	4322.294	6568.419	
CDD	overall	1094.492	881.2423	0	4267.5	408
	between		878.4284	2.6875	4044.41	
	within		134.9925	774.6171	1413.867	
ln(Moving Average of Fossil Fuel Price)	overall	0.839613	0.099118	0.711969	1.030333	408
	between		0	0.839613	0.839613	
	within		0.099118	0.711969	1.030333	
ln(Fossil Fuel Price Difference)	overall	-0.08471	0.089785	-0.19885	0.068015	408
	between		0	-0.08471	-0.08471	
	within		0.089785	-0.19885	0.068015	

Table A8.4: Summary Statistics, Period 2, Part 1

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Energy Intensity)	overall	2.16848	0.441534	0.71295	3.298795	663
	between		0.438534	0.873405	3.12133	
	within		0.078266	1.893596	2.470944	
ln(Carbon Intensity)	overall	4.082311	0.328412	2.807654	5.066967	663
	between		0.328185	2.977259	4.98817	
	within		0.045845	3.912706	4.235343	
ln(1+S)	overall	-0.00187	0.264926	-0.78063	1.356089	663
	between		0.264412	-0.67791	1.216376	
	within		0.039235	-0.18063	0.148428	
ln(Population Density)	overall	4.531166	1.534051	0.080556	9.195429	663
	between		1.547535	0.142167	9.145345	
	within		0.043122	4.310495	4.688422	
ln(Income)	overall	10.41047	0.237586	9.963378	11.64868	663
	between		0.232885	10.014	11.55026	
	within		0.05652	10.21448	10.63699	
ln(Income) Squared	overall	108.4342	5.065698	99.26891	135.6917	663
	between		4.9713	100.2806	133.4156	
	within		1.181294	104.3741	113.1567	
Nuke/Hydro Capacity Per Capita	overall	0.00074	0.00075	0	0.003805	663
	between		0.000755	0	0.003534	
	within		0.000049	0.000492	0.001011	
Fossil Fuel Endowment Per Capita	overall	996.9922	4482.499	0	36005.52	663
	between		4512.523	0	31920.03	
	within		314.7189	-2185.89	5082.478	
Nuke/Hydro Capacity Per Capita, Squared	overall	1.11E-06	2.22E-06	0	1.45E-05	663
	between		2.23E-06	0	1.25E-05	
	within		2.22E-07	-6.12E-07	3.07E-06	

Table A8.5: Summary Statistics, Period 2, Part 2

Variable		Mean	Std. Dev.	Min	Max	Observations
NERC_FRCC	overall	0.019608	0.138753	0	1	663
	between		0.140028	0	1	
	within		0	0.019608	0.019608	
NERC_MRO	overall	0.156863	0.363946	0	1	663
	between		0.36729	0	1	
	within		0	0.156863	0.156863	
NERC_NPCC	overall	0.137255	0.344376	0	1	663
	between		0.34754	0	1	
	within		0	0.137255	0.137255	
NERC_RFC	overall	0.27451	0.446604	0	1	663
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SERC	overall	0.27451	0.446604	0	1	663
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SPP	overall	0.176471	0.381508	0	1	663
	between		0.385013	0	1	
	within		0	0.176471	0.176471	
NERC_TRE	overall	0.019608	0.138753	0	1	663
	between		0.140028	0	1	
	within		0	0.019608	0.019608	
NERC_WECC	overall	0.254902	0.436135	0	1	663
	between		0.440143	0	1	
	within		0	0.254902	0.254902	

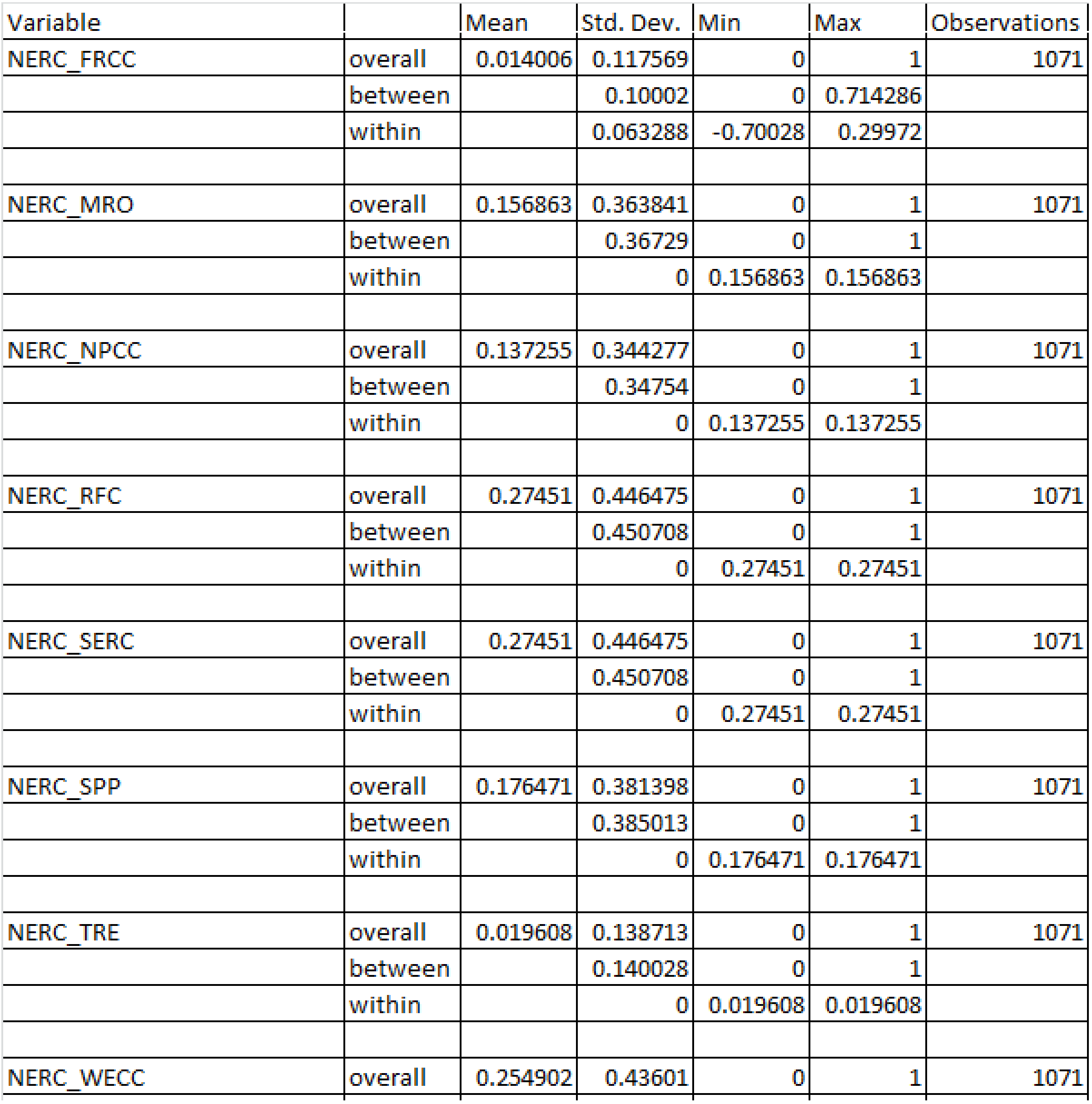
Table A8.6: Summary Statistics, Period 2, Part 3

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Fossil Fuel Composite Price)	overall	1.21696	0.36768	0.500775	1.793425	663
	between		0	1.21696	1.21696	
	within		0.36768	0.500775	1.793425	
ln(% Age 0-19)	overall	-1.2841	0.113229	-1.66844	0.248217	663
	between		0.080978	-1.51894	-1.01732	
	within		0.079889	-1.54687	-0.01856	
ln(% Age 20-39)	overall	-1.29823	0.067144	-1.47281	-0.95366	663
	between		0.059136	-1.40084	-1.04919	
	within		0.032781	-1.43433	-1.14487	
ln(% Age 55 and Over)	overall	-1.48271	0.127451	-2.0677	-1.18864	663
	between		0.106921	-1.85343	-1.27489	
	within		0.070845	-1.69698	-1.24525	
HDD	overall	5065.919	2168.368	0	11161	663
	between		2162.043	0.423077	10138.69	
	within		334.8529	4136.689	6256.689	
CDD	overall	1180.334	896.4702	0	4349	663
	between		893.1448	4.346154	3929.676	
	within		142.8672	532.1876	1690.949	
ln(Moving Average of Fossil Fuel Price)	overall	1.049564	0.323591	0.65959	1.556881	663
	between		0	1.049564	1.049564	
	within		0.323591	0.65959	1.556881	
ln(Fossil Fuel Price Difference)	overall	0.167396	0.23141	-0.27041	0.448135	663
	between		0	0.167396	0.167396	
	within		0.23141	-0.27041	0.448135	

Table A8.7: Summary Statistics, All Years, Part 1

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Energy Intensity)	overall	2.250893	0.445265	0.71295	3.380314	1071
	between		0.428383	0.932977	3.196711	
	within		0.134832	1.785088	2.732543	
ln(Carbon Intensity)	overall	4.084165	0.331166	2.807654	5.066967	1071
	between		0.329937	3.046088	4.979659	
	within		0.053358	3.80137	4.274717	
ln(1+S)	overall	-0.00489	0.262753	-0.78063	1.356089	1071
	between		0.261133	-0.69077	1.16014	
	within		0.046081	-0.17761	0.347299	
ln(Population Density)	overall	4.48943	1.54362	-0.03317	9.196104	1071
	between		1.556233	0.101318	9.15393	
	within		0.07856	4.025296	4.820712	
ln(Income)	overall	10.33322	0.259812	9.763762	11.64868	1071
	between		0.231944	9.956424	11.47719	
	within		0.121284	9.968553	10.67702	
ln(Income) Squared	overall	106.8429	5.479528	95.33104	135.6917	1071
	between		4.9208	99.13782	131.739	
	within		2.502709	99.50664	113.9585	
Nuke/Hydro Capacity Per Capita	overall	0.000778	0.000792	0	0.004247	1071
	between		0.000792	0	0.003715	
	within		0.000109	0.000349	0.001575	
Fossil Fuel Endowment Per Capita	overall	1033.798	4483.765	0	36005.52	1071
	between		4515.288	0	31828.06	
	within		312.098	-2057.11	5211.259	
Nuke/Hydro Capacity Per Capita, Squared	overall	1.23E-06	2.47E-06	0	0.000018	1071
	between		2.45E-06	0	1.39E-05	
	within		4.58E-07	-1.85E-06	5.74E-06	

Table A8.8: Summary Statistics, All Years, Part 2



Variable		Mean	Std. Dev.	Min	Max	Observations
NERC_FRCC	overall	0.014006	0.117569	0	1	1071
	between		0.10002	0	0.714286	
	within		0.063288	-0.70028	0.29972	
NERC_MRO	overall	0.156863	0.363841	0	1	1071
	between		0.36729	0	1	
	within		0	0.156863	0.156863	
NERC_NPCC	overall	0.137255	0.344277	0	1	1071
	between		0.34754	0	1	
	within		0	0.137255	0.137255	
NERC_RFC	overall	0.27451	0.446475	0	1	1071
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SERC	overall	0.27451	0.446475	0	1	1071
	between		0.450708	0	1	
	within		0	0.27451	0.27451	
NERC_SPP	overall	0.176471	0.381398	0	1	1071
	between		0.385013	0	1	
	within		0	0.176471	0.176471	
NERC_TRE	overall	0.019608	0.138713	0	1	1071
	between		0.140028	0	1	
	within		0	0.019608	0.019608	
NERC_WECC	overall	0.254902	0.43601	0	1	1071

Table A8.9: Summary Statistics, All Years, Part 3

Variable		Mean	Std. Dev.	Min	Max	Observations
ln(Fossil Fuel Composite Price)	overall	1.040939	0.371001	0.500775	1.793425	1071
	between		0	1.040939	1.040939	
	within		0.371001	0.500775	1.793425	
ln(% Age 0-19)	overall	-1.26089	0.169014	-1.66844	0.273761	1071
	between		0.129172	-1.52807	-0.52927	
	within		0.110419	-2.01171	-0.45786	
ln(% Age 20-39)	overall	-1.25326	0.0892	-1.47281	-0.94675	1071
	between		0.053163	-1.36128	-1.04102	
	within		0.071995	-1.43146	-1.02721	
ln(% Age 55 and Over)	overall	-1.52183	0.141166	-2.36923	-1.18864	1071
	between		0.116928	-2.00184	-1.28691	
	within		0.080691	-1.88921	-1.13596	
HDD	overall	5123.3	2211.92	0	11161	1071
	between		2203.381	0.452381	10217	
	within		358.3931	3996.3	6712.253	
CDD	overall	1147.632	891.2632	0	4349	1071
	between		886.9056	3.714286	3973.384	
	within		149.8375	455.7779	1722.537	
ln(Moving Average of Fossil Fuel Price)	overall	0.969583	0.280937	0.65959	1.556881	1071
	between		0	0.969583	0.969583	
	within		0.280937	0.65959	1.556881	
ln(Fossil Fuel Price Difference)	overall	0.071356	0.226274	-0.27041	0.448135	1071
	between		0	0.071356	0.071356	
	within		0.226274	-0.27041	0.448135	

Appendix 9: Sensitivity Analysis

For each model and time period, one can observe some differences when atypical areas – such as the District of Columbia, with its unusually high income and population density, as well as the two non-contiguous states – are removed from the data set. In particular, income and its squared term lose significance in many cases. This is particularly striking given our focus on income as a key variable for EKC analysis. Future studies are well advised to pay more attention to these areas and their consequences on a possible EKC with regard to CO_2 emissions in the United States. The sensitivity analysis outcomes are provided in the following tables.

