A Meta-Analysis of the Economic Impacts of Climate Change Policy in the United States

Adam Rose and Noah Dormady***

This paper provides a meta-analysis of a broad set of recent studies of the economic impacts of climate change mitigation policies. It evaluates the influences of the impacts of causal factors, key economic assumptions and macroeconomic linkages on the outcome of these studies. A quantile regression analysis is also performed on the meta sample, to evaluate the robustness of those key factors throughout the full range of macro findings. Results of these analyses suggest that study results are strongly driven by data inputs, economic assumptions and modeling approaches. However, they are sometimes affected in counterintuitive ways.

1. INTRODUCTION

The macroeconomic impacts of climate change mitigation policies are controversial among both scholars and the policy-making community. Results range from predictions of severe economic harm to significant overall economic gains. Given the unresolved nature of this debate, this paper seeks to shed light on it by evaluating a wide range of macroeconomic studies through a meta-analytic approach. Meta-analysis is a method for evaluating a cross-section of studies on a given topic, and evaluating the impacts of assumptions, input variables and modeling approaches on the overall findings of the studies. In essence, meta-analysis is a study of studies (Borenstein et al., 2009; Lipsey and Wilson, 2001).

The Energy Journal, Vol. 32, No. 2.

* Corresponding author. Research Professor, School of Policy, Planning and Development (SPPD), University of Southern California (USC), Los Angeles, CA 90089. E-mail: adamzros@sppd.usc.edu.

** Ph.D. Candidate, SPPD, USC.

This paper was supported by a grant from the Center for Climate Strategies. The authors wish to thank Thomas Peterson and Jeffrey Wenneberg for their helpful suggestions at an early stage of this research, and Brock Blomberg for his advice on the use of quantile regression. We are also grateful to 3 anonymous referees.

The purpose of this paper is to refine techniques to evaluate the relative influence of assumptions, input variables and macroeconomic linkages on a wide range of macroeconomic studies of climate change policy. Repetto and Austin (1997), Barker et al. (2002), and Barker and Jenkins (2007) have recently performed meta-analyses to evaluate several macroeconomic studies in this area. This paper expands upon that foundation by evaluating a broader set of studies (both national and sub-national) and using a broader set of techniques (including quantile regression).

Section 2 of this paper provides a discussion of the key assumptions, causal factors and modeling approaches that influence macroeconomic findings. The following three sections include the standards of any empirical paper, detailing the data, methods and results of the meta-analysis. Section 6 develops the meta-analysis further, through the use quantile regression analysis, which is particularly helpful in explaining the effect of those economic assumptions on subsets of the meta sample. Section 7 focuses on two key studies, and elaborates on how the modeling methodologies, data and economic assumptions drive their results. Section 8 summarizes the contributions of the paper.

2. FACTORS AFFECTING MACROECONOMIC IMPACTS

The economy of a state, region, or nation is a complex mega-institution. It consists of the interactions of millions of individual consumers and businesses, primarily through the workings of markets. The macroeconomic linkages work not only through markets for goods and services, but also through factors of production (labor, capital, and land and other natural resources). Even the macroeconomy of a small state is likely to involve over a million businesses because of cross-border trade.

For many years, macroeconomics was dominated by considerations of aggregate components, such as production, consumption, investment, export/imports and government spending. Over the years, there has been a growing appreciation of two considerations: 1) major differences in production across sectors, and 2) the importance of microeconomic foundations of macro relationships. These considerations are especially critical in evaluating the broader impacts of climate policy. Most mitigation and sequestration policy options are sector-specific (e.g., automobile fuel efficiency, renewable portfolio standards, and reforestation). Also, the success of their implementation depends on behavioral factors that should be taken into account in policy design (e.g., the extent of the response to a market signal like a tax or subsidy).

Each mitigation/sequestration option would ideally be linked to appropriate variables beyond its narrow on-site application. These linkages help determine the potential effect on investment, the implications for prices, and the effects on other markets in general. The outcome of this process is best measured in terms of changes in key macroeconomic indicators, such as gross domestic product (GDP) or gross state product (GSP) and employment.

2.1 Causal Factors

Below, we explain how key factors influence the macroeconomics of climate policy options. The first set of causal factors relates to macroeconomic linkages. If a policy option requires capital investment, such as energy-saving equipment, it makes a significant difference whether the investment funds are additive to the geographic area or whether they offset ordinary investment in plant and equipment or ordinary consumption. If they are additive (e.g., if they attract investors from outside the region or from increased savings within its boundaries without somehow reducing consumption there), they will, all other things equal, have a stimulating effect on the economy. If they displace other investment, the effect is unknown. It could be positive if this investment calls forth greater productivity increases than the investment that it displaces, but it is equally likely that it will have a neutral or negative effect.

Note also that the various direct positive or negative stimuli of such investments have ripple, or multiplier, effects. That is, increased production of energy-saving equipment will require successive rounds of upstream demands for inputs into the supply chain of the production process.[1] This is also true of any downside effects. The multiplier can be more than three times the impact of the direct effects for the nation as a whole and a factor of two for an average-size state (MIG, 2010). However, other considerations are likely to mute its influence.

Cost savings or cost increases associated with a policy option also have multiplier effects that spread throughout the economy. This succession of cost pass-throughs moves in the same direction as the initial stimulus or dampening effects. Savings should result in decreases in overall production costs, and hence in prices, in sectors where the product is used directly and in turn in all downstream sectors dependent on the product indirectly. Cost increases move in the other direction. However, it is important to emphasize that costs or savings are not typically passed through entirely to the next round, with the extent depending on the degree of competition in the industry. Typically, sectors with higher competitive pressures are less likely to be able to pass any costs or savings onto their customers. Also, regulated industries may not be able to pass on cost changes or will only be able to do so with some time delay.

Various offsetting effects exist in relation to the implementation of climate policy options. For example, an option that promotes energy conservation, such as household appliance efficiency, even if it involves cost savings, will have a dampening effect through a decrease in demand for electricity. In a similar vein, some policy options increase the demand for one product and therefore have a stimulating effect, while decreasing the demand for its direct substitute. Interestingly, energy conservation has another unusual aspect, often referred to as the "rebound effect." This refers to the fact that an increase in vehicle fuel efficiency,

1. In sophisticated models, these impacts are referred to as general-equilibrium or macroeconomic effects.

for example, makes it cheaper to drive, and hence stimulates the demand for gasoline, thereby partly offsetting the initial GHG reductions. Studies indicate that this rebound effect is on the order of 15%–20% (see, e.g., Greene et al., 1999; Maggioni, 2008). It can be interpreted as an increase in cost per unit of emissions reduced, and has an effect on aggregate demand for gasoline in relation to other goods and services.

Another causal effect results from assumptions regarding the manner in which tax or auction revenue is spent. This consideration relates to whether or not the revenues obtained from auctioning of emission permits or establishing a carbon tax are used to reduce an existing, distorting tax, such as a sales tax. Another expansionary use is the application of these funds for research and development in lowering the costs of climate policy options in the future.

Other potential influences on macroeconomic impacts are more idiosyncratic. These relate to certain types of policy options, such as the use of nuclear power, which typically represents a relatively expensive option. Another relates to the displacement of domestic, or within-state/region, electricity generation.

Finally, the type of model used to analyze the macro impacts has an effect on the outcome (see below). Likewise, the data utilized will have a major effect. In this analysis we distinguish between primary data from actual operating experience, data obtained through a stakeholder consensus process, data from individual engineering/policy design, and secondary (published) data (see also the following section). It is not clear at the outset whether these various origins of data have positive or negative effects on macro impacts. Our formal statistical analysis helps provide some insights, however.

2.2 Macroeconomic Modeling Approaches

Three major types of models are typically used to analyze the macroeconomic impacts of climate policy. The most basic is input-output (I-O) analysis. I-O, in its most fundamental form, is a static, linear model of all purchases and sales between sectors of an economy, based on the technological relationships of production (Rose and Miernyk, 1989).

I-O models are widely applied, in part because they are inexpensive to construct and easy to use. At the same time, they are very limited. The basic model is static and unable to perform any forecasting, or to factor in technological change without serious modification. It also represents a linear view of the world. The basic units of analysis are sectors, and thus this model does not contain any behavioral content regarding the motivations of individual decision makers.

Although the I-O approach has a very sound basis in production technology and is based on extensive primary data related to purchases and sales of individual businesses, it completely omits the real workings of markets and prices. Also, I-O model calculations typically work in a unidirectional manner—the multiplier process will automatically move in the same direction as the initial stimulus. Any offsetting, rebound, or substitution effects must be explicitly entered into the model. Most I-O models used in the United States today are constructed from the Impact Analysis for Planning (IMPLAN) system (MIG, 2010), which provides a complete data set of county- and state-level economic indicators and computer algorithms for generating non-survey-based I-O tables from a national table. Examples include Bezdek and Wendling (2005) and Pollin et al. (2009).

Computable general equilibrium (CGE) models are based on the decisions of individual producers and consumers in response to markets and prices within the bounds of explicit constraints on the availability of labor, capital, and natural resources. These models build on the I-O model's strengths (e.g., sectoral distinctions, full accounting of all inputs) and focus on interdependence, since a major source of data on which these models are built comes from I-O tables, but overcome many of its limitations (Rose, 1996).

CGE models automatically incorporate such considerations as substitution and rebound effects, and require only minor modification to ensure that investment addition/displacement is adequately analyzed. Still, these models have some shortcomings, such as the assumption that the economy is always in equilibrium, which smoothes out the adjustment process (i.e., tends to minimize adjustment costs). Most CGE models are custom-built, with a good deal of variation in the functional forms of the production and consumption relationships and closure rules (account balances in terms of endogenous and exogenous considerations). Example applications include Hanson and Laitner (2006), Oladosu and Rose (2007), Roland-Holst and Kahrl (2009), and CRA (2009).

Macroeconomic (ME) models cover the entire economy, typically in a "top-down" manner, based on aggregate relationships, such as consumption and investment. This model type usually has the advantage of a forecasting capability, and more modern versions have multisector detail. While this approach typically includes price variables, the behavioral responses are not as detailed as in a CGE model. Also, most ME models focus on aggregates, and thus one needs to carefully link policy options to the appropriate macro variables. These models are based on a statistical estimation using time series data, and therefore are considered more accurate than I-O and CGE models (which are based on single-year "calibration" and also on various down-scaling adjustment methods when one moves below the national level to the regional or state level). Most ME models are based on published data made available by the U.S. Department of Commerce. Regional Economic Models, Inc (REMI) constructs the most popular version of these models. Applications of the REMI model include Rose and Wei (2010).

In addition some primarily partial equilibrium or cost-based models have been used. Several of the modeling approaches summarized above are also supplemented by mathematical programming (MP) systems that contain extensive information on the choice between energy technologies and fuels.

3. DATA

Meta-analyses have proven to be particularly robust in illuminating the influence of analytic methods on their results. While individual analyses focus on

Table 1: Studies and Observations Included in the Meta-Analysis

Study Name	Number of Observations Considered	Satisfactory Observations	Policy Option/Area	Model Type	Planning Horizon
ACEEE (2008)	1	1	Energy Efficiency Programs/ Southeast US	I-O	2008–2025
ACEEE (2006)	1	1	Energy Efficiency Programs/ Northeast US	ME & MP	2006–2024
Bezdek and Wendling (2003)	2	0	CAFE Standard/ US	I-O	2005–2030
BHI (2008)	6	6	Climate Action Plan/South Carolina	CGE	2008–2020
Chamberlain (2009)	1	1	Cap-and-Trade/ US	I-O	N/A
ERCOT (2009)	1	0	Cap-and-Trade/ Texas	Cost-based Model	2005–2013
McKinsey (2009)	1	1	Broad Range of Options/US	ME	2009–2020
Hanson and Laitner (2006)	1	1	Long-Term Climate Stabilization Using Broad Set of Policies/US	CGE	2020–2100
MISI (2008a)	1	1	Climate Action Plan/North Carolina	I-O	2010–2025
MISI (2008b)	1	1	Climate Action Plan/South Carolina	I-O	2010–2020
CRA (2009)	1	1	H.R. 2454 (ACES)/US	CGE	2015–2050
CRA (2007)	3	3	EO-07-127/ Florida	CGE & MP	2020–2050
Oladosu and Rose (2007)	2	2	Carbon Tax/ Susquehanna RiverBasin	CGE	2000–2010
Paltsev et al. (2009)	1	1	Cap-and-Trade/ US	CGE	2010–2050
Pollin et al. (2009)	1	1	H.R. 2454 (ACES) Combined with Federal Stimulus/US	I-O	Differs by policy option

(continued)

Table 1: Continued

Study Name	Number of Observations Considered	Satisfactory Observations	Policy Option/Area	Model Type	Planning Horizon
Ponder et al. (2008)	6	6	Climate Action Plan/North Carolina	I-O	2007–2020
Roland-Holst and Kahrl (2009)	2	2	Cap-and-Trade/ Florida	CGE	2008–2025
Rose and Wei (2010)	6	6	Climate Action Plan/Florida	ME	2008–2025
Ross et al. (2008)	2	0	Cap-and-Trade/ US	CGE	2005–2020
SAIC (2008)	2	2	S.2191 (Lieberman-Warner Bill)/US	ME	2012–2030
Total	42	37			

the impact of a study and its precipitant causes, meta analytic methods can bring to light the effect of assumptions made by researchers in studies on a given subject.