Table A9.1: Electricity Trade Effect Sensitivity Analysis

ln(1 + S) with Panel-Corrected Standard Errors - Sensitivity Analysis (S2)						
	1990-1997		1998-2010		1990-2010	
Variable	No DC	No DC, AK, HI	No DC	No DC, AK, HI	No DC	No DC, AK, HI
ln(Population Density)	.0215736* (.0122108)	.0841966*** (.0181842)	.0214015** (.0108073)	.0805112*** (.0137597)	.0334922*** (.0113113)	.0926936*** (.0150419)
ln(Income)	-5.759687* (3.212841)	3.336798 (4.913402)	3.260518 (3.396767)	3.276842 (3.510187)	-.8184528 (1.791987)	.2523167 (2.068283)
ln(Income) Squared	.2874777* (.1578947)	-.1675102 (.242026)	-.1479013 (.1630268)	-.1540304 (.1683014)	.0437422 (.0866332)	-.0120117 (.1001983)
ln(Nuke/Hydro Capacity Per Capita)	.0066452 (.007832)	.0004846 (.0097387)	-.0015702 (.0074092)	-.0017059 (.0075246)	-.0039481 (.008141)	-.0030562 (.0081495)
ln(Fossil Fuel Endowment Per Capita)	-.0479785*** (.0053837)	-.04956*** (.0064606)	-.0315*** (.0059732)	-.0326519*** (.006183)	-.027221*** (.0058721)	-.0290106*** (.0059693)
NERC_FRCC	.0180619 (.0126067)	.0126914 (.0136896)	.0061694 (.0224604)	-.0301254 (.0252633)	.0040384 (.0116588)	-.0027574 (.0129594)
NERC_MRO	-.0567072* (.0325351)	.0353842 (.0427947)	-.0300147 (.0284768)	.0760928** (.0350552)	-.0174489 (.0317421)	.0881161** (.0383215)
NERC_NPCC	-.0690998** (.0294023)	-.0374946 (.0373776)	-.0551462** (.0271008)	-.0176395 (.0306155)	-.0471571 (.0321527)	-.0093236 (.0330192)
NERC_RFC	.0781834*** (.02017)	.0847929*** (.0237285)	.0633916** (.0280738)	.0766693*** (.028782)	.0395358 (.0268984)	.058191** (.0273952)
NERC_SERC	.0499756*** (.0182023)	.0828956*** (.0235399)	.0639729*** (.0241923)	.1045219*** (.0243148)	.0600173** (.0250438)	.1027361*** (.0258123)
NERC_SPP	.1213523*** (.0189035)	.1860396*** (.0226738)	.0922562*** (.0290714)	.1619132*** (.0318537)	.0709502*** (.0273912)	.1508222*** (.0309928)
NERC_TRE	-.0184923 (.0349418)	-.1710866*** (.0534418)	-.0618391 (.0415452)	-.2136089*** (.048269)	-.0483926 (.0437945)	-.2124397*** (.0529989)
NERC_WECC	.0864532*** (.0264803)	.2358424*** (.042642)	.0625551*** (.0194333)	.2091191*** (.0282436)	.0673127*** (.0241388)	.2206251*** (.0359507)
Intercept	28.76317* (16.2948)	-16.99075 (24.912)	-17.97141 (17.69149)	-17.8365 (18.28995)	3.677935 (9.256134)	-1.797769 (10.65852)
Observations	400	384	650	624	1050	1008
R Squared	0.3491	0.3794	0.2826	0.3571	0.1637	0.2274
Wald Chi Sq	3.74e+07	1.76e+07	857.46	1027.58	360.72	511.31
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	.8395667	.8740172	.8570463	.8499841	.9009445	.893084
* 10% significance, ** 5%, *** 1%						

Table A9.2: Carbon Intensity Sensitivity Analysis

ln(Carbon Intensity) with Panel-Corrected Standard Errors - Sensitivity Analysis (S2)						
	1990-1997		1998-2010		1990-2010	
Variable	No DC	No DC, AK, HI	No DC	No DC, AK, HI	No DC	No DC, AK, HI
ln(Population Density)	-.0194927*	-.1064078***	-.0527246***	-.1251236***	-.0579789***	-.1322546***
	(.0101667)	(.0147608)	(.0161056)	(.0195211)	(.0128902)	(.0162987)
ln(Income)	7.430034**	-5.399145	1.956011	2.509143	1.857724	.9744619
	(3.492554)	(3.785839)	(4.313534)	(4.401295)	(2.114131)	(2.396769)
ln(Income) Squared	-.3688421**	.2728151	-.1007168	-.1213836	-.093697	-.0459018
	(.1719017)	(.1864755)	(.2073448)	(.2111727)	(.1024495)	(.1163666)
ln(Nuke/Hydro Capacity Per Capita)	-.0762718***	-.0715917***	-.063004***	-.0628828***	-.0633131***	-.0661426***
	(.0045977)	(.0061998)	(.0066308)	(.0062608)	(.0059327)	(.0058706)
ln(Fossil Fuel Endowment Per Capita)	.0724488***	.074227***	.0358082***	.0420799***	.0339385***	.0399892***
	(.0040511)	(.0050081)	(.0093533)	(.0095403)	(.0073142)	(.0075339)
NERC_FRCC	-.009205	-.0025737	.0496411*	.0928575***	.0066531	.0162139
	(.0172885)	(.0251162)	(.029512)	(.0287465)	(.0156094)	(.0178626)
NERC_MRO	.1549051***	.0256325	.0631967*	-.0725215*	.060944*	-.0754555*
	(.0324776)	(.0436984)	(.0376633)	(.0430884)	(.0342864)	(.0400406)
NERC_NPCC	-.0061575	-.058918	-.0508892	-.0991432**	-.0677015*	-.1216563***
	(.0312217)	(.0445744)	(.0402916)	(.0414071)	(.0371204)	(.0401651)
NERC_RFC	-.0818591***	-.1014788***	-.0044864	-.0374478	.0042572	-.0375576
	(.0215497)	(.0270289)	(.0358902)	(.0325506)	(.0299677)	(.02807)
NERC_SERC	-.0222357	-.0688349**	-.0365137	-.0948774***	-.0339768	-.0942747***
	(.0209528)	(.0270769)	(.0313101)	(.0299737)	(.0286277)	(.0285287)
NERC_SPP	-.1712504***	-.2679049***	-.0819679**	-.186449***	-.0868797***	-.2043216***
	(.0211072)	(.0269347)	(.039183)	(.0384767)	(.0329316)	(.03428)
NERC_TRE	-.0092837	.2084123***	.01151	.214735***	.0207888	.2397764***
	(.0491729)	(.0779114)	(.0592618)	(.063918)	(.058518)	(.0663973)
NERC_WECC	-.1712948***	-.3856105***	-.130453***	-.3316405***	-.1340472***	-.346338***
	(.0400118)	(.0599363)	(.0398712)	(.045886)	(.0409033)	(.048005)
ln(Moving Average of Fossil Fuel Price)	-.0326334	-.0055003	-.037892	-.0407272	-.0325398	-.0352486
	(.0423632)	(.0352779)	(.0279154)	(.0253809)	(.0242467)	(.0223626)
Intercept	-32.87765*	31.65765*	-4.756317	-7.826753	-4.473631	.0279231
	(17.69803)	(19.20516)	(22.43322)	(22.92014)	(10.90427)	(12.33787)
Observations	400	384	650	624	1050	1008
R Squared	0.9881	0.9902	0.9840	0.9850	0.9771	0.9787
Wald Chi Sq	23437.07	27314.30	6942.02	4766.87	707.66	801.31
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	.8421075	.8741992	0.8855983	0.8607566	0.9051716	0.8865683

* 10% significance, ** 5%, *** 1%

Table A9.3: Energy Intensity Sensitivity Analysis

ln(Energy Intensity) with Panel-Corrected Standard Errors - Sensitivity Analysis (S2)						
	1990-1997		1998-2010		1990-2010	
Variable	No DC	No DC, AK, HI	No DC	No DC, AK, HI	No DC	No DC, AK, HI
ln(Population Density)	-.1247441***	-.1315844***	-.1554919***	-.1674491***	-.1577569***	-.1804623***
	(.0065372)	(.0079266)	(.012297)	(.0142715)	(.0099262)	(.0124523)
ln(Income)	-2.011649	-3.366387	-3.124649	-1.309013	-3.745933*	-4.356922**
	(1.725222)	(2.126224)	(3.655658)	(3.694934)	(2.020805)	(2.169506)
ln(Income) Squared	.059341	.1268105	.1206187	.0337161	.1478666	.1796567*
	(.0837721)	(.1043106)	(.1745785)	(.1766378)	(.0975295)	(.1049571)
ln(Nuke/Hydro Capacity Per Capita)	.0031998	.0002017	.0031324	-.0083462*	.0078099*	.0010285
	(.0031919)	(.0030626)	(.0042539)	(.0045425)	(.0045392)	(.0046474)
ln(Fossil Fuel Endowment Per Capita)	.0238389***	.0232294***	.0185439***	.0159209***	.0167718***	.0148287***
	(.0018048)	(.0018909)	(.0041054)	(.0041151)	(.0032527)	(.0032142)
NERC_FRCC	-.092127	-.0976573	-.2855789***	-.3850055***	-.0584741*	-.0550065*
	(.0682089)	(.077235)	(.0378956)	(.0488651)	(.0303455)	(.0315814)
NERC_MRO	-.173759***	-.1830034***	-.04548	-.0943934***	-.0781661**	-.1394282***
	(.01486)	(.0171952)	(.0339524)	(.0301951)	(.0313237)	(.0314655)
NERC_NPCC	-.251231***	-.2696525***	-.2410007***	-.329443***	-.2039649***	-.2774209***
	(.0230141)	(.0251067)	(.0287811)	(.0289737)	(.0275475)	(.0279085)
NERC_RFC	-.0376159***	-.054684***	.0294812	-.0413316	.0586446**	.0094223
	(.0136416)	(.0107085)	(.0270267)	(.0253711)	(.0243409)	(.0231124)
NERC_SERC	.0674312***	.0354261***	.1486936***	.0996117***	.0998435***	.0543086***
	(.0145002)	(.0122439)	(.0143301)	(.016879)	(.0160143)	(.0177157)
NERC_SPP	.0285032*	.0005419	.0414026**	-.0292794*	.0752338***	.0185866
	(.0168088)	(.0137187)	(.0202788)	(.0150184)	(.0197791)	(.0149634)
NERC_TRE	.5874581***	.6117133***	.4019676***	.4919619***	.4252914***	.5201893***
	(.0186973)	(.0182815)	(.0530963)	(.0502203)	(.0416626)	(.0421)
NERC_WECC	-.2687027***	-.3148391***	-.246948***	-.3279448***	-.2318463***	-.3351442***
	(.0197771)	(.0254604)	(.0250108)	(.0382049)	(.024529)	(.0361682)
ln(Moving Average of Fossil Fuel Price)	.1357209*	.132309*	-.1612155***	-.1701759***	-.1162175***	-.0998495***
	(.0781214)	(.0774514)	(.0417369)	(.0427464)	(.0384846)	(.0379588)
ln(% Age 0-19)	.0295947**	.0449328***	-.0144229	-.0094844	-.0025015	.0038689
	(.0120084)	(.0145944)	(.0277879)	(.0292652)	(.0219646)	(.0225977)
ln(% Age 20-39)	-.4627866**	-.4919674**	-.1836905	-.183245	.1390321	.1466536
	(.2009427)	(.2040596)	(.1690542)	(.1638916)	(.1295916)	(.1239543)
ln(% Age 55 and Over)	-.0620121	-.1393787	.1245878	.209557	.0684988	.0016781
	(.0889044)	(.0927876)	(.1330725)	(.1561721)	(.1088013)	(.122959)
HDD	.0000172**	.0000142*	.0000301***	.0000268***	.0000247***	.0000252***
	(7.13e-06)	(7.40e-06)	(6.44e-06)	(6.63e-06)	(4.80e-06)	(4.83e-06)
CDD	-.000028*	-.0000148	.0000409***	.0000509***	.0000239**	.0000276***
	(.0000153)	(.0000145)	(.0000139)	(.0000129)	(.0000105)	(.0000103)
Intercept	16.50681*	23.25993**	22.18773	13.08269	26.04079**	29.09322***
	(8.916488)	(10.80192)	(19.09151)	(19.25244)	(10.47687)	(11.20959)
Observations	400	384	650	624	1050	1008
R Squared	0.9628	0.9644	0.9665	0.9689	0.9589	0.9610
Wald Chi Sq	1.24e+07	338592.94	88044.90	51407.93	5814.12	6506.39
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rho	.6896725	.7011743	.8489727	.860285	.8705985	.8807217
* 10% significance, ** 5%, *** 1%						

Table A9.4: Energy *Consumption* Sensitivity Analysis

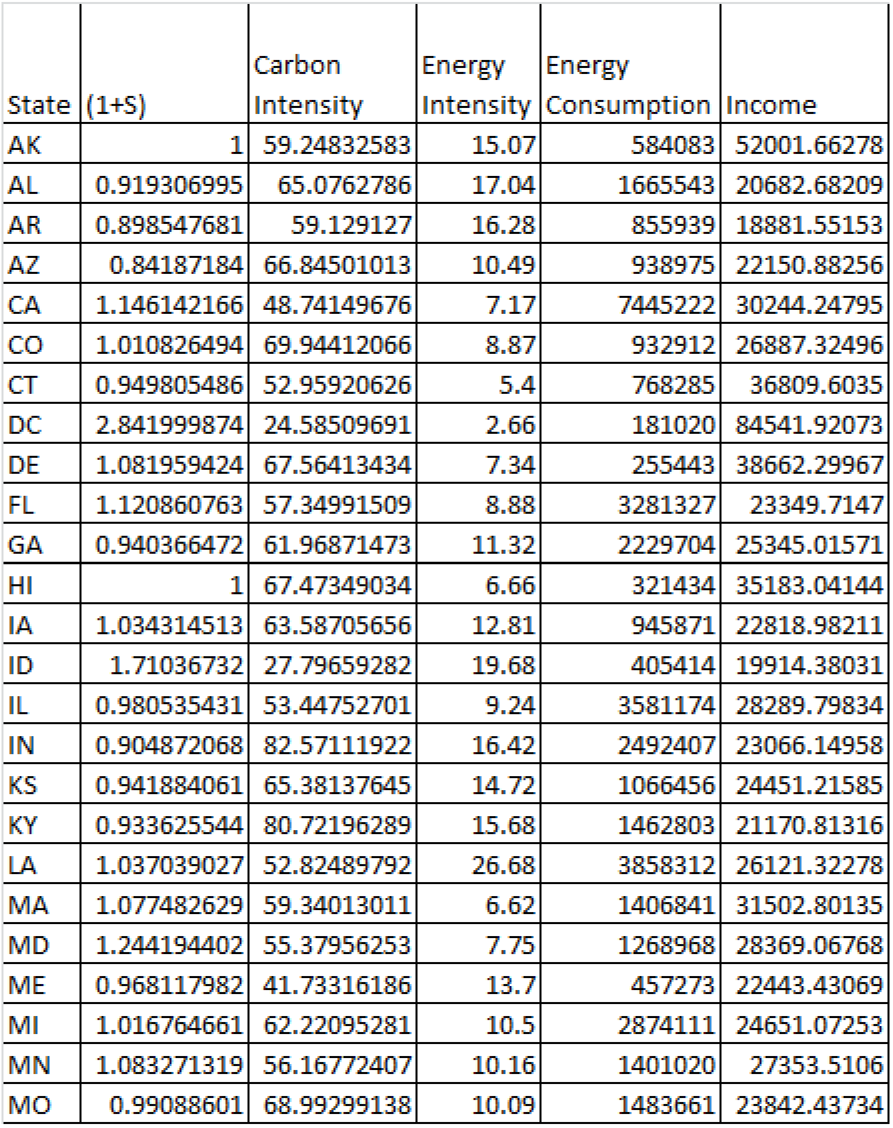
ln(Energy *Consumption*) with Panel-Corrected Standard Errors - Sensitivity Analysis