Given the fact that there is significant debate among scholars and policymakers regarding the potential macroeconomic impacts of changes to a national or regional economy in combating climate change, meta-analytic methods can be useful in navigating through the discourse. This is because the method uncovers more than simply cause and effect; it shows how the base economic and behavioral assumptions made by researchers influence that relationship.

The data for the meta-analysis presented in this paper is a comprehensive set of recent studies that examine the impact of either state or national climate change mitigation measures on macroeconomic performance in the U.S. This is typically measured as either an increase or decrease in gross domestic/state product (GDP/GSP) or employment. Our analysis is broad in scope, as studies include a wide array of academic and research-related organizations.

In selecting relevant studies, a series of standards must be met in order to ensure that we evaluate equivalent or competing studies. Studies must evaluate the impact of a climate mitigation or sequestration measure or policy on a state, regional or national economy within the United States. Studies must evaluate the impact on GDP/GSP. This excludes studies that, for example, evaluate only the potential for growth within one sector of the economy, such as green jobs. This also excludes partial equilibrium analyses. These criteria caused us to reduce significantly the number of studies originally considered.

Moreover, some studies are more broad or comprehensive in scope than others, which necessitates another level of scrutiny. Some studies analyze dozens of disaggregated policy options separately (e.g. land-use policies versus demand-side management). Moreover, others analyze only one broad policy option (e.g. national cap-and-trade or regional carbon tax). Given this, we endeavor to analyze only the most consistent level of scope possible. For those studies that analyze a large set of disaggregated policy options, we include up to five of their most cost-saving or cost-incurring policy options. If they also include an analysis of the sum of all policy options, we include that case as an additional observation. Table 1 above summarizes the observations included in this analysis from each study evaluated.

4. METHOD OF ANALYSIS

Meta-analysis typically makes use of quantitative regression analysis. The focus of the macroeconomic results is on changes in state or national product.

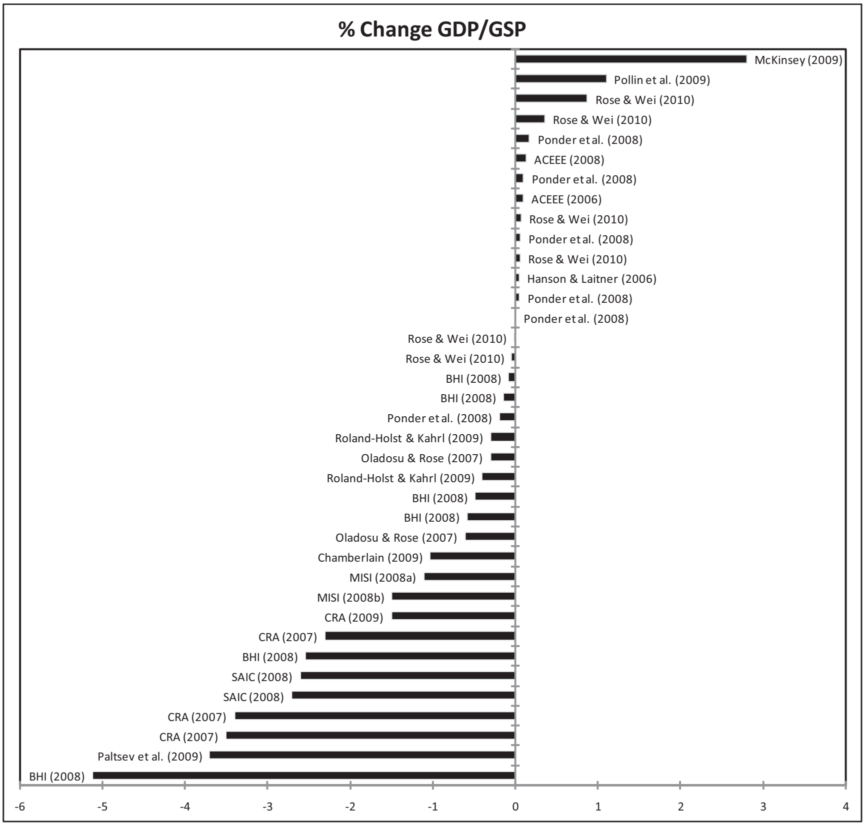
Analytic equivalence is particularly important in meta-analyses (Lipsey and Wilson 2001). This is because studies that are aggregated within the meta-analysis may have originally been focused on a specific level of analysis. For example, one study may suggest that a particular sequestration measure will have a positive impact of 10,000 jobs to the state of South Carolina, whereas another study may provide results that a particular sequestration measure may have a positive impact of 150,000 jobs on the national economy. Therefore, the dependent variable in this analysis is measured in terms of percent change, and provides a measure of equivalence between state, regional and national macroeconomic impacts. This method of equivalence has been consistently applied in past meta studies of climate impact analyses (Barker et al. 2002; Barker and Jenkins 2007).

Furthermore, to ensure accurate accounting, when percent change figures were not available, we converted impact levels figures into percent changes using the GDP/GSP forecasted for that study's terminal year. If an official forecast was unavailable, we generated our own forecast using Holt's Double Exponential smoothing method. For the two observations for which this was necessary, the forecast correctly identified 97 and 99 percent of the variance, respectively.

As can be seen from Figure 1 below, there is a significant amount of variance in our dependent variable. At the extremes, a report by McKinsey and Company (2009) finds that there will be a positive impact to the US GDP of 2.8 percent, whereas the Beacon Hill Institute (2008) finds that there will be a negative impact of 5.12 percent to the South Carolina GSP, among equivalent cases. On the average, there is a negative 0.76 percent impact to GDP/GSP among equivalent cases.

The independent (regressor) variables for the analysis stem from the structure of the individual study designs. Each of these variables are coded binary (dummy) variables. Each of these major variables is discussed in Section 2 and summarized in Table 2. The major independent variable in the analyses that does not usually stem from assumptions made by the researcher is *Positive Costs*, which

Figure 1: Range of GDP/GSP Impacts Across Studies



is typically borrowed from outside sources, such as stakeholder groups or cost-engineering data, as discussed above.

Aside from cost measures, all of our independent variables are fairly consistent with assumptions of macroeconomic theory, except for the variable "nuclear', which should be explained further. Given that our unit of observation is either an individual climate change mitigation policy option or a suite of options, depending upon the context of the macro study, the variable "nuclear" is agnostic to the current use of nuclear power within a state, region or the nation as a whole. The variable takes a value of "1" if the policy option includes nuclear electricity generation, and "0" otherwise. As such, climate change mitigation measures such as low carbon fuel standards, biofuels, and green building codes would not contain a mechanism for the utilization of nuclear power.