	1990-1997		1998-2010	
Variable	No DC	No DC, AK, HI	No DC	No DC, AK, HI
ln(Population Density)	.5784854***	.6914016***	.5091015***	.5930233***
	(.0147536)	(.0172631)	(.017547)	(.0160472)
ln(Income)	12.7437**	44.70199***	27.48478***	35.39844***
	(6.00091)	(11.88204)	(6.426878)	(7.969495)
ln(Income) Squared	-.5945373**	-2.180926***	-1.293334***	-1.684346***
	(.294687)	(.5820483)	(.308335)	(.3840634)
ln(Nuke/Hydro Capacity Per Capita)	.2260904***	.1904384***	.2395264***	.2048039***
	(.0071533)	(.0077279)	(.005475)	(.0061477)
ln(Fossil Fuel Endowment Per Capita)	.0870365***	.0737828***	.0630046***	.0536456***
	(.0038605)	(.0044251)	(.0089727)	(.0087119)
NERC_FRCC	.1433982	.0361877	1.093248***	.5538975***
	(.2045775)	(.0711049)	(.0750039)	(.07188)
NERC_MRO	.0550113*	.2120317***	-.020902	.0701038
	(.0310229)	(.028514)	(.0420858)	(.0428076)
NERC_NPCC	-1.299518***	-1.281854***	-1.190357***	-1.342244***
	(.0482982)	(.0496076)	(.0498908)	(.0459245)
NERC_RFC	-.1675051***	-.2013086***	.0259407	-.1360204***
	(.0299728)	(.0225324)	(.0383871)	(.0318929)
NERC_SERC	.2286685***	.1955246***	.1607617***	.1210902***
	(.0261312)	(.0214247)	(.0240154)	(.0260567)
NERC_SPP	.2270942***	.2478912***	.3200633***	.250196***
	(.0294284)	(.0260361)	(.023711)	(.0208908)
NERC_TRE	1.632817***	1.426709***	1.555905***	1.509281***
	(.0443904)	(.0445958)	(.0559173)	(.0599782)
NERC_WECC	-.0001397	.2767984***	-.0902339**	.0364547
	(.0396532)	(.0318595)	(.0359751)	(.0463183)
ln(Moving Average of Fossil Fuel Price)	.0837324	.1478859*	.2065288***	.0604832
	(.0721814)	(.0874848)	(.0634272)	(.0550738)
% Age 0-19	-.6898824***	-.8362401***	-.1242556	-.1271462
	(.0495628)	(.0548224)	(.1432792)	(.1412398)
% Age 20-39	.2118603	-1.743364*	1.596632	1.502756*
	(.5723282)	(.9174546)	(.9892126)	(.8674811)
% Age 55 and Over	-3.207324***	-1.259865**	-5.491198***	-2.045497**
	(.699214)	(.6323137)	(.8724604)	(.8043854)
HDD	.0000346***	.0000164	.0000355***	.0000176*
	(.0000122)	(.0000101)	(.0000115)	(.0000106)
CDD	-.0000112	.0000357***	-5.93e-06	.0000356**
	(.0000182)	(.0000127)	(.0000243)	(.0000152)
Intercept	-57.67026*	-218.6445***	-135.2359***	-175.8907***
	(30.48092)	(60.61621)	(33.48044)	(41.38064)
Observations	400	384	650	624
R Squared	0.9932	0.9946	0.9924	0.9937
Wald Chi Sq	2.20e+08	3.74e+11	76521.36	444288.93
Prob>Chisquare	0.0000	0.0000	0.0000	0.0000
Rho	.8102214	.8225363	.8208082	.8405715

* 10% significance, ** 5%, *** 1%

Appendix 10: Data for Selected Years

Table A10.1: 1990 Data, Part 1

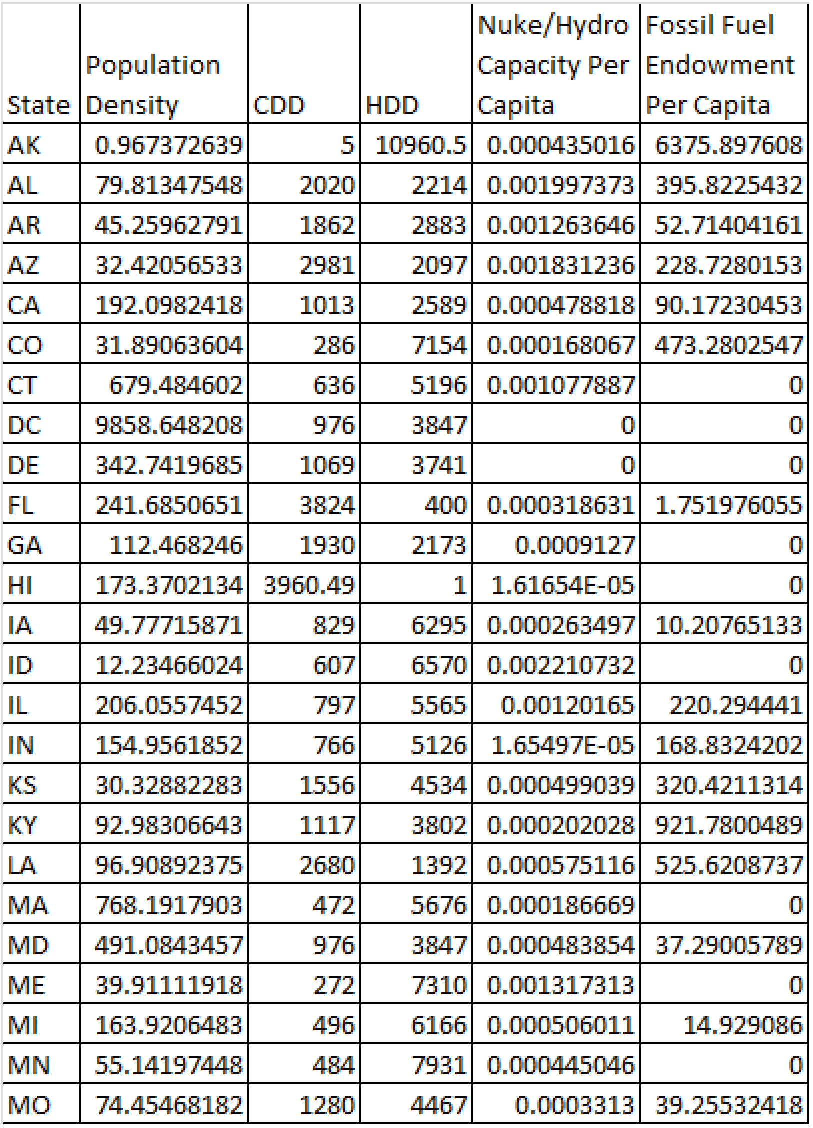


State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
AK	1	59.24832583	15.07	584083	52001.66278
AL	0.919306995	65.0762786	17.04	1665543	20682.68209
AR	0.898547681	59.129127	16.28	855939	18881.55153
AZ	0.84187184	66.84501013	10.49	938975	22150.88256
CA	1.146142166	48.74149676	7.17	7445222	30244.24795
CO	1.010826494	69.94412066	8.87	932912	26887.32496
CT	0.949805486	52.95920626	5.4	768285	36809.6035
DC	2.841999874	24.58509691	2.66	181020	84541.92073
DE	1.081959424	67.56413434	7.34	255443	38662.29967
FL	1.120860763	57.34991509	8.88	3281327	23349.7147
GA	0.940366472	61.96871473	11.32	2229704	25345.01571
HI	1	67.47349034	6.66	321434	35183.04144
IA	1.034314513	63.58705656	12.81	945871	22818.98211
ID	1.71036732	27.79659282	19.68	405414	19914.38031
IL	0.980535431	53.44752701	9.24	3581174	28289.79834
IN	0.904872068	82.57111922	16.42	2492407	23066.14958
KS	0.941884061	65.38137645	14.72	1066456	24451.21585
KY	0.933625544	80.72196289	15.68	1462803	21170.81316
LA	1.037039027	52.82489792	26.68	3858312	26121.32278
MA	1.077482629	59.34013011	6.62	1406841	31502.80135
MD	1.244194402	55.37956253	7.75	1268968	28369.06768
ME	0.968117982	41.73316186	13.7	457273	22443.43069
MI	1.016764661	62.22095281	10.5	2874111	24651.07253
MN	1.083271319	56.16772407	10.16	1401020	27353.5106
MO	0.99088601	68.99299138	10.09	1483661	23842.43734

Table A10.2: 1990 Data, Part 2

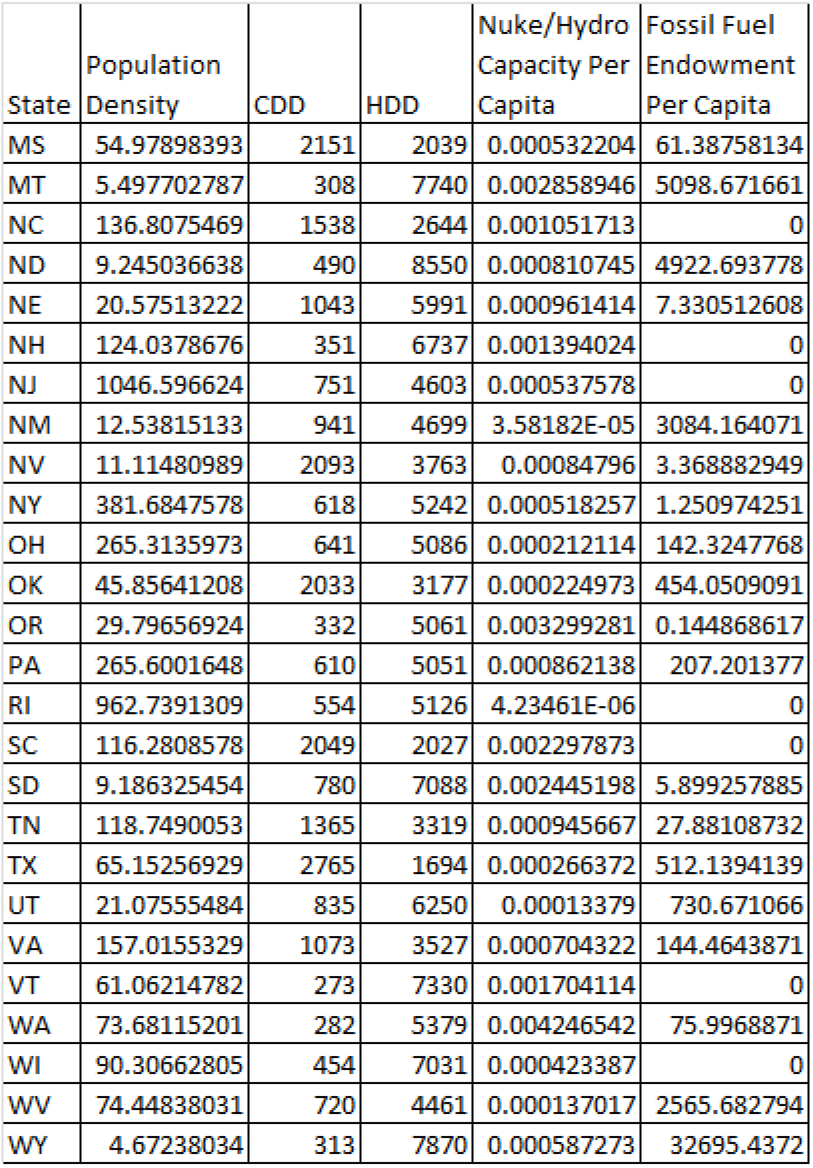
State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
MS	1.19173976	46.87871652	19.26	1029011	17391.93151
MT	0.722637118	79.56267857	17.84	347551	19188.85684
NC	1.108552859	53.60118536	10.4	2055660	24309.3654
ND	0.529154241	142.0465276	20.25	312502	20638.71661
NE	0.950314493	62.0417834	11.24	525503	24664.5929
NH	0.927951966	55.0298297	9.05	267455	24505.02704
NJ	1.213500829	47.96955577	7.29	2245820	32637.02275
NM	0.735063149	89.21902249	18.98	596449	18871.2478
NV	0.928997127	75.79125914	8.84	403074	30221.30835
NY	1.021939474	55.64296297	5.43	3735466	33067.81769
OH	1.086955635	64.9954625	11.9	3770731	24387.33885
OK	0.995780494	63.79228551	16.52	1382847	21304.13726
OR	0.993624513	31.38628253	14.77	978200	22682.69021
PA	0.876652676	72.57526887	10.34	3636089	24275.20303
RI	1.531698871	41.1746604	6.85	212706	25782.43431
SC	0.940245551	46.77691117	13.79	1262961	21519.75562
SD	1.025856768	54.30734089	13.09	217317	21081.59363
TN	1.070179865	57.29579815	13.6	1792042	22539.8264
TX	1.002294705	58.47583975	18.96	10305355	25637.46738
UT	0.727859445	101.347962	11.74	535857	21197.15369
VA	1.239020673	48.17262205	9.27	1963686	27830.98414
VT	0.997968398	43.53526975	8.5	126148	23571.25911
WA	0.995845963	34.47210129	11.59	2046537	28950.59252
WI	1.067739392	57.53131089	10.78	1484770	23577.64057
WV	0.509207544	145.0843021	18.31	704527	17488.51356
WY	0.493415246	141.7633952	22.4	399431	30137.31843

Table A10.3: 1990 Data, Part 3



State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
AK	0.967372639	5	10960.5	0.000435016	6375.897608
AL	79.81347548	2020	2214	0.001997373	395.8225432
AR	45.25962791	1862	2883	0.001263646	52.71404161
AZ	32.42056533	2981	2097	0.001831236	228.7280153
CA	192.0982418	1013	2589	0.000478818	90.17230453
CO	31.89063604	286	7154	0.000168067	473.2802547
CT	679.484602	636	5196	0.001077887	0
DC	9858.648208	976	3847	0	0
DE	342.7419685	1069	3741	0	0
FL	241.6850651	3824	400	0.000318631	1.751976055
GA	112.468246	1930	2173	0.0009127	0
HI	173.3702134	3960.49	1	1.61654E-05	0
IA	49.77715871	829	6295	0.000263497	10.20765133
ID	12.23466024	607	6570	0.002210732	0
IL	206.0557452	797	5565	0.00120165	220.294441
IN	154.9561852	766	5126	1.65497E-05	168.8324202
KS	30.32882283	1556	4534	0.000499039	320.4211314
KY	92.98306643	1117	3802	0.000202028	921.7800489
LA	96.90892375	2680	1392	0.000575116	525.6208737
MA	768.1917903	472	5676	0.000186669	0
MD	491.0843457	976	3847	0.000483854	37.29005789
ME	39.91111918	272	7310	0.001317313	0
MI	163.9206483	496	6166	0.000506011	14.929086
MN	55.14197448	484	7931	0.000445046	0
MO	74.45468182	1280	4467	0.0003313	39.25532418

Table A10.4: 1990 Data, Part 4



State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
MS	54.97898393	2151	2039	0.000532204	61.38758134
MT	5.497702787	308	7740	0.002858946	5098.671661
NC	136.8075469	1538	2644	0.001051713	0
ND	9.245036638	490	8550	0.000810745	4922.693778
NE	20.57513222	1043	5991	0.000961414	7.330512608
NH	124.0378676	351	6737	0.001394024	0
NJ	1046.596624	751	4603	0.000537578	0
NM	12.53815133	941	4699	3.58182E-05	3084.164071
NV	11.11480989	2093	3763	0.00084796	3.368882949
NY	381.6847578	618	5242	0.000518257	1.250974251
OH	265.3135973	641	5086	0.000212114	142.3247768
OK	45.85641208	2033	3177	0.000224973	454.0509091
OR	29.79656924	332	5061	0.003299281	0.144868617
PA	265.6001648	610	5051	0.000862138	207.201377
RI	962.7391309	554	5126	4.23461E-06	0
SC	116.2808578	2049	2027	0.002297873	0
SD	9.186325454	780	7088	0.002445198	5.899257885
TN	118.7490053	1365	3319	0.000945667	27.88108732
TX	65.15256929	2765	1694	0.000266372	512.1394139
UT	21.07555484	835	6250	0.00013379	730.671066
VA	157.0155329	1073	3527	0.000704322	144.4643871
VT	61.06214782	273	7330	0.001704114	0
WA	73.68115201	282	5379	0.004246542	75.9968871
WI	90.30662805	454	7031	0.000423387	0
WV	74.44838031	720	4461	0.000137017	2565.682794
WY	4.67238034	313	7870	0.000587273	32695.4372