Table 2: Variables Analyzed in Meta-Analysis

Variables Analyzed	Definition
Positive Costs	Costs refer to the value of resources incurred in operating a mitigation or sequestration option or set of options. Zero values of this variable represent cost savings, where actions more than offset any positive expenditure. Cost estimates are taken as presented in the studies analyzed. Some are provided through the stakeholder process, or some alternative collaborative process. Others are based on cost-engineering analyses (by the author of the study or derived from secondary sources) or syntheses of the literature. Note that these are not impacts or results of the study in question.
Substitution Effects	This indicates whether the modeling effort includes the possibility for substitution across inputs, or if cost savings may be used to stimulate other spending.
Investment Addition	This refers to whether investment in mitigation or sequestration options is additive, or offsets ordinary investment in the region or nation.
Offsetting Effects	Offsetting effects are tertiary economic impacts (other than investment and substitution) that may displace the direct cost or employment impacts of the mitigation option.
Revenue Recycling	Revenue recycling refers to whether the model has accounted for the respending of particular tax or auction revenue stemming from the implementation of a policy option. Such uses include return to ratepayers as a lump-sum transfer or offsets of other taxes.
Electricity Displacement	This indicates whether the policy option causes a displacement of electricity generation within the state (or nation). This occurs for example, when local electricity generation is displaced by electricity imports from neighboring states.
Nuclear	This indicates whether the policy option contains a mechanism for the utilization of nuclear power.

5. RESULTS

5.1 Reduced Form Statistical Model

We apply meta-analysis, which uses the individual study data inputs, assumptions, background characteristics, and outcomes themselves as observations in a multivariate regression analysis. This approach has proven very successful in the past in explaining the economic impacts of climate policy at the national and international levels (Repetto and Austin, 1997; Barker et al., 2002; Barker and Jenkins, 2007).

The main results of our meta-analysis are presented in Table 4. Our dependent variable, the percent change in Gross Domestic Product/Gross State Product, is a continuous variable. All other independent variables are binary,

Table 3: Descriptive Statistics

Variable	Mean	Min Value	Max Value
Percent Change GDP/GSP	–0.76	–5.12	2.8
Positive Costs	0.59	0	1
Substitution Effects	0.67	0	1
Nuclear	0.35	0	1
Investment Addition	0.46	0	1
Offsetting Effects	0.92	0	1
Revenue Recycling	0.16	0	1
Electricity Displacement	0.72	0	1

taking a value of "1" if the assumption or causal factor was included in the analysis, and "0" otherwise. For example, *Positive Costs* takes a value of "1" if an official stakeholder group or engineering analysis indicates that the policy option will incur a direct positive cost (at the site of its implementation) on the state or national economy, and "0" if they indicate that it will incur a negative direct cost. One limitation is that only half of the studies actually listed the dollar cost or saving of the option(s) they analyzed, so this variable had to be coded as just positive or negative, which does not allow for as finely grained a delineation of the effect of this variable.

Note that for some studies we included the analysis of individual options, as well as the total package of options, typically a state or national climate action plan. Still, only a portion of the set of studies included all of the variable values, which limited the number of overall observations to 37.

Past meta studies (Barker et al., 2002; Barker and Jenkins, 2007) had nearly 50 times more observations than our meta-analysis. However, these past studies are limited in providing causality between a model's assumptions and overall results because they rely on only a handful of studies and use all outputs from those studies (most of these outputs are just variants or sensitivity tests of the same basic policy design with respect to background conditions such as atmospheric concentrations, and emission caps) as separate observations in the meta-analysis. This leads to a disproportionate weighting between studies within the overall meta sample, to the degree that one or two studies can provide nearly 50 percent of all observations for the entire meta analysis. When this is the case, there is hardly any variability among regressors, because the assumptions of one or two studies become dominant throughout the entire sample.

Our selection method on the other hand, overcomes this problem. Despite the fact that our overall number of observations is fewer than past meta studies, it gives nearly equal weight to all studies, and independent variables are not skewed toward those studies that provide the largest percentage of the overall sample.[2]

Our meta-analysis began with nearly 20 variables present in the studies that could be quantified as binary variables for estimation in the model. As is often the case, not all of those quantified variables were statistically significant, and in some cases, their presence caused issues of multi-collinearity. In statistical analyses, this problem exists when two or more variables are highly correlated with one another, and thereby bias the results of the analysis. As a result, simplifying changes in the estimating equation were necessary, and the method most appropriate was forward stepwise regression, which maximized statistical significance and explained variance, while minimizing collinearity.

Two models are presented in Table 4. Model 1 is the most parsimonious, a reduced-form model with four key explanatory variables. Each of the four variables is statistically significant at the 95% confidence level. The first regressor is a measure of *Total Costs or Savings* of a policy option or sum of options. It is determined exogenously by a collaborative stakeholder process, by cost-engineering data, or by some other process, and is usually not a direct calculation of the study. The variable takes a value of "1" if the policy option was identified to have a positive direct cost, and a value of "0" if the policy option was identified to incur a negative direct cost (savings).[3]

2. Sampling methodology is a highly important consideration. We strive to the degree possible to balance the tradeoffs between sample size and selection bias. It should be noted that we considered more than twice as many studies for the meta sample than we actually included, which reflects a rigorous selection process. Studies were excluded from our analysis mainly because they were not macro studies, or they were studies of outdated climate proposals that never came anywhere near fruition on a national or sub-national level. Including those studies would heavily bias the findings and lead to spurious results. At the same time, we were equally conscientious in our selection process *within* each individual study. Some of the studies included in our meta sample are of state climate action plans that include individual analyses of the macroeconomic impacts of individual mitigation or sequestration options. To avoid oversampling, we selected up to five individual mitigation options (for our observations) from each study and systematically selected those options that had the largest absolute value net impact. Some of those studies included more than two dozen possible observations, but it would be highly problematic to juxtapose those against studies that include only one or two mitigation options as observations. A good meta analysis should attempt to allow all observations to have near equal weight on explanatory power, all other things being equal.

3. In our analysis, some variables must be binary, or "dummies," because they represent either the inclusion or exclusion of important modeling considerations. Repetto and Austin (1997) and Barker et al. (2002) employ similar sets of binary variables in their meta models. This of course excludes the first variable in our models, which is the direct net cost of the policy observation, which *can* be a scalar. In our analysis, we tested this variable as a scalar, and found it to be non-significant. This is the case, mainly because of our unit of analysis. It is particularly problematic, for example, to compare a high direct cost mitigation option for a state like South Carolina (which may have a high percent change impact on GSP for that option), with a high direct cost mitigation option for the US economy as a whole. We also considered translating those figures into percent change figures like our dependent variable; however, doing so for future years would require the use of unofficial GSP predictions for many states, which would introduce unwanted bias. Similarly, doing so would exclude about a quarter of our overall observations because exact levels figures for direct costs are unavailable

Table 4: OLS Regression Analysis of Percent Change in GDP/GSP

	Model 1	Model 2
Positive Costs	−0.75*	−0.7*
	(−2.31)	(−2.23)
Substitution Effects	−0.81**	−0.40
	(−2.59)	(−1.31)
Nuclear	−1.54**	−1.56**
	(−3.84)	(−3.54)
Investment Addition	0.75*	0.67
	(2.13)	(1.92)
Offsetting Effects		−1.51**
		(−2.85)
Revenue Recycling		0.26
		(0.56)
Electricity Displacement		−0.12
		(−0.40)
Intercept	0.43	1.59
R^2	0.58	0.66
F-statistic	10.06**	7.41**

** $\alpha < 0.01$, * $\alpha < 0.05$, t-values in parentheses, based on White's robust standard errors.

Investment Addition is a binary regressor, which takes a value of "1" if the parameters of the study are such that, investment in GHG mitigation policies are additive to the economy. This parameter takes a value of "0" if they are assumed to displace existing investment. *Nuclear* is binary as well, and takes a value of "1" if the study includes nuclear as a policy option for meeting mitigation targets. Model 1 has relatively strong summary statistics as indicated by the coefficient of determination (R^2); the model explains almost 60 percent of the variance in economic impacts on GDP/GSP across all cases analyzed. The model also has a strong F-statistic, indicating that the model has included a proper set of independent variables.

The inference that can be drawn from Model 1 is that climate mitigation measures that are identified to be cost-incurring result in generally negative impacts to a state or national economy. On average, policy options that are assessed positive costs result in a ¾ percentage point decrease in GDP/GSP, holding all other variables constant at their mean. On the other hand, this also indicates that policy options identified as cost-saving achieve a direct positive impact of ¾ percent on GDP/GSP, on the average.

The other two coefficients of Model 1 pertain to modeling assumptions inherent to a study's macroeconomic analysis. On average, policy options from

or unreported in many of these sorts of studies. In sum, scale variables are desirable but not possible in a meta analysis of this kind because of the relative size disparities across large and small regional and national macroeconomies, limitations of official GDP/GSP forecasts at those levels, and limitations in reported cost figures in many macro studies.

studies that include substitution effects produce a 0.81 percentage point decrease in GDP/GSP. On the other hand, policy options from studies that include investment addition as a modeling assumption lead to, on average, a ¾ percent increase in GDP/GSP. One inference that can be drawn from these results is that investment in climate mitigation technology, when additive to a state or national economy has a stimulating effect that, in studies analyzed, is almost large enough to overcome the costs associated with substituting toward more costly and less carbon-intensive forms of production.

Another inference that can be drawn from Model 1 is that the use of nuclear electricity generation in a state, regional or national mitigation policy can dramatically push the overall macroeconomic impacts in a negative direction. Studies of mitigation policies that include nuclear find on average, more than a 1.5 percent drop in GDP/GSP overall with the coefficient being highly significant. There are potentially two reasons for this. First, nuclear power is a relatively expensive policy option, and as such would otherwise be expected to raise costs and have a negative impact on a state's economy. Second, studies that commonly show negative impacts tend to include this option. Whereas the first reason is intuitive, our analysis also supports the second. Cross tabulation indicates that of the 37 observations in our analysis, 13 included nuclear. Of those 13, 10 cases were from observations that generated negative impacts.

5.2 Extended Form Statistical Model

Table 4 also provides the results of an extended form linear model. Model 2 includes three additional regressors, *Offsetting Effects, Revenue Recycling* and *Electricity Displacement.* These three are also binary regressors. Offsetting effects takes a value of "1" if these effects are included in the study. Revenue recycling takes a value of "1" if the model allows for tax or auction revenue generated from the policy option to be returned to ratepayers. Electricity displacement takes a value of "1" if the model allows for the displacement of generated electricity from neighboring states or across state lines.

The extended form model (Model 2) retains much of the same inference of the reduced form model. Three of the original four regressors remain roughly equivalent in magnitude and statistical significance, with the exception of *Substitution Effects*, which is suppressed in both magnitude and standard error. One possible cause for this is potential collinearity between added regressors of the extended form model and *Substitution Effects*. This was evaluated however, and there exists a small degree of collinearity between it and *Offsetting Effects* ($\rho = 0.42$); however this was not of sufficient magnitude to warrant elimination from the model.

Offsetting Effects have a significant and negative impact on GDP/GSP (−1.51 percent) on the average, holding all other variables constant at their mean. As discussed above, offsetting effects can often have dampening impacts on the demand side. Revenue recycling on the other hand is positive but usually not significant. Intuitively, policy options that return GHG tax or GHG auction revenue to ratepayers will have less of a dampening impact than those that do not; however, only 6 (of 37) observations include revenue recycling, and 5 of those 6 observations also include offsetting effects.[4] Therefore, the coefficient is in the expected direction; however, it falls short of statistical significance because of characteristics inherent to the sample.

The coefficient for *Electricity Displacement* is also in the expected direction; however, it also falls short of statistical significance. Intuitively, the displacement of electricity across state lines constitutes leakage, and can have a dampening impact on a state's economy. It can also have a slight stimulating effect on a state's economy if imported electricity generates a savings because neighboring states use more efficient production or cheaper fuels. In that case, electricity displacement represents a cheap substitute and produces a savings. In our analysis there are a total of 27 policy options that allow for electricity displacement. Stakeholder groups identify 10 of those 27 (or 37%) to constitute cost-savings (negative costs). Because both of these competing effects occur simultaneously and differ by context (state by state, or region by region), this coefficient is not statistically significant.

6. QUANTILE REGRESSION ANALYSIS

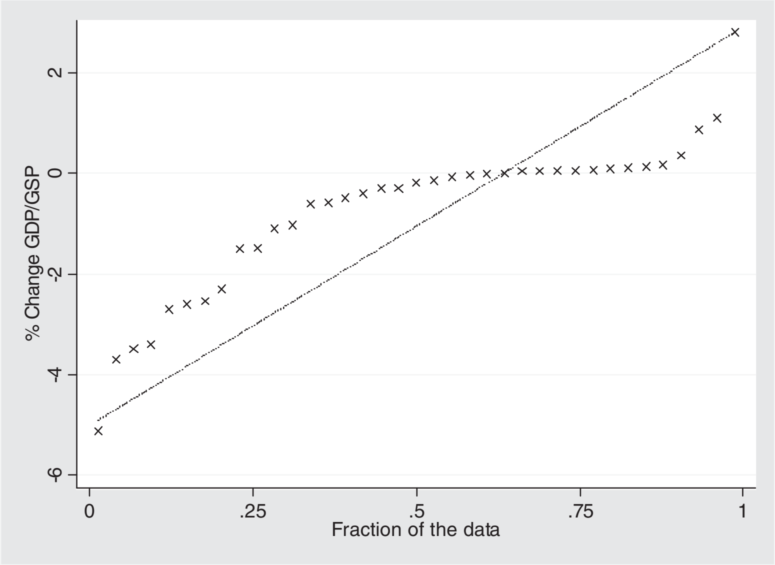
The statistical analysis of climate impact studies provided here warrants further inquiry through alternative statistical models. Frequently the most parsimonious statistical model provides the greatest explanatory power, but scrutiny is warranted.