Table A10.5: 1990 Data, Part 5

State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
AK	0	0	0	0	0	0	0	0
AL	0	0	0	0	1	0	0	0
AR	0	0	0	0	1	1	0	0
AZ	0	0	0	0	0	0	0	1
CA	0	0	0	0	0	0	0	1
CO	0	0	0	0	0	0	0	1
CT	0	0	1	0	0	0	0	0
DC	0	0	0	1	0	0	0	0
DE	0	0	0	1	0	0	0	0
FL	0	0	0	0	1	0	0	0
GA	0	0	0	0	1	0	0	0
HI	0	0	0	0	0	0	0	0
IA	0	1	0	0	0	0	0	0
ID	0	0	0	0	0	0	0	1
IL	0	0	0	1	1	0	0	0
IN	0	0	0	1	0	0	0	0
KS	0	0	0	0	0	1	0	0
KY	0	0	0	1	1	0	0	0
LA	0	0	0	0	1	1	0	0
MA	0	0	1	0	0	0	0	0
MD	0	0	0	1	0	0	0	0
ME	0	0	1	0	0	0	0	0
MI	0	1	0	1	0	0	0	0
MN	0	1	0	0	0	0	0	0
MO	0	0	0	0	1	1	0	0

Table A10.6: 1990 Data, Part 6

State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
MS	0	0	0	0	1	1	0	0
MT	0	1	0	0	0	0	0	1
NC	0	0	0	0	1	0	0	0
ND	0	1	0	0	0	0	0	0
NE	0	1	0	0	0	1	0	0
NH	0	0	1	0	0	0	0	0
NJ	0	0	0	1	0	0	0	0
NM	0	0	0	0	0	1	0	1
NV	0	0	0	0	0	0	0	1
NY	0	0	1	0	0	0	0	0
OH	0	0	0	1	0	0	0	0
OK	0	0	0	0	0	1	0	0
OR	0	0	0	0	0	0	0	1
PA	0	0	0	1	0	0	0	0
RI	0	0	1	0	0	0	0	0
SC	0	0	0	0	1	0	0	0
SD	0	1	0	0	0	0	0	1
TN	0	0	0	1	1	0	0	0
TX	0	0	0	0	1	1	1	1
UT	0	0	0	0	0	0	0	1
VA	0	0	0	1	1	0	0	0
VT	0	0	1	0	0	0	0	0
WA	0	0	0	0	0	0	0	1
WI	0	1	0	1	0	0	0	0
WV	0	0	0	1	0	0	0	0
WY	0	0	0	0	0	0	0	1

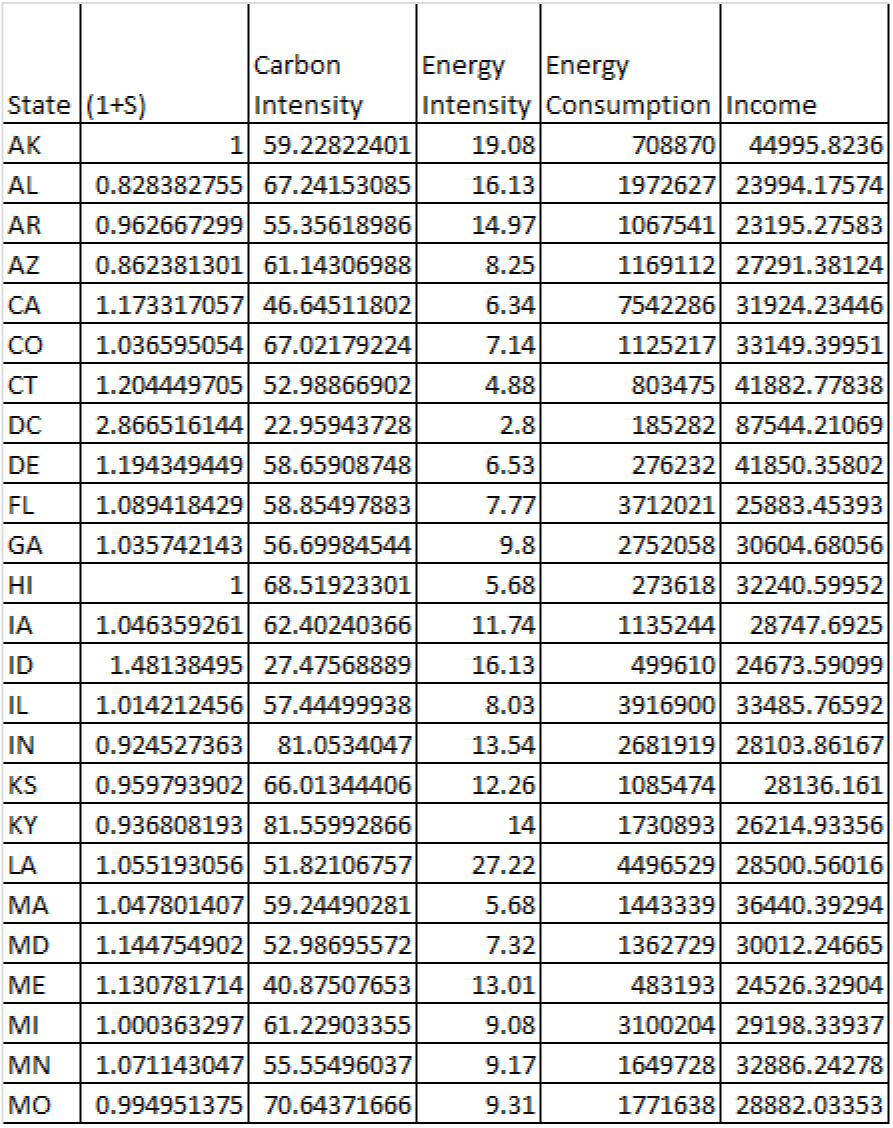
Table A10.7: 1990 Data, Part 7

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
AK	2.802	0.347895317	0.379186322	0.09355311
AL	2.802	0.292977256	0.313660926	0.219209863
AR	2.802	0.29468392	0.294421676	0.23907848
AZ	2.802	0.303500152	0.323172273	0.211021588
CA	2.802	0.29644078	0.356877439	0.178609233
CO	2.802	0.295582198	0.346670625	0.175628201
CT	2.802	0.256873474	0.334577473	0.224556018
DC	2.802	0.222039216	0.387999095	0.211942094
DE	2.802	0.278978803	0.33854267	0.209722104
FL	2.802	0.255536143	0.301203754	0.278338261
GA	2.802	0.301155514	0.343252973	0.176929743
HI	2.802	0.278955106	0.349554689	0.197222968
IA	2.802	0.289753968	0.300895931	0.243203388
ID	2.802	0.341340835	0.294230253	0.19706554
IL	2.802	0.287437629	0.329537664	0.210305557
IN	2.802	0.291966171	0.320680421	0.212634752
KS	2.802	0.29663824	0.318160001	0.222180757
KY	2.802	0.289206312	0.320408127	0.214101982
LA	2.802	0.318721024	0.323372416	0.192796359
MA	2.802	0.256722012	0.349313316	0.220903328
MD	2.802	0.273866664	0.349250485	0.190335162
ME	2.802	0.280545319	0.320629949	0.220904281
MI	2.802	0.296089523	0.325745579	0.204442464
MN	2.802	0.29676912	0.331362958	0.203088392
MO	2.802	0.286913517	0.313154334	0.229107719

Table A10.8: 1990 Data, Part 8

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
MS	2.802	0.321654568	0.307583048	0.208158759
MT	2.802	0.307347876	0.296788069	0.218476788
NC	2.802	0.278006986	0.334771255	0.208885753
ND	2.802	0.299544446	0.318252742	0.227305017
NE	2.802	0.301609069	0.309345877	0.226331829
NH	2.802	0.279996836	0.347746821	0.191797077
NJ	2.802	0.261730862	0.329533324	0.224930996
NM	2.802	0.327890066	0.317289202	0.186961659
NV	2.802	0.284697652	0.335531808	0.193402938
NY	2.802	0.267480594	0.332692573	0.22079389
OH	2.802	0.286967923	0.318479695	0.219987055
OK	2.802	0.298505633	0.307613792	0.222841536
OR	2.802	0.286838264	0.310666608	0.219285234
PA	2.802	0.265362653	0.311259173	0.250798707
RI	2.802	0.259108644	0.33645197	0.237677126
SC	2.802	0.297688049	0.330720862	0.197301176
SD	2.802	1.31489985	0.299374122	0.232449817
TN	2.802	0.281535857	0.321355107	0.215321835
TX	2.802	0.319900063	0.33902193	0.176100261
UT	2.802	0.39825372	0.312081113	0.149389767
VA	2.802	0.276315756	0.351483315	0.187888981
VT	2.802	0.287844504	0.333823774	0.197348433
WA	2.802	0.293191799	0.332321785	0.194755583
WI	2.802	0.295643525	0.320166001	0.217031409
WV	2.802	0.27711336	0.29300359	0.24889208
WY	2.802	0.330020499	0.312539399	0.182307302

Table A10.9: 1997 Data, Part 1

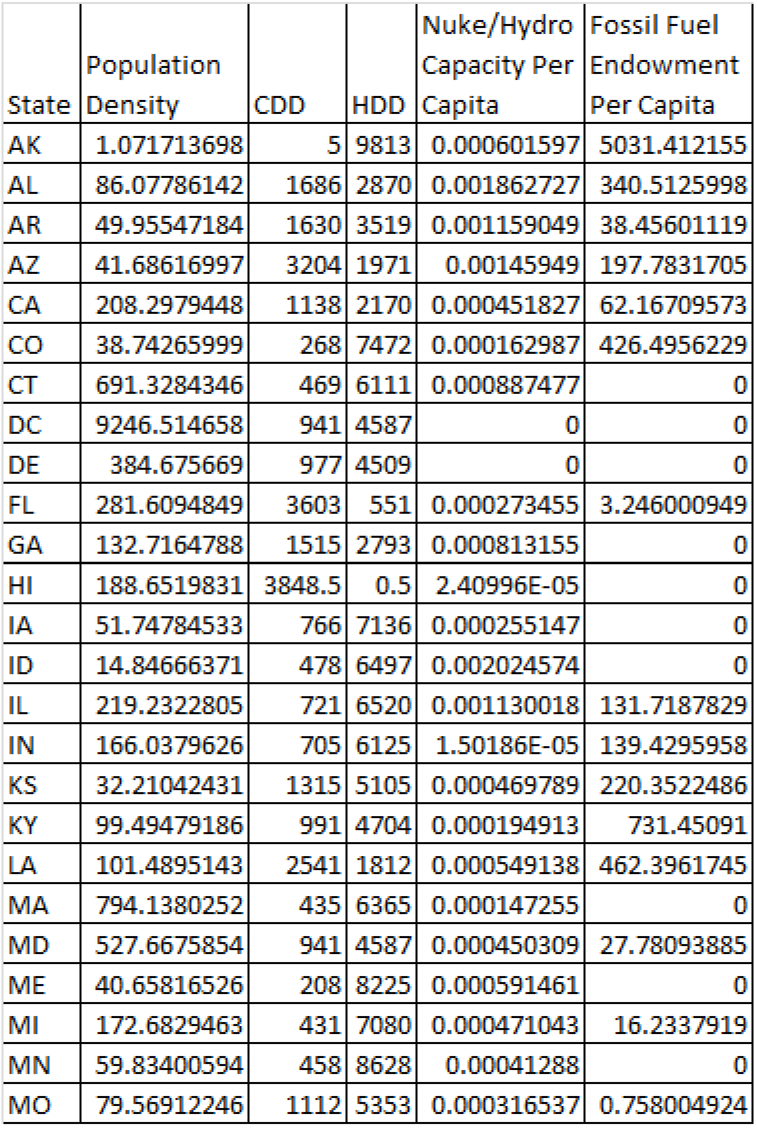


State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
AK	1	59.22822401	19.08	708870	44995.8236
AL	0.828382755	67.24153085	16.13	1972627	23994.17574
AR	0.962667299	55.35618986	14.97	1067541	23195.27583
AZ	0.862381301	61.14306988	8.25	1169112	27291.38124
CA	1.173317057	46.64511802	6.34	7542286	31924.23446
CO	1.036595054	67.02179224	7.14	1125217	33149.39951
CT	1.204449705	52.98866902	4.88	803475	41882.77838
DC	2.866516144	22.95943728	2.8	185282	87544.21069
DE	1.194349449	58.65908748	6.53	276232	41850.35802
FL	1.089418429	58.85497883	7.77	3712021	25883.45393
GA	1.035742143	56.69984544	9.8	2752058	30604.68056
HI	1	68.51923301	5.68	273618	32240.59952
IA	1.046359261	62.40240366	11.74	1135244	28747.6925
ID	1.48138495	27.47568889	16.13	499610	24673.59099
IL	1.014212456	57.44499938	8.03	3916900	33485.76592
IN	0.924527363	81.0534047	13.54	2681919	28103.86167
KS	0.959793902	66.01344406	12.26	1085474	28136.161
KY	0.936808193	81.55992866	14	1730893	26214.93356
LA	1.055193056	51.82106757	27.22	4496529	28500.56016
MA	1.047801407	59.24490281	5.68	1443339	36440.39294
MD	1.144754902	52.98695572	7.32	1362729	30012.24665
ME	1.130781714	40.87507653	13.01	483193	24526.32904
MI	1.000363297	61.22903355	9.08	3100204	29198.33937
MN	1.071143047	55.55496037	9.17	1649728	32886.24278
MO	0.994951375	70.64371666	9.31	1771638	28882.03353

Table A10.10: 1997 Data, Part 2

State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
MS	1.157240212	47.69049101	16.17	1153289	21561.00603
MT	0.685473648	80.96289457	15.22	365513	21275.13724
NC	1.031162574	58.5387657	8.97	2421875	28896.96447
ND	0.549693759	131.5643107	18.56	359013	25397.25049
NE	0.929345145	62.90819227	10.75	647948	29831.27552
NH	0.857908578	59.42374421	6.97	279327	31052.81964
NJ	1.193544832	48.82422249	7.02	2500782	35609.9084
NM	0.776256082	86.96944614	12.05	642020	27429.53023
NV	0.982655868	68.31326123	7.55	555280	33709.46384
NY	1.010560683	51.20822755	5.19	3986803	35627.11983
OH	1.08125513	63.02714018	10.35	4113137	29481.73052
OK	0.96218484	68.97918747	14.17	1434820	24046.2484
OR	0.999074319	32.76404015	10.71	1096799	30373.36085
PA	0.877217801	71.18043143	9.3	3876466	28023.16097
RI	0.936284865	62.15645445	6.29	216304	28006.94005
SC	0.967567142	46.22904082	12.8	1501627	24992.901
SD	0.905296703	54.32140866	10.87	242770	26557.89998
TN	0.998687627	59.04789732	11.12	2028301	27765.1447
TX	1.010120157	56.99732714	16.28	12287692	30748.34107
UT	0.806552984	89.58050515	9.91	680756	26046.04997
VA	1.190110614	49.56942807	8.56	2205538	30803.24542
VT	0.998863831	44.80567977	8.37	144867	25987.92108
WA	0.970183851	37.03861522	9.5	2123532	31655.8606
WI	1.105898648	58.28532593	9.83	1769135	28680.00212
WV	0.46623743	154.271598	14.99	709545	21202.64107
WY	0.492746551	140.8580328	19.79	415039	32861.30787