On occasion, researchers find themselves in the middle of intractable debates among dialectally opposed camps. We believe this to also be the case for economic analyses of climate mitigation policy. On one side, there are researchers who find that climate change mitigation policies are potentially damaging to economic output or employment because they minimize the economic incentives to utilize cheap fuels or production processes that are carbon and energy-intensive. On the other side, there are researchers who find that climate mitigation policies can be productive to an economy overall, because they can induce key capital investments, technological improvements, and more energy-efficient outcomes.

Because of this natural schism among researchers, meta-analytic methods should evaluate the sensitivity of impacts given the predisposition of the studies analyzed. To accomplish this, we employ quantile regression analysis. To date, no comprehensive meta-analysis of climate change mitigation policy includes this approach.

4. Most studies are vague about the use of tax or auction revenues. Clearly recycling (whether in terms of lump sum transfers or tax reduction) is more stimulating in the short-run than is the use of these revenues for deficit reduction.

Figure 2: Quantile Plot of Percent Change in GDP/GSP



Quantile regression is similar to Ordinary Least Squares regression in that there is a continuous dependent variable evaluated asymptotically. However, rather than evaluate the impact on the mean of that dependent variable given parameter changes in the estimating equation, quantile models evaluate changes in the dependent variable at varying points on the distribution of the dependent variable (quantiles) within that dependent variable's range.

This allows us to evaluate the impact of macroeconomic assumptions on the full range of economic impacts within our dependent variable. We can now evaluate the impact of modeling assumptions (e.g. Investment Addition) on studies that find significant negative GDP/GSP impacts separately from those that find significant positive GDP/GSP impacts. This means that we can evaluate the impact of investment addition on studies within the 95th percentile (or any other) of GDP/GSP impacts, and not be limited to inference based on the "mean" climate economic impact analysis of the ordinary approach.

For the sake of equivalence and comparison, we evaluate Models 1 and 2 via quantile regression. The reduced form model (Model 1) is given by: $Q_\tau(\%\Delta GDP/GSP) = \alpha + \beta_1(Positive\ Costs) + \beta_2(Substitution\ Effects) + \beta_3(Nuclear) + \beta_4(Investment\ Addition) + \varepsilon$. The extended form model (Model 2) is given by: $Q_\tau(\%\Delta GDP/GSP) = \alpha + \beta_1(Positive\ Costs) + \beta_2(Substitution\ Effects) + \beta_3(Nuclear) + \beta_4(Investment\ Addition) + \beta_5(Offsetting\ Effects) + \beta_6(Revenue\ Recycling) + \beta_7(Electricity\ Displacement) + \varepsilon$. The quantiles that we evaluate are $\tau = (0.5, 0.25, 0.5, 0.75, 0.95)$, or the 5th, 25th, median, 75th and 95th quantiles, respectively.[5] Our results were produced using R-project software (Koenker 2010).

The OLS models provided in Section 5, are more sensitive to outlying observations (e.g., BHI, 2008; McKinsey, 2009). OLS regression is, in general, more sensitive to outliers than median quantile regression ($\tau = 0.5$), because OLS minimizes the sum of squared residuals, whereas median quantile regression minimizes the sum of absolute residuals. Figure 2 above provides a quantile plot of our dependent variable. OLS regression would tend to sample less heavily those observations along the intersection point—about the 65th percentile.

Table 5 provides the results for both the reduced and extended form quantile models. The standard error estimation method for quantile models in R is typically considered to be more accurate than in competing statistical software packages. Note that the estimation of our models in Stata 10 yielded smaller standard errors and larger t-values for most coefficients and most τ parameters.

The variable *Positive Costs* is roughly equivalent in magnitude and significance to both OLS models, at most quantiles. In both the reduced and extended form models, *Positive Costs* have the largest and most statistically significant impact on extreme quantiles ($\tau = 0.5$ and 0.95). This indicates that climate change mitigation policies that are assessed positive costs by stakeholder groups are less likely to result in negative macroeconomic impacts for studies that find little to no change in the macroeconomy. This is intuitive. However, what is less intuitive is why this coefficient remains large and significant at higher quantiles. The inference that can be drawn from this is: some of those studies that generally find positive macroeconomic impacts from climate mitigation policies still yield negative macro impacts from positive cost policy options. This would tend to lend credence to those studies that have found overall positive macroeconomic impacts, as this shows that their analyses are consistent with stakeholder assessments but also conscientious to the fact not all policy options will result in positive macro impacts.

On the other hand, the variable *Nuclear*, which is consistently negative, tends to be most statistically significant and largest in magnitude at the lowest quantiles. When included in a climate change mitigation policy, it is intuitive that nuclear electricity generation is a costly policy option, mainly due to the liability and regulatory costs associated with its implementation. The fact that it is large in magnitude and statistical significance for those studies that assess largely negative macroeconomic impacts would tend to lend credence to those studies that typically assess negative macroeconomic impacts. On the whole, those studies tend to favor nuclear generation as a policy option, but they still attribute large negative macroeconomic impacts to nuclear policy options. In comparison to the coefficient for direct cost across equivalent quantiles, the impact of nuclear generation can be as much as four and a half times larger in magnitude than positive

5. See Koenker and Bassett (1978), Koenker and Hallock (2001) and Koenker (2005) for detailed descriptions of quantile regression models.

Table 5: Quantile Regression Analysis of Percent Change in GDP/GSP

	Model 1					Model 2				
Positive Costs	–0.56**	–0.58*	–0.35	–0.26	–0.82**	–1.61**	–0.58*	–0.26	–0.29	–0.82**
	(–2.98)	(2.42)	(–0.93)	(–0.51)	(–2.66)	(–5.25)	(–2.07)	(–0.89)	(–1.70)	(–4.11)
Substitution Effects	–0.04	–0.13	–0.81**	–0.57	–2.05**	0.01	–0.13	–0.21	–0.21	–0.21
	(–0.21)	(–0.54)	(–2.11)	(–1.11)	(–6.63)	(0.02)	(–0.42)	(–0.66)	(–1.12)	(–0.95)
Nuclear	–2.58**	–2.24	–1.46**	–1.10*	–0.04	–2.97**	–2.24**	–1.90**	–1.20**	–0.05
	(–13.79)	(–9.58)	(–3.89)	(–2.20)	(–0.15)	(–8.64)	(–7.27)	(–5.94)	(–6.43)	(–0.21)
Investment Addition	1.93**	0.55	0.54	0.49	0.17	0.63*	0.55*	–0.02	0.14	0.05**
	(10.81)	(2.47)	(1.50)	(1.04)	(0.60)	(2.11)	(2.01)	(–0.08)	(0.86)	(2.52)
Offsetting Effects						–3.01**	–1.58**	–1.98**	–2.28**	–1.71**
						(–5.05)	(–2.92)	(–3.52)	(–6.92)	(–4.39)
Revenue Recycling						–0.05	–0.09	0.10	0.10	0.10
						(–0.12)	(–0.27)	(0.26)	(0.46)	(0.38)
Electricity Displacement						0.34	0.01	–0.23	–0.32	–0.36
						(0.96)	(0.03)	(–0.68)	(–1.61)	(–1.52)
Intercept	–1.93**	–0.45	0.32	0.43	2.80**	2.07**	1.12**	2.28**	2.70**	2.70**
	(–9.58)	(–1.85)	(0.83)	(0.82)	(8.83)	(3.55)	(2.13)	(4.15)	(8.39)	(7.09)
τ	0.05	0.25	0.5	0.75	0.95	0.05	0.25	0.5	0.75	0.95

** $\alpha < 0.01$, * $\alpha < 0.05$, t-values in parentheses. Model results produced using Project R software (Koenker, 2010).

direct costs. If the coefficients for *Nuclear* were significant at the 95th quantile, it would suggest that those studies that assess overall positive economic impacts are most amenable to nuclear policy options. Although this is highly counterintuitive, the opposite, which is equally counterintuitive, is affirmed by these results: those studies that assess overall negative economic impacts are least amenable to nuclear electricity generation.

Evaluation of the coefficients for *Investment Addition* is also insightful. The quantile regression results suggest that investment addition has the most significant and positive impact for those studies that result in the most negative macroeconomic impacts. As mentioned above, the impact from additive investment can go either way, because of its potential reciprocal relationship with consumption. Additive investments that lead to efficiency gains that have dampening effects on the economy (e.g., lower demand for electricity or fuel) can still lead to increased consumption in other sectors (e.g., building retrofits). It would seem, therefore, that the assumption of investment addition has its most positive macroeconomic impact where the most negative macroeconomic impacts are found. Its coefficient is both large and robust about the lowest quantiles.

As discussed in Section 5 above, *Offsetting Effects* can also have both a positive and a negative impact on the study's overall assessment. These effects have the most robust negative impacts on studies within the lowest quantiles, although they have robust negative impacts at nearly all quantiles. Also of note, *Revenue Recycling* and *Electricity Displacement* carry the expected sign in all but the lower quantiles. Although short of statistical significance, these coefficients suggest that, where positive macroeconomic impacts are found, revenue returned to consumers and ratepayers has a neutral or stimulating effect on the economy. They also suggest that, where positive macroeconomic impacts are found, the displacement of in-state electricity generation does not have a stimulus effect.

7. THE EFFECT OF MODELING STRUCTURE AND ASSUMPTIONS ON RESULTS

To illustrate the effect of macroeconomic modeling approaches, data, assumptions, linkages, and macro impact results, we will elaborate on two key studies contained within this meta-analysis. One study yields negative impacts of climate change policy on the macroeconomy, and the other yields some positive impacts. CRA International, under the authorship of David Montgomery et al. (2009), performs the first of these studies. The study examines the effect of the Waxman-Markey American Clean Energy and Security Act of 2009 (ACESA or H.R. 2454). It makes use of CRA's multi-regional model of the U.S. known as the Multi-Sector, Multi-Region Trade Model (MS-MRT), the Multi-Regional National Model (MRN), and the North American Electricity and Environment Model (NEEM). The first model is basically a combined CGE/econometric model, the second a multi-regional CGE model with international linkages, and the third an electricity sector, technology-specific model. The first two models have gone through significant peer review and are considered among the leaders in the field. Any criticism of the results therefore must rest more on the data and assumptions used and the manner in which macro linkages are specified.

Although the authors do perform sensitivity analyses, their basic energy data base projections are highly dependent on the U.S. Energy Information Administration (EIA), which has traditionally been considered to perform relatively pessimistic evaluations of energy efficiency and renewable technologies. In addition, the analysts note some of the duplicative aspects of the Waxman-Markey Bill that would likely increase its compliance costs.

Such findings are thus likely to call for greater scrutiny and a streamlining of what causes unnecessary expenditures. The model essentially includes all of the major macro linkages. However, assumptions relating to some of them are extreme, especially one on the crowding-out effect of investment in mitigation and sequestration. The authors are also critical of the cap and trade approach to implementing much of the legislation because it raises more uncertainty about the future costs than would a carbon tax. An indication of the pessimistic nature of the key data input to the model is the CRA projection of the allowance price of $124/metric ton CO_2e in the year 2050.

Another study of the impacts of mitigation policy by Hanson and Laitner (2006), which uses Argonne National Laboratory's excellent AMIGA model, a state of the art computable general equilibrium model of 21 world regions, to analyze the impact of refining technology policy to reduce the investment requirements of meeting long-term climate stabilization goals. The model is based on an extensive and detailed analysis of individual technologies in relation to U.S. EPA studies. Again, it should be noted that EPA estimates are traditionally considered more optimistic about the future costs of renewables and energy efficiency. The analysis focuses on issues of investment levels and displacement, and how technology policy and mitigation policy design can lower investment requirements to a very low level and can mute negative impacts on GDP, so that they are trivial, and in some cases even positive. Thus, two excellent models of very similar forms yield disparate results. The explanation must fall on differences in data inputs and assumptions, including those that affect model parameter values.[6,7]

6. Note that some study results are due to the severe limitations of less sophisticated models, such as input-output analysis. For example, Chamberlain's (2009) analysis does not allow offsetting effects to the cost increasing effect of mitigation options, such as the fact that any dampening effect will lower prices, thus causing some rebound in the economy. This is similarly the case in I-O studies that indicate a positive impact of climate mitigation policy on the macro economy, such as Pollin et al. (2009), which exclude offsetting effects that might somewhat offset these impacts.

7. Other studies yield some important insights into the importance of individual state conditions, such as whether a state is a major coal producer or importer. Rose and Wei (2006) analyzed the impacts of the displacement of coal-fired electricity generation by a combination of a 20 percent renewable portfolio standard (RPS) and a shift to natural gas-fired generation on the economies of each of the 48 continental states. The analysis was restricted in that it analyzed high levels of coal-fired displacement of 33 percent and 67 percent. Moreover, it assumed that the RPS mix projected

8. CONCLUSIONS

Climate change mitigation policies, such as cap-and-trade, carbon taxation, renewable portfolio standards (RPS), corporate average fuel economy standards (CAFE), low-carbon fuel standards, aforestation measures, etc., are hotly contested within both the scholarly and policy communities. Given this divergence, this paper has provided a meta-analytic approach to a comprehensive sample of climate mitigation studies, to identify how data inputs, assumptions, and causal mechanisms affect their outcomes. Key macroeconomic linkages were identified throughout the sample of studies that explain how two (or more) macroeconomic analyses of comparable policies can lead to fundamentally different predictions for the impact of those policies. This paper also elaborated on the modeling methodologies used across our meta sample, and how different macroeconomic modeling approaches (I-O, CGE, and ME) can lead to fundamentally different results because of the differences between microeconomic foundations of macroeconomic relationships.