Table A10.11: 1997 Data, Part 3

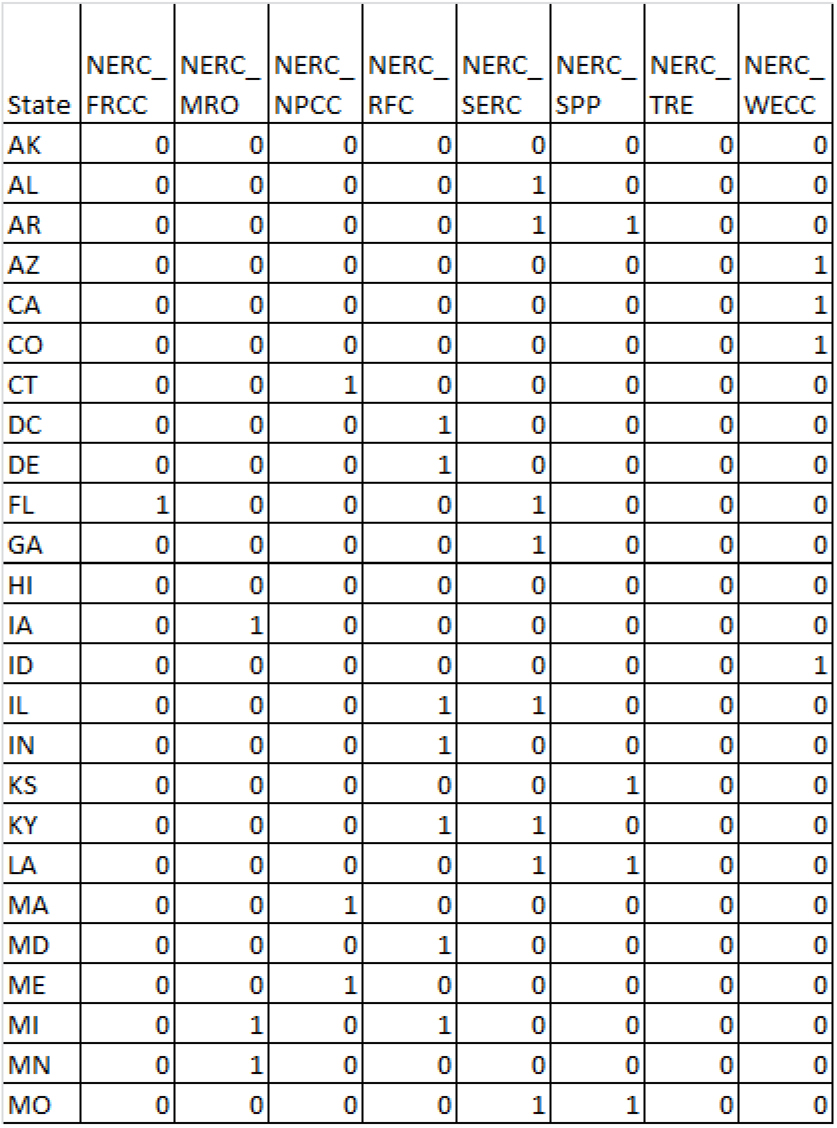


State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
AK	1.071713698	5	9813	0.000601597	5031.412155
AL	86.07786142	1686	2870	0.001862727	340.5125998
AR	49.95547184	1630	3519	0.001159049	38.45601119
AZ	41.68616997	3204	1971	0.00145949	197.7831705
CA	208.2979448	1138	2170	0.000451827	62.16709573
CO	38.74265999	268	7472	0.000162987	426.4956229
CT	691.3284346	469	6111	0.000887477	0
DC	9246.514658	941	4587	0	0
DE	384.675669	977	4509	0	0
FL	281.6094849	3603	551	0.000273455	3.246000949
GA	132.7164788	1515	2793	0.000813155	0
HI	188.6519831	3848.5	0.5	2.40996E-05	0
IA	51.74784533	766	7136	0.000255147	0
ID	14.84666371	478	6497	0.002024574	0
IL	219.2322805	721	6520	0.001130018	131.7187829
IN	166.0379626	705	6125	1.50186E-05	139.4295958
KS	32.21042431	1315	5105	0.000469789	220.3522486
KY	99.49479186	991	4704	0.000194913	731.45091
LA	101.4895143	2541	1812	0.000549138	462.3961745
MA	794.1380252	435	6365	0.000147255	0
MD	527.6675854	941	4587	0.000450309	27.78093885
ME	40.65816526	208	8225	0.000591461	0
MI	172.6829463	431	7080	0.000471043	16.2337919
MN	59.83400594	458	8628	0.00041288	0
MO	79.56912246	1112	5353	0.000316537	0.758004924

Table A10.12: 1997 Data, Part 4

State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
MS	59.20238702	1946	2614	0.000494238	39.68280678
MT	6.113707617	243	7972	0.002809168	2881.433314
NC	157.1892152	1210	3525	0.000920451	0
ND	9.419459803	499	9370	0.000795732	4157.846271
NE	21.93788383	972	6512	0.000901692	5.603566686
NH	132.6284274	260	7685	0.001334376	0
NJ	1108.053291	670	5360	0.00050611	0
NM	14.62511844	989	4841	3.27635E-05	2453.910779
NV	16.06271885	2195	3380	0.00059526	1.164305349
NY	395.1503576	549	6065	0.000533287	0.73558533
OH	275.4042284	569	6084	0.000204577	65.53485005
OK	49.11986912	1729	3691	0.000224198	357.6012109
OR	34.42104679	291	4818	0.00250094	0.127093318
PA	272.8411185	554	5924	0.000840822	164.1429917
RI	981.2647737	452	5896	4.31071E-06	0
SC	128.1887725	1568	2740	0.002087128	0
SD	9.807294335	700	7907	0.002325419	2.759865958
TN	133.4210881	1141	4084	0.00111255	22.14862375
TX	75.40310986	2546	2157	0.000292535	383.8756048
UT	25.805817	722	6218	0.000130617	531.064067
VA	172.4799446	876	4538	0.000642613	83.03808368
VT	64.56944979	190	8457	0.00164358	0
WA	85.27803984	249	5106	0.003852607	63.27636423
WI	96.96562886	387	7791	0.000396672	0
WV	75.55168199	594	5508	0.000134687	2106.698452
WY	5.040669245	286	8216	0.000599733	30149.24039

Table A10.13: 1997 Data, Part 5



State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
AK	0	0	0	0	0	0	0	0
AL	0	0	0	0	1	0	0	0
AR	0	0	0	0	1	1	0	0
AZ	0	0	0	0	0	0	0	1
CA	0	0	0	0	0	0	0	1
CO	0	0	0	0	0	0	0	1
CT	0	0	1	0	0	0	0	0
DC	0	0	0	1	0	0	0	0
DE	0	0	0	1	0	0	0	0
FL	1	0	0	0	1	0	0	0
GA	0	0	0	0	1	0	0	0
HI	0	0	0	0	0	0	0	0
IA	0	1	0	0	0	0	0	0
ID	0	0	0	0	0	0	0	1
IL	0	0	0	1	1	0	0	0
IN	0	0	0	1	0	0	0	0
KS	0	0	0	0	0	1	0	0
KY	0	0	0	1	1	0	0	0
LA	0	0	0	0	1	1	0	0
MA	0	0	1	0	0	0	0	0
MD	0	0	0	1	0	0	0	0
ME	0	0	1	0	0	0	0	0
MI	0	1	0	1	0	0	0	0
MN	0	1	0	0	0	0	0	0
MO	0	0	0	0	1	1	0	0

Table A10.14: 1997 Data, Part 6

State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
MS	0	0	0	0	1	1	0	0
MT	0	1	0	0	0	0	0	1
NC	0	0	0	0	1	0	0	0
ND	0	1	0	0	0	0	0	0
NE	0	1	0	0	0	1	0	0
NH	0	0	1	0	0	0	0	0
NJ	0	0	0	1	0	0	0	0
NM	0	0	0	0	0	1	0	1
NV	0	0	0	0	0	0	0	1
NY	0	0	1	0	0	0	0	0
OH	0	0	0	1	0	0	0	0
OK	0	0	0	0	0	1	0	0
OR	0	0	0	0	0	0	0	1
PA	0	0	0	1	0	0	0	0
RI	0	0	1	0	0	0	0	0
SC	0	0	0	0	1	0	0	0
SD	0	1	0	0	0	0	0	1
TN	0	0	0	1	1	0	0	0
TX	0	0	0	0	1	1	1	1
UT	0	0	0	0	0	0	0	1
VA	0	0	0	1	1	0	0	0
VT	0	0	1	0	0	0	0	0
WA	0	0	0	0	0	0	0	1
WI	0	1	0	1	0	0	0	0
WV	0	0	0	1	0	0	0	0
WY	0	0	0	0	0	0	0	1

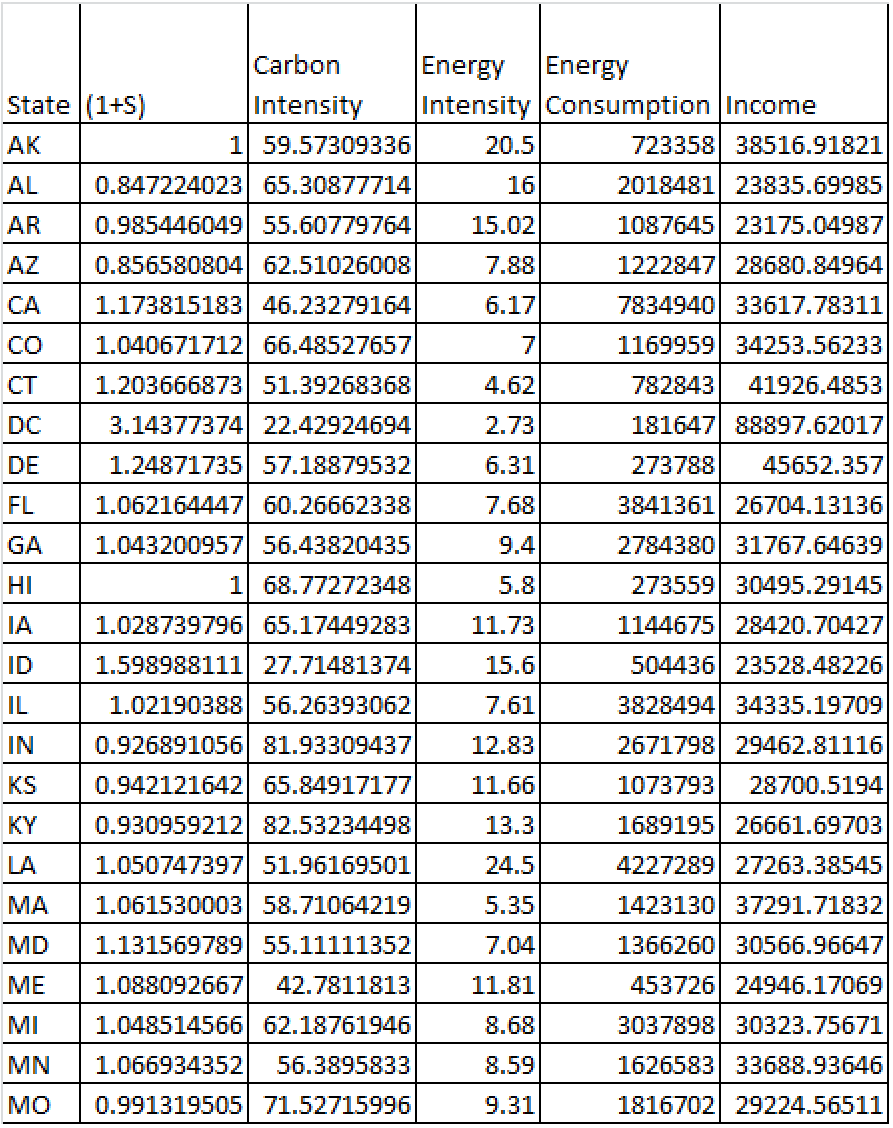
Table A10.15: 1997 Data, Part 7

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
AK	2.038	0.342750356	0.295008875	0.121423957
AL	2.038	0.277937057	0.291497012	0.217123423
AR	2.038	0.28278068	0.268365954	0.228241237
AZ	2.038	0.289616613	0.279758454	0.204974467
CA	2.038	0.301713199	0.316377973	0.178944044
CO	2.038	0.281490175	0.284886144	0.177791913
CT	2.038	0.258711248	0.287938727	0.220303175
DC	2.038	0.206780969	0.321897854	0.210404131
DE	2.038	0.263344542	0.308063879	0.20584255
FL	2.038	0.251903426	0.261995677	0.264914426
GA	2.038	0.287213606	0.312719849	0.17119337
HI	2.038	0.277121092	0.284299792	0.208449705
IA	2.038	0.280374485	0.270045612	0.23634482
ID	2.038	0.321227168	0.271797773	0.193012731
IL	2.038	0.288411144	0.294138095	0.202983493
IN	2.038	0.282864563	0.29166249	0.20743436
KS	2.038	0.29314778	0.284000027	0.214091645
KY	2.038	0.278947274	0.290749952	0.212419616
LA	2.038	0.306582726	0.285286077	0.195099332
MA	2.038	0.255703047	0.306558982	0.215305094
MD	2.038	0.272632456	0.310127066	0.191002007
ME	2.038	0.262694318	0.286480275	0.222162716
MI	2.038	0.288477244	0.29459384	0.20503747
MN	2.038	0.291511088	0.289587878	0.198893435
MO	2.038	0.284499196	0.282994231	0.22033415