This paper has also spoken to the divide that exists among scholars of climate mitigation policy. On one side, climate mitigation measures are said to be ultimately damaging to the macroeconomy because of their elimination of cheap fuels or negative externalities in production processes. On the other side, climate mitigation measures are said to promote a more productive macroeconomy, because they can induce key capital investments, technological improvements, and energy-efficiency. A quantile regression analysis of a comprehensive meta sample was performed, that highlights the nature of those assumptions and economic linkages across this ideological divide.

Several key findings were provided. Those mitigation measures that are identified by stakeholder working groups or cost-engineering reports as cost incurring (positive cost) policies lead to an average impact of ¾ percent reduction in GDP/GSP. These impacts become most extreme at both ends of the ideological divide. Key economic linkages such as substitution and offsetting effects, and investment addition were also evaluated. While investment addition has an overall positive macroeconomic impact across all studies, its affects are most profound on those studies that assess negative macroeconomic impacts. And, nuclear power, which is typically a high cost option, has its least negative impacts for those studies that find economic benefits in climate mitigation measures.

for 2015 was an extrapolation from each state's conditions at the time of the writing, rather at a least-cost mix. In addition, gas prices were based on EIA estimates. Even with these data and assumptions that push the results toward negative macro impacts, the report did identify ten states for which the move away from coal-fired generation would yield overall positive macroeconomic outcomes. The distinguishing characteristic was not surprising: major coal producing states typically were projected to lose, while states that do not have any coal mining jobs to lose and for which geographic conditions favored renewables like solar and wind stood to gain. We could not enter the "coal state" variable into our meta-analysis below because several jurisdictions in the various studies could not readily be labeled as "coal" versus "non-coal" (e.g., the Susquehanna River Basin and the U.S. as a whole).

It is important to note that one should not dismiss the findings of this paper as simply stating the fact that assumptions drive results. Assumptions do ultimately have a significant impact on results in macroeconomic impact studies; however, this paper has shown that assumptions often work in counterintuitive ways. Those economic assumptions that would otherwise drive the most negative findings are often most key for those studies that reach the most optimistic conclusions. And, the opposite is sometimes true. Moreover, our analysis has identified the extent to which some assumptions are relatively much more important than others in driving results on the economic impacts of climate action plans.

REFERENCES

Barker, T., and K. Jenkins. (2007). "The Costs of Avoiding Dangerous Climate Change: Estimates Derived from a Meta-Analysis of the Literature." United Nations Human Development Report 2007/2008.

Barker, T., J. Kohler and M. Villena. (2002). "Costs of Greenhouse Gas Abatement: Meta-Analysis of Post-SRES Mitigation Scenarios." *Environmental Economics and Policy Studies* 5: 135–166.

Bezdek, R., and R. Wendling. (2003). "Potential Long-term Impacts of Changes in US Vehicle Fuel Efficiency Standards." *Energy Policy* 33: 407–419.

Borenstein, M., L.V. Hedges, J.Higgins and H.R. Rothstein. (2009). *Introduction to Meta-Analysis*. West Sussex, UK: John Wiley and Sons.

Chamberlain, A. (2009). "Who Pays for Climate Policy? New Estimates of the Household Burden and Economic Impact of a US Cap-and-Trade System." Tax Foundation Working Paper No. 6.

Eldridge, M., S. Watson, M. Neubauer, R.N. Elliott, A. Korane, J. "Skip" Laitner, and V. McKinney. (2008) "Energizing Virginia: Efficiency First." American Council for Energy Efficient Economy (ACEEE) Report Number E085, September.

Electric Reliability Council of Texas. (2009). "Analysis of Potential Impacts of CO_2 Emissions Limits on Electric Power Costs in the ERCOT Region." May.

Granade, H.C., J. Creyts, A. Derkach, P. Farase, S.Nyquist, and K. Ostrowski. (2009). "Unlocking Energy Efficiency in the U.S. Economy." McKinsey Global Energy and Materials.

Greene, D.L., J.R. Kahn, and R.C. Gibson. (1999). "Fuel Economy Rebound Effect for U.S. Household Vehicles." *Energy Journal* 20(3): 1–31.

Hanson, K. and J. Laitner. (2006). "Technology Policy and World Greenhouse Gas Emissions in the AMIGA Model." *Energy Journal* 27(Hybrid Modeling Special Issue): 355–71.

Koenker, R. (2005). *Quantile Regression*. New York: Cambridge University Press.

Koenker, R. and G. Bassett. (1978). "Regression Quantiles." *Econometrica* 46: 33–50.

Koenker, R. and K.F. Hallock. (2001). "Quantile Regression." *Journal of Economic Perspectives* 15(4): 143–156.

Koenker, R. (2010). "Quantreg: Quantile Regression Package for R-Project Software." Available at: http://cran.rproject.org/web/packages/quantreg/index.html

Lipsey, M.W. and D.B. Wilson. (2001). *Practical Meta-analysis.* Thousand Oaks, CA: Sage Publications.

Maggioni, E. (2008). "The Rebound Effect: Summary of Findings." School of Policy, Planning and Development, USC, Los Angeles, California.

Management Information Services, Inc. (2008a). "Potential Impact of Florida's Greenhouse Gas Reduction Mandates in North Carolina on the State's Economy, Jobs, and Industry." Prepared for American Coalition for Clean Coal Electricity.

Management Information Services, Inc. (2008b). "Potential Impact of South Carolina's Greenhouse Gas Reduction Plan on that State's Economy and Jobs." Prepared for American Coalition for Clean Coal Electricity.

Minnesota IMPLAN Group (MIG). (2010). http://www.implan.com

Montgomery, W.D., J. Plewes, A. Smith, and S. Tuladhar. (2007). "Economic Analysis of Florida's Executive Order 07-127." Charles Rivers Associates. Prepared for Florida Chamber of Commerce and U.S. Chamber of Commerce.

Montgomery, W.D., R. Baron, P. Bernstein, S. Bloomberg, K. Ditzel, L. Lane, A. Smith, S. Tuladhar, and M. Yuan. (2009). "Impact on the Economy of the Clean Energy and Security Act of 2009 (H.R. 2454)." Charles Rivers Associates. Prepared for the National Black Chamber of Commerce.

Oladosu, G. and A. Rose. (2007). "Income Distribution Impacts of Climate Change Mitigation Policy in the Susquehanna River Basin Economy." *Energy Economics* 29: 520–544.

Paltsev, S., J.M. Reilly, H. D. Jacoby and J.F. Morris. (2009). "The Cost of Climate Policy in the United States." MIT Joint Program on the Science