Table A10.16: 1997 Data, Part 8

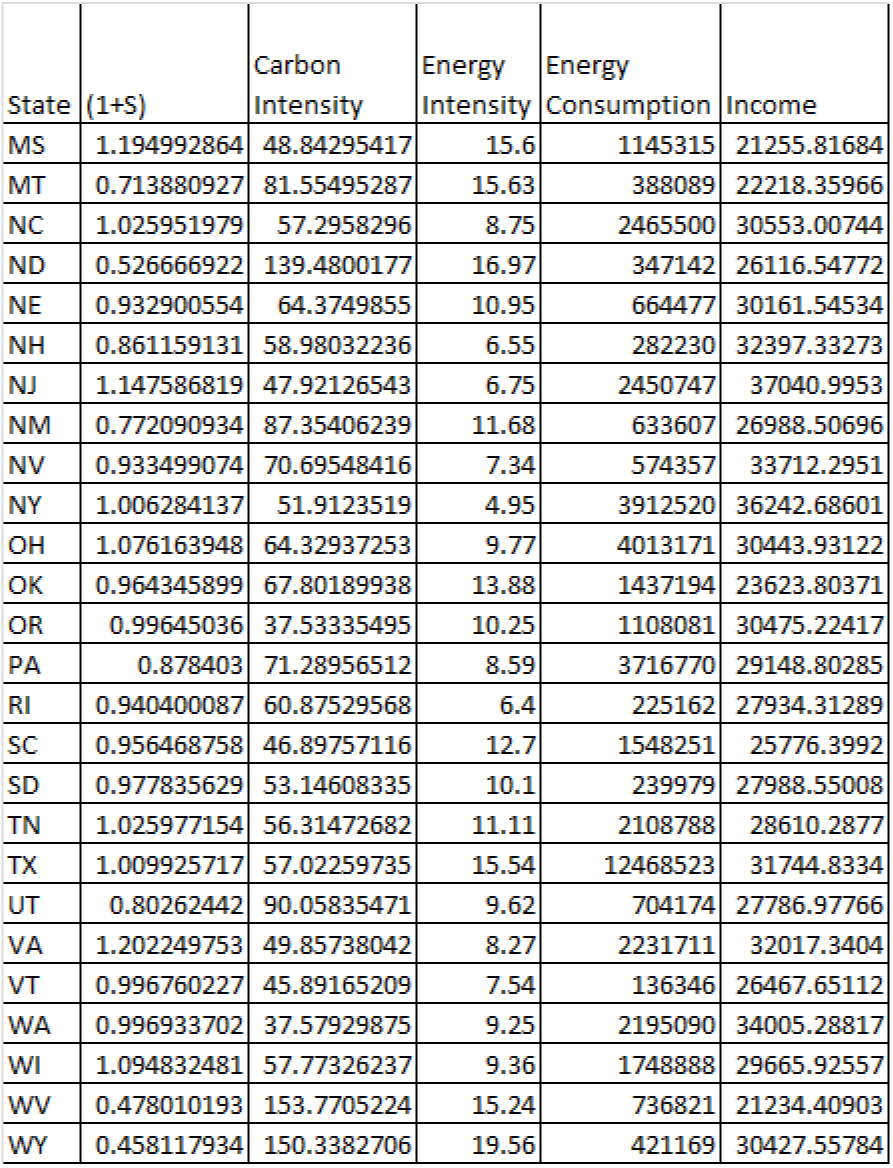
State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
MS	2.038	0.3064324	0.286302072	0.202595315
MT	2.038	0.287897602	0.253297972	0.222972024
NC	2.038	0.271418898	0.294567265	0.204828503
ND	2.038	0.28602651	0.277916813	0.225453891
NE	2.038	0.293773548	0.27497216	0.215873526
NH	2.038	0.273455661	0.308579356	0.190630767
NJ	2.038	0.266071917	0.287548511	0.217190984
NM	2.038	0.313592388	0.270807099	0.188355113
NV	2.038	0.274701492	0.282423825	0.192859945
NY	2.038	0.26687791	0.291962725	0.212910257
OH	2.038	0.28127344	0.288972053	0.217778421
OK	2.038	0.290716908	0.272981517	0.221384635
OR	2.038	0.274563222	0.271988706	0.213175519
PA	2.038	0.260328461	0.274973188	0.241738303
RI	2.038	0.255468117	0.29034001	0.223884847
SC	2.038	0.277253183	0.297027538	0.202992412
SD	2.038	1.285978799	0.265570938	0.221195797
TN	2.038	0.269188449	0.290621801	0.210001649
TX	2.038	0.312120621	0.297657023	0.174546133
UT	2.038	0.369079114	0.295022983	0.147000355
VA	2.038	0.266604512	0.316776546	0.190588684
VT	2.038	0.267040498	0.291256934	0.199544906
WA	2.038	0.284442813	0.295253163	0.190031556
WI	2.038	0.285342427	0.285995078	0.21162171
WV	2.038	0.259206547	0.269619314	0.250660074
WY	2.038	0.303153942	0.259390623	0.196775571

Table A10.17: 1998 Data, Part 1



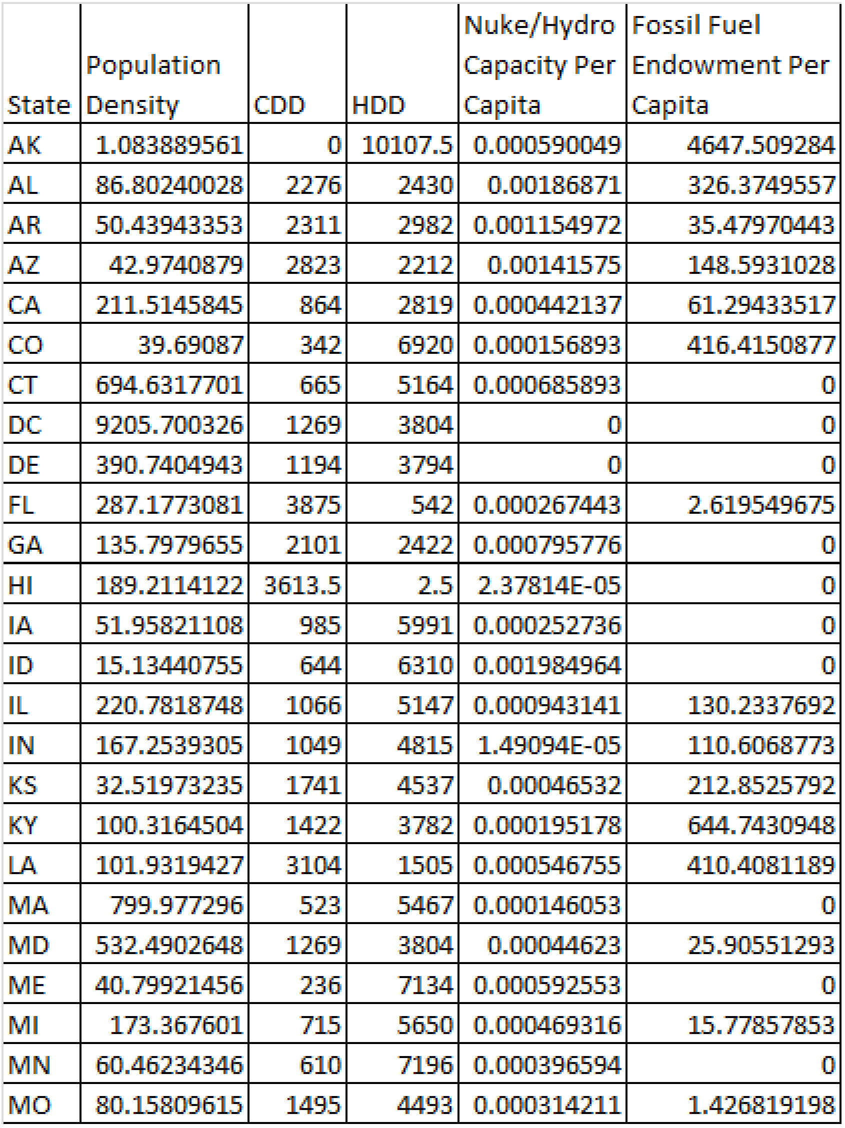
State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
AK	1	59.57309336	20.5	723358	38516.91821
AL	0.847224023	65.30877714	16	2018481	23835.69985
AR	0.985446049	55.60779764	15.02	1087645	23175.04987
AZ	0.856580804	62.51026008	7.88	1222847	28680.84964
CA	1.173815183	46.23279164	6.17	7834940	33617.78311
CO	1.040671712	66.48527657	7	1169959	34253.56233
CT	1.203666873	51.39268368	4.62	782843	41926.4853
DC	3.14377374	22.42924694	2.73	181647	88897.62017
DE	1.24871735	57.18879532	6.31	273788	45652.357
FL	1.062164447	60.26662338	7.68	3841361	26704.13136
GA	1.043200957	56.43820435	9.4	2784380	31767.64639
HI	1	68.77272348	5.8	273559	30495.29145
IA	1.028739796	65.17449283	11.73	1144675	28420.70427
ID	1.598988111	27.71481374	15.6	504436	23528.48226
IL	1.02190388	56.26393062	7.61	3828494	34335.19709
IN	0.926891056	81.93309437	12.83	2671798	29462.81116
KS	0.942121642	65.84917177	11.66	1073793	28700.5194
KY	0.930959212	82.53234498	13.3	1689195	26661.69703
LA	1.050747397	51.96169501	24.5	4227289	27263.38545
MA	1.061530003	58.71064219	5.35	1423130	37291.71832
MD	1.131569789	55.11111352	7.04	1366260	30566.96647
ME	1.088092667	42.7811813	11.81	453726	24946.17069
MI	1.048514566	62.18761946	8.68	3037898	30323.75671
MN	1.066934352	56.3895833	8.59	1626583	33688.93646
MO	0.991319505	71.52715996	9.31	1816702	29224.56511

Table A10.18: 1998 Data, Part 2



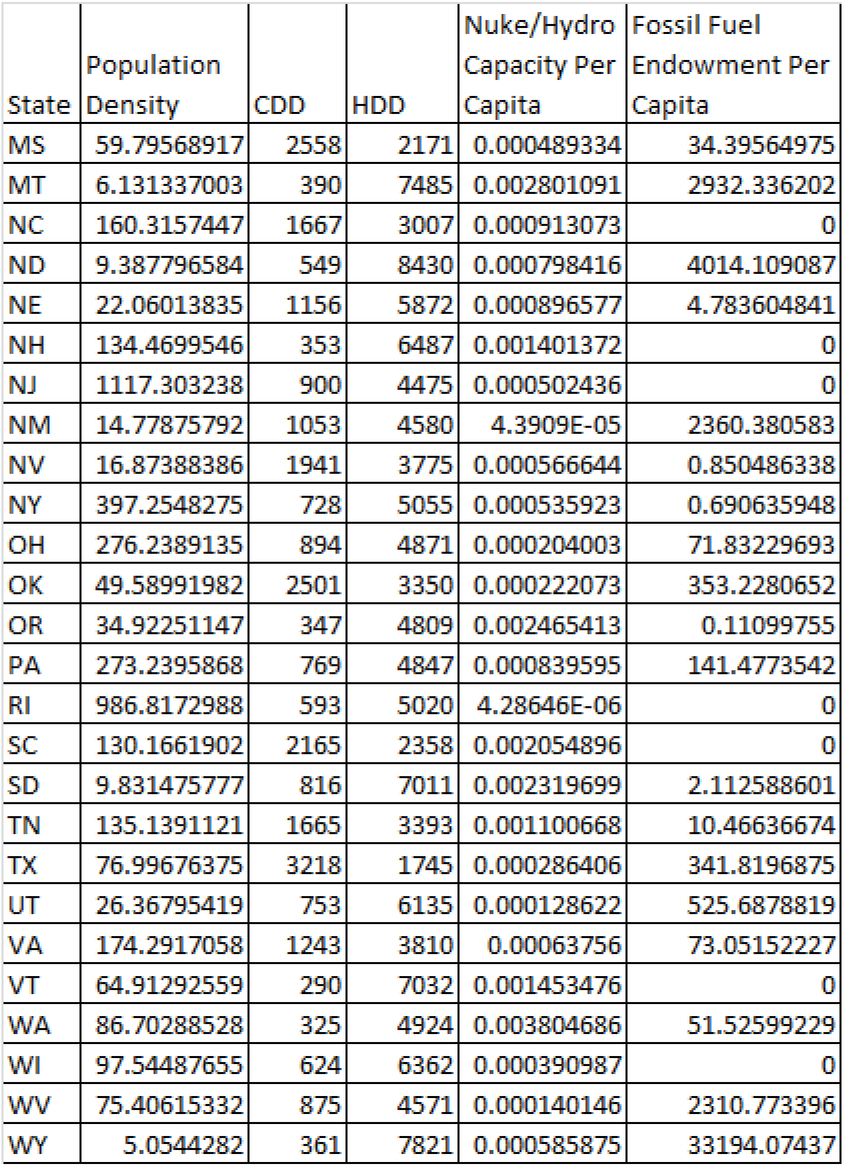
State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
MS	1.194992864	48.84295417	15.6	1145315	21255.81684
MT	0.713880927	81.55495287	15.63	388089	22218.35966
NC	1.025951979	57.2958296	8.75	2465500	30553.00744
ND	0.526666922	139.4800177	16.97	347142	26116.54772
NE	0.932900554	64.3749855	10.95	664477	30161.54534
NH	0.861159131	58.98032236	6.55	282230	32397.33273
NJ	1.147586819	47.92126543	6.75	2450747	37040.9953
NM	0.772090934	87.35406239	11.68	633607	26988.50696
NV	0.933499074	70.69548416	7.34	574357	33712.2951
NY	1.006284137	51.9123519	4.95	3912520	36242.68601
OH	1.076163948	64.32937253	9.77	4013171	30443.93122
OK	0.964345899	67.80189938	13.88	1437194	23623.80371
OR	0.99645036	37.53335495	10.25	1108081	30475.22417
PA	0.878403	71.28956512	8.59	3716770	29148.80285
RI	0.940400087	60.87529568	6.4	225162	27934.31289
SC	0.956468758	46.89757116	12.7	1548251	25776.3992
SD	0.977835629	53.14608335	10.1	239979	27988.55008
TN	1.025977154	56.31472682	11.11	2108788	28610.2877
TX	1.009925717	57.02259735	15.54	12468523	31744.8334
UT	0.80262442	90.05835471	9.62	704174	27786.97766
VA	1.202249753	49.85738042	8.27	2231711	32017.3404
VT	0.996760227	45.89165209	7.54	136346	26467.65112
WA	0.996933702	37.57929875	9.25	2195090	34005.28817
WI	1.094832481	57.77326237	9.36	1748888	29665.92557
WV	0.478010193	153.7705224	15.24	736821	21234.40903
WY	0.458117934	150.3382706	19.56	421169	30427.55784

Table A10.19: 1998 Data, Part 3



State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
AK	1.083889561	0	10107.5	0.000590049	4647.509284
AL	86.80240028	2276	2430	0.00186871	326.3749557
AR	50.43943353	2311	2982	0.001154972	35.47970443
AZ	42.9740879	2823	2212	0.00141575	148.5931028
CA	211.5145845	864	2819	0.000442137	61.29433517
CO	39.69087	342	6920	0.000156893	416.4150877
CT	694.6317701	665	5164	0.000685893	0
DC	9205.700326	1269	3804	0	0
DE	390.7404943	1194	3794	0	0
FL	287.1773081	3875	542	0.000267443	2.619549675
GA	135.7979655	2101	2422	0.000795776	0
HI	189.2114122	3613.5	2.5	2.37814E-05	0
IA	51.95821108	985	5991	0.000252736	0
ID	15.13440755	644	6310	0.001984964	0
IL	220.7818748	1066	5147	0.000943141	130.2337692
IN	167.2539305	1049	4815	1.49094E-05	110.6068773
KS	32.51973235	1741	4537	0.00046532	212.8525792
KY	100.3164504	1422	3782	0.000195178	644.7430948
LA	101.9319427	3104	1505	0.000546755	410.4081189
MA	799.977296	523	5467	0.000146053	0
MD	532.4902648	1269	3804	0.00044623	25.90551293
ME	40.79921456	236	7134	0.000592553	0
MI	173.367601	715	5650	0.000469316	15.77857853
MN	60.46234346	610	7196	0.000396594	0
MO	80.15809615	1495	4493	0.000314211	1.426819198

Table A10.20: 1998 Data, Part 4



State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
MS	59.79568917	2558	2171	0.000489334	34.39564975
MT	6.131337003	390	7485	0.002801091	2932.336202
NC	160.3157447	1667	3007	0.000913073	0
ND	9.387796584	549	8430	0.000798416	4014.109087
NE	22.06013835	1156	5872	0.000896577	4.783604841
NH	134.4699546	353	6487	0.001401372	0
NJ	1117.303238	900	4475	0.000502436	0
NM	14.77875792	1053	4580	4.3909E-05	2360.380583
NV	16.87388386	1941	3775	0.000566644	0.850486338
NY	397.2548275	728	5055	0.000535923	0.690635948
OH	276.2389135	894	4871	0.000204003	71.83229693
OK	49.58991982	2501	3350	0.000222073	353.2280652
OR	34.92251147	347	4809	0.002465413	0.11099755
PA	273.2395868	769	4847	0.000839595	141.4773542
RI	986.8172988	593	5020	4.28646E-06	0
SC	130.1661902	2165	2358	0.002054896	0
SD	9.831475777	816	7011	0.002319699	2.112588601
TN	135.1391121	1665	3393	0.001100668	10.46636674
TX	76.99676375	3218	1745	0.000286406	341.8196875
UT	26.36795419	753	6135	0.000128622	525.6878819
VA	174.2917058	1243	3810	0.00063756	73.05152227
VT	64.91292559	290	7032	0.001453476	0
WA	86.70288528	325	4924	0.003804686	51.52599229
WI	97.54487655	624	6362	0.000390987	0
WV	75.40615332	875	4571	0.000140146	2310.773396
WY	5.0544282	361	7821	0.000585875	33194.07437

Table A10.21: 1998 Data, Part 5

State	NERC_FRCC	NERC_MRO	NERC_NPCC	NERC_RFC	NERC_SERC	NERC_SPP	NERC_TRE	NERC_WECC
AK	0	0	0	0	0	0	0	0
AL	0	0	0	0	1	0	0	0
AR	0	0	0	0	1	1	0	0
AZ	0	0	0	0	0	0	0	1
CA	0	0	0	0	0	0	0	1
CO	0	0	0	0	0	0	0	1
CT	0	0	1	0	0	0	0	0
DC	0	0	0	1	0	0	0	0
DE	0	0	0	1	0	0	0	0
FL	1	0	0	0	1	0	0	0
GA	0	0	0	0	1	0	0	0
HI	0	0	0	0	0	0	0	0
IA	0	1	0	0	0	0	0	0
ID	0	0	0	0	0	0	0	1
IL	0	0	0	1	1	0	0	0
IN	0	0	0	1	0	0	0	0
KS	0	0	0	0	0	1	0	0
KY	0	0	0	1	1	0	0	0
LA	0	0	0	0	1	1	0	0
MA	0	0	1	0	0	0	0	0
MD	0	0	0	1	0	0	0	0
ME	0	0	1	0	0	0	0	0
MI	0	1	0	1	0	0	0	0
MN	0	1	0	0	0	0	0	0
MO	0	0	0	0	1	1	0	0

Table A10.22: 1998 Data, Part 6

State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
MS	0	0	0	0	1	1	0	0
MT	0	1	0	0	0	0	0	1
NC	0	0	0	0	1	0	0	0
ND	0	1	0	0	0	0	0	0
NE	0	1	0	0	0	1	0	0
NH	0	0	1	0	0	0	0	0
NJ	0	0	0	1	0	0	0	0
NM	0	0	0	0	0	1	0	1
NV	0	0	0	0	0	0	0	1
NY	0	0	1	0	0	0	0	0
OH	0	0	0	1	0	0	0	0
OK	0	0	0	0	0	1	0	0
OR	0	0	0	0	0	0	0	1
PA	0	0	0	1	0	0	0	0
RI	0	0	1	0	0	0	0	0
SC	0	0	0	0	1	0	0	0
SD	0	1	0	0	0	0	0	1
TN	0	0	0	1	1	0	0	0
TX	0	0	0	0	1	1	1	1
UT	0	0	0	0	0	0	0	1
VA	0	0	0	1	1	0	0	0
VT	0	0	1	0	0	0	0	0
WA	0	0	0	0	0	0	0	1
WI	0	1	0	1	0	0	0	0
WV	0	0	0	1	0	0	0	0
WY	0	0	0	0	0	0	0	1

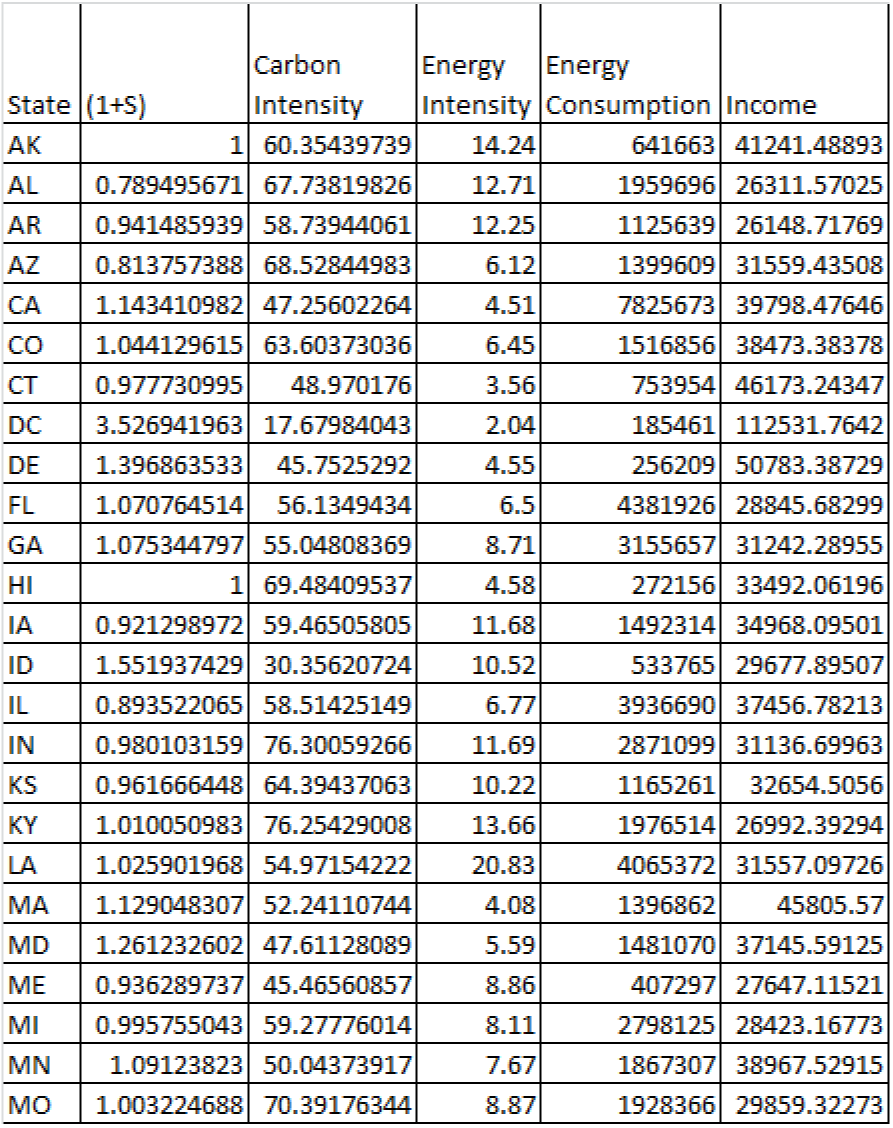
Table A10.23: 1998 Data, Part 7

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
AK	2.032	0.347402618	0.283805321	0.126476775
AL	2.032	0.274284679	0.288515611	0.218745608
AR	2.032	0.28093519	0.264285081	0.228862094
AZ	2.032	0.292157707	0.270609554	0.205278066
CA	2.032	0.298797809	0.312294971	0.180726074
CO	2.032	0.282653641	0.275193914	0.179912788
CT	2.032	0.263273203	0.278003906	0.22168736
DC	2.032	0.19571148	0.315634344	0.213196398
DE	2.032	0.262567549	0.300723798	0.207603477
FL	2.032	0.251099615	0.255668222	0.264978166
GA	2.032	0.286526062	0.307431797	0.172228372
HI	2.032	0.272318971	0.278554812	0.21336649
IA	2.032	0.279924847	0.265134667	0.236936041
ID	2.032	0.317427515	0.268974631	0.1956545
IL	2.032	0.287246003	0.288700959	0.204290764
IN	2.032	0.282967654	0.286333616	0.208853653
KS	2.032	0.293666687	0.278959091	0.214173656
KY	2.032	0.275290499	0.287094362	0.214302741
LA	2.032	0.304040633	0.280296301	0.197105675
MA	2.032	0.256229673	0.29879391	0.216631552
MD	2.032	0.273545556	0.30287019	0.193302903
ME	2.032	0.2598745	0.281335401	0.224475371
MI	2.032	0.288211182	0.289021909	0.207392062
MN	2.032	0.291783666	0.282546352	0.20034167
MO	2.032	0.28305569	0.27829109	0.221413081

Table A10.24: 1998 Data, Part 8

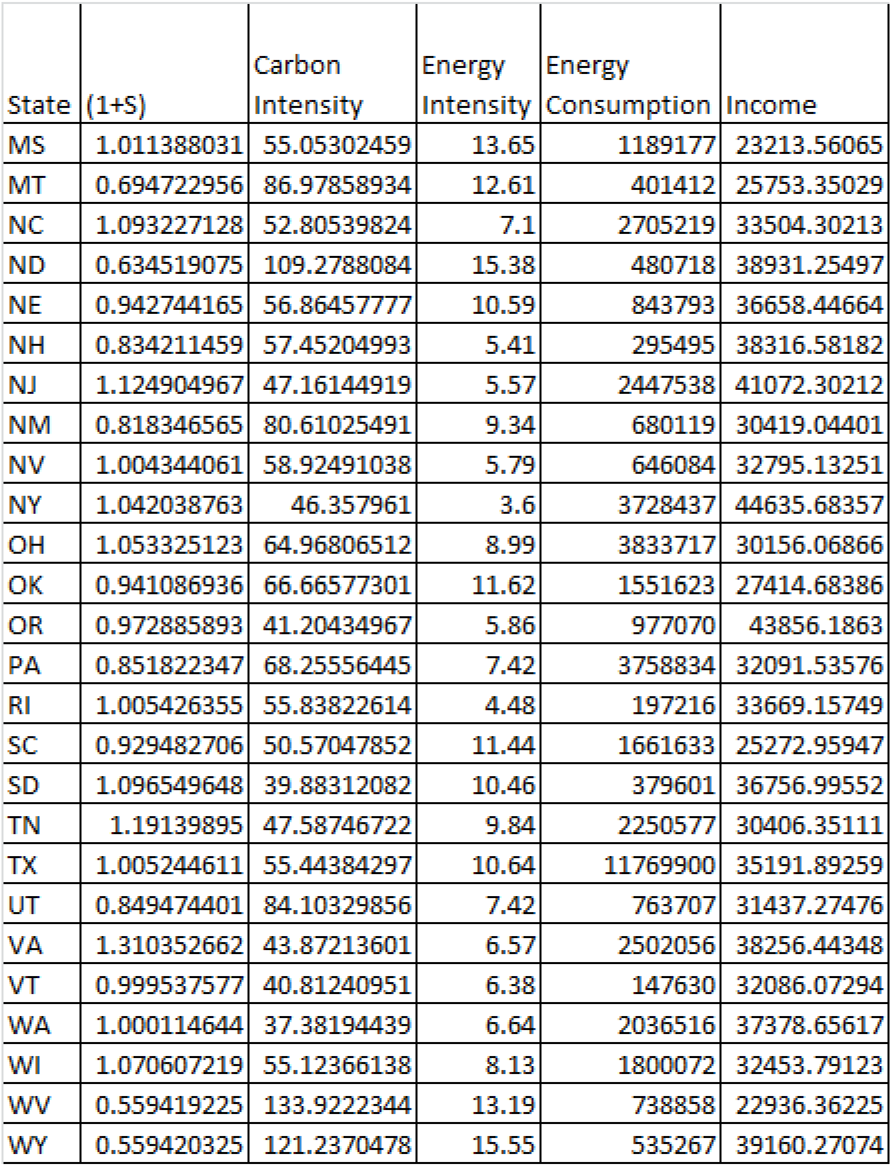
State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
MS	2.032	0.303181222	0.282942948	0.203198835
MT	2.032	0.285921265	0.247062238	0.226574379
NC	2.032	0.271217337	0.288100031	0.205743771
ND	2.032	0.284393667	0.271592755	0.22743432
NE	2.032	0.29331661	0.269439019	0.216479264
NH	2.032	0.274034363	0.300742989	0.192492993
NJ	2.032	0.265170165	0.281186855	0.218780445
NM	2.032	0.309891808	0.264432802	0.191056625
NV	2.032	0.276490659	0.271783642	0.193443633
NY	2.032	0.263775208	0.286465234	0.214488706
OH	2.032	0.28077575	0.283657852	0.219400619
OK	2.032	0.289911823	0.26762763	0.222821079
OR	2.032	0.273802525	0.26705492	0.215275758
PA	2.032	0.259691996	0.268583464	0.242999159
RI	2.032	0.254542722	0.282962309	0.224426008
SC	2.032	0.273683512	0.292773972	0.205245922
SD	2.032	1.281738149	0.260666061	0.221935828
TN	2.032	0.267716688	0.285879917	0.211309244
TX	2.032	0.31161996	0.290731985	0.17584857
UT	2.032	0.366270384	0.292142052	0.147730337
VA	2.032	0.267120983	0.310036433	0.193104019
VT	2.032	0.263162541	0.285417111	0.202997588
WA	2.032	0.284415871	0.289278805	0.192025495
WI	2.032	0.284760363	0.279972411	0.213162121
WV	2.032	0.256243497	0.266093085	0.253161336
WY	2.032	0.29914199	0.253150552	0.201127984

Table A10.25: 2010 Data, Part 1



State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
AK	1	60.35439739	14.24	641663	41241.48893
AL	0.789495671	67.73819826	12.71	1959696	26311.57025
AR	0.941485939	58.73944061	12.25	1125639	26148.71769
AZ	0.813757388	68.52844983	6.12	1399609	31559.43508
CA	1.143410982	47.25602264	4.51	7825673	39798.47646
CO	1.044129615	63.60373036	6.45	1516856	38473.38378
CT	0.977730995	48.970176	3.56	753954	46173.24347
DC	3.526941963	17.67984043	2.04	185461	112531.7642
DE	1.396863533	45.7525292	4.55	256209	50783.38729
FL	1.070764514	56.1349434	6.5	4381926	28845.68299
GA	1.075344797	55.04808369	8.71	3155657	31242.28955
HI	1	69.48409537	4.58	272156	33492.06196
IA	0.921298972	59.46505805	11.68	1492314	34968.09501
ID	1.551937429	30.35620724	10.52	533765	29677.89507
IL	0.893522065	58.51425149	6.77	3936690	37456.78213
IN	0.980103159	76.30059266	11.69	2871099	31136.69963
KS	0.961666448	64.39437063	10.22	1165261	32654.5056
KY	1.010050983	76.25429008	13.66	1976514	26992.39294
LA	1.025901968	54.97154222	20.83	4065372	31557.09726
MA	1.129048307	52.24110744	4.08	1396862	45805.57
MD	1.261232602	47.61128089	5.59	1481070	37145.59125
ME	0.936289737	45.46560857	8.86	407297	27647.11521
MI	0.995755043	59.27776014	8.11	2798125	28423.16773
MN	1.09123823	50.04373917	7.67	1867307	38967.52915
MO	1.003224688	70.39176344	8.87	1928366	29859.32273

Table A10.26: 2010 Data, Part 2



State	(1+S)	Carbon Intensity	Energy Intensity	Energy Consumption	Income
MS	1.011388031	55.05302459	13.65	1189177	23213.56065
MT	0.694722956	86.97858934	12.61	401412	25753.35029
NC	1.093227128	52.80539824	7.1	2705219	33504.30213
ND	0.634519075	109.2788084	15.38	480718	38931.25497
NE	0.942744165	56.86457777	10.59	843793	36658.44664
NH	0.834211459	57.45204993	5.41	295495	38316.58182
NJ	1.124904967	47.16144919	5.57	2447538	41072.30212
NM	0.818346565	80.61025491	9.34	680119	30419.04401
NV	1.004344061	58.92491038	5.79	646084	32795.13251
NY	1.042038763	46.357961	3.6	3728437	44635.68357
OH	1.053325123	64.96806512	8.99	3833717	30156.06866
OK	0.941086936	66.66577301	11.62	1551623	27414.68386
OR	0.972885893	41.20434967	5.86	977070	43856.1863
PA	0.851822347	68.25556445	7.42	3758834	32091.53576
RI	1.005426355	55.83822614	4.48	197216	33669.15749
SC	0.929482706	50.57047852	11.44	1661633	25272.95947
SD	1.096549648	39.88312082	10.46	379601	36756.99552
TN	1.19139895	47.58746722	9.84	2250577	30406.35111
TX	1.005244611	55.44384297	10.64	11769900	35191.89259
UT	0.849474401	84.10329856	7.42	763707	31437.27476
VA	1.310352662	43.87213601	6.57	2502056	38256.44348
VT	0.999537577	40.81240951	6.38	147630	32086.07294
WA	1.000114644	37.38194439	6.64	2036516	37378.65617
WI	1.070607219	55.12366138	8.13	1800072	32453.79123
WV	0.559419225	133.9222344	13.19	738858	22936.36225
WY	0.559420325	121.2370478	15.55	535267	39160.27074

Table A10.27: 2010 Data, Part 3

State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
AK	1.248613387	0	10057.5	0.000588115	3211.417073
AL	94.3047651	2332	3276	0.001786684	184.2907742
AR	56.11082548	2214	3697	0.001083657	264.5545492
AZ	56.4366812	3009	2024	0.001080123	77.70419973
CA	239.4098231	731	2716	0.000391636	43.70566404
CO	48.66768424	368	7071	0.000127781	443.8678858
CT	738.0073481	817	5505	0.000638233	0
DC	9851.986971	1355	4845	0	0
DE	460.5909212	1467	4584	0	0
FL	349.3366195	3375	1230	0.000221142	0.568751047
GA	167.7224039	2114	3394	0.000615105	0
HI	212.2745858	3694.23	0	1.83371E-05	0
IA	54.59525579	934	7040	0.000265884	0
ID	18.98676705	352	6756	0.001614154	0
IL	231.0390946	1108	6126	0.000969866	257.3389825
IN	180.9641201	1187	5742	1.41743E-05	218.3517489
KS	34.9464914	1649	5088	0.000433347	135.9024761
KY	109.4241669	1554	4838	0.000184946	703.9685209
LA	104.3422857	2895	2229	0.000534173	564.3022394
MA	836.1542445	677	5776	0.000143697	0
MD	591.956983	1355	4845	0.000407212	6.164124428
ME	43.01076906	353	6752	0.000545436	0
MI	173.8816685	779	6393	0.000475542	18.88681967
MN	66.70836155	567	8175	0.000380555	0
MO	87.03831102	1513	5232	0.000289373	5.73434733

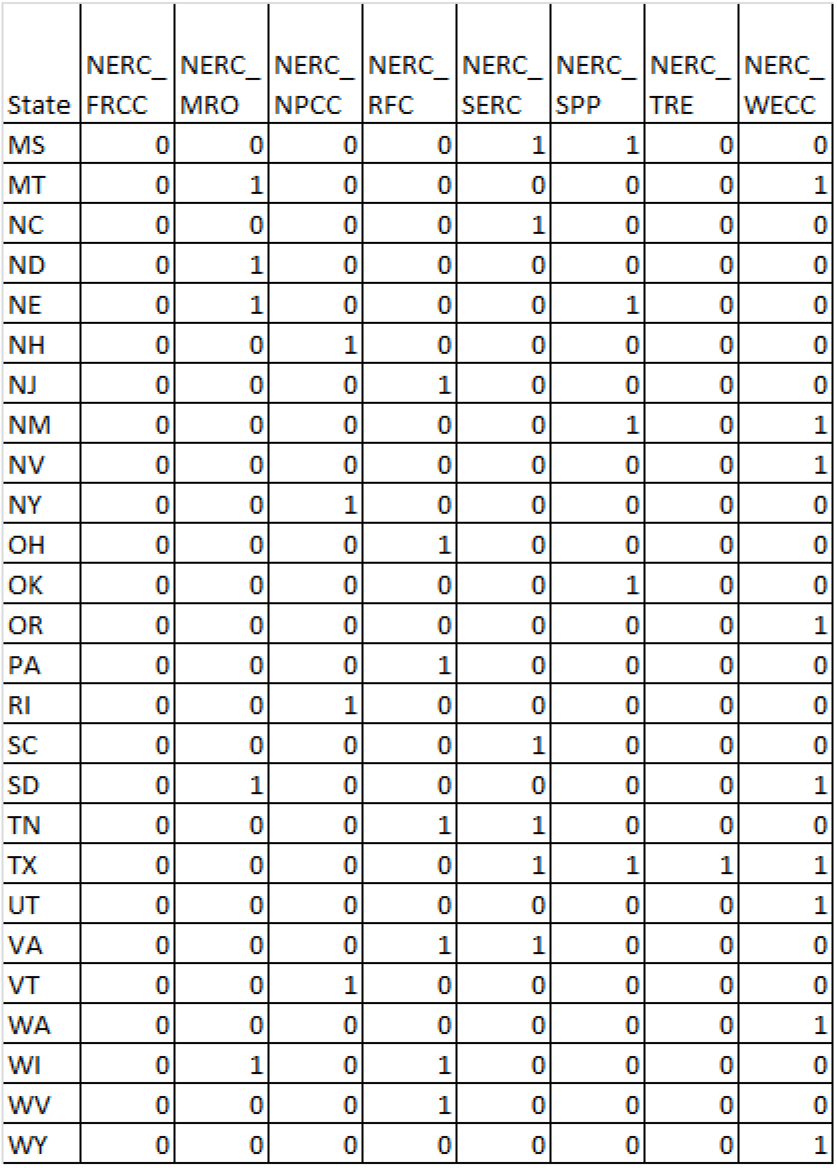
Table A10.28: 2010 Data, Part 4

State	Population Density	CDD	HDD	Nuke/Hydro Capacity Per Capita	Fossil Fuel Endowment Per Capita
MS	63.31836469	2480	3025	0.000462278	137.7217366
MT	6.808254593	181	8236	0.00259345	2109.290334
NC	196.2648591	1820	3896	0.000757617	0
ND	9.78064377	414	9269	0.00091013	5183.958866
NE	23.8075143	1031	6661	0.000893374	3.470010575
NH	146.8323279	446	6599	0.001281889	0
NJ	1186.354273	1149	4966	0.000462862	0
NM	17.0236412	1072	4675	3.82398E-05	1023.490853
NV	24.6233428	1990	3689	0.000389013	1.871331005
NY	410.795363	881	5571	0.00053441	0.934616427
OH	281.7686072	1015	5883	0.000204975	54.20906136
OK	54.75964749	2133	3858	0.000214085	567.3890192
OR	39.98396196	174	5065	0.002148068	0.534244725
PA	283.772512	937	5590	0.000848422	153.3853963
RI	1007.2713	743	5217	2.85028E-06	0
SC	154.008224	2224	3270	0.001776539	0
SD	10.76104466	744	7770	0.001956899	6.197184691
TN	154.242606	1826	4269	0.000976809	2.778714876
TX	96.46197025	2838	2197	0.000231137	400.4668922
UT	33.78811387	672	6464	9.43981E-05	376.2865569
VA	202.6554229	1500	4506	0.000559076	109.5387115
VT	67.66905669	377	7229	0.00140276	0
WA	101.3306071	154	5227	0.003285506	0
WI	104.7992731	644	7102	0.000373529	0
WV	77.01589809	1051	5408	0.000175262	2458.132291
WY	5.814126409	263	8108	0.000536707	28857.22035

Table A10.29: 2010 Data, Part 5

State	NERC_FRCC	NERC_MRO	NERC_NPCC	NERC_RFC	NERC_SERC	NERC_SPP	NERC_TRE	NERC_WECC
AK	0	0	0	0	0	0	0	0
AL	0	0	0	0	1	0	0	0
AR	0	0	0	0	1	1	0	0
AZ	0	0	0	0	0	0	0	1
CA	0	0	0	0	0	0	0	1
CO	0	0	0	0	0	0	0	1
CT	0	0	1	0	0	0	0	0
DC	0	0	0	1	0	0	0	0
DE	0	0	0	1	0	0	0	0
FL	1	0	0	0	1	0	0	0
GA	0	0	0	0	1	0	0	0
HI	0	0	0	0	0	0	0	0
IA	0	1	0	0	0	0	0	0
ID	0	0	0	0	0	0	0	1
IL	0	0	0	1	1	0	0	0
IN	0	0	0	1	0	0	0	0
KS	0	0	0	0	0	1	0	0
KY	0	0	0	1	1	0	0	0
LA	0	0	0	0	1	1	0	0
MA	0	0	1	0	0	0	0	0
MD	0	0	0	1	0	0	0	0
ME	0	0	1	0	0	0	0	0
MI	0	1	0	1	0	0	0	0
MN	0	1	0	0	0	0	0	0
MO	0	0	0	0	1	1	0	0

Table A10.30: 2010 Data, Part 6



State	NERC_ FRCC	NERC_ MRO	NERC_ NPCC	NERC_ RFC	NERC_ SERC	NERC_ SPP	NERC_ TRE	NERC_ WECC
MS	0	0	0	0	1	1	0	0
MT	0	1	0	0	0	0	0	1
NC	0	0	0	0	1	0	0	0
ND	0	1	0	0	0	0	0	0
NE	0	1	0	0	0	1	0	0
NH	0	0	1	0	0	0	0	0
NJ	0	0	0	1	0	0	0	0
NM	0	0	0	0	0	1	0	1
NV	0	0	0	0	0	0	0	1
NY	0	0	1	0	0	0	0	0
OH	0	0	0	1	0	0	0	0
OK	0	0	0	0	0	1	0	0
OR	0	0	0	0	0	0	0	1
PA	0	0	0	1	0	0	0	0
RI	0	0	1	0	0	0	0	0
SC	0	0	0	0	1	0	0	0
SD	0	1	0	0	0	0	0	1
TN	0	0	0	1	1	0	0	0
TX	0	0	0	0	1	1	1	1
UT	0	0	0	0	0	0	0	1
VA	0	0	0	1	1	0	0	0
VT	0	0	1	0	0	0	0	0
WA	0	0	0	0	0	0	0	1
WI	0	1	0	1	0	0	0	0
WV	0	0	0	1	0	0	0	0
WY	0	0	0	0	0	0	0	1

Table A10.31: 2010 Data, Part 7

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
AK	4.722	0.292039723	0.286683675	0.198697465
AL	4.722	0.266181037	0.262275199	0.261685698
AR	4.722	0.27223243	0.260535709	0.265334469
AZ	4.722	0.284199298	0.268215285	0.252519741
CA	4.722	0.280232163	0.285879356	0.22329144
CO	4.722	0.270891132	0.284064677	0.229142151
CT	4.722	0.255760456	0.243726328	0.266928131
DC	4.722	0.205287711	0.385327122	0.220812283
DE	4.722	0.259882284	0.256082517	0.268143082
FL	4.722	0.239415609	0.249803794	0.29888469
GA	4.722	0.286410629	0.280278727	0.21791462
HI	4.722	0.247716852	0.269493948	0.274955459
IA	4.722	0.268599588	0.253943837	0.271926908
ID	4.722	0.302574881	0.264409949	0.240034702
IL	4.722	0.271898181	0.273686768	0.241236398
IN	4.722	0.277880148	0.261761045	0.249381954
KS	4.722	0.283472355	0.264626498	0.248757757
KY	4.722	0.263317755	0.263159953	0.258447059
LA	4.722	0.275723526	0.274437155	0.242122102
MA	4.722	0.247059324	0.265671273	0.26167232
MD	4.722	0.261964668	0.265663109	0.244131158
ME	4.722	0.23351733	0.229279656	0.30463417
MI	4.722	0.267203583	0.247566427	0.265602817
MN	4.722	0.269155536	0.263981412	0.248437764
MO	4.722	0.266615575	0.260121437	0.261846335

Table A10.32: 2010 Data, Part 8

State	Moving Average of Fossil Fuel Price	% Age 0-19	% Age 20-39	% Age 55 and Over
MS	4.722	0.285418333	0.265029939	0.246140498
MT	4.722	0.253085398	0.248611949	0.289542039
NC	4.722	0.267666984	0.269416732	0.249941058
ND	4.722	0.255269192	0.277473989	0.267277274
NE	4.722	0.280038533	0.265737449	0.252572343
NH	4.722	0.246932162	0.23660263	0.271793057
NJ	4.722	0.260034413	0.254699166	0.254997021
NM	4.722	0.281030711	0.258598983	0.257925189
NV	4.722	0.272123886	0.279948511	0.238056076
NY	4.722	0.252035323	0.274672824	0.255003118
OH	4.722	0.265012175	0.25070957	0.267590099
OK	4.722	0.277048676	0.269137361	0.253592643
OR	4.722	0.253159445	0.268444991	0.273385158
PA	4.722	0.24941094	0.247841398	0.282929207
RI	4.722	0.248294582	0.259502835	0.269056025
SC	4.722	0.26387816	0.264119906	0.26385983
SD	4.722	0.278011947	0.256718728	0.264060162
TN	4.722	0.263316375	0.263863608	0.259358018
TX	4.722	0.302671404	0.28601171	0.207631776
UT	4.722	0.347556944	0.30817059	0.177917758
VA	4.722	0.259752892	0.275351064	0.242534696
VT	4.722	0.239881516	0.23962429	0.290285009
WA	4.722	0.262637718	0.274219592	0.248418867
WI	4.722	0.263441292	0.255704708	0.260712738
WV	4.722	0.236286972	0.245729003	0.304448739
WY	4.722	0.268488045	0.269789958	0.255364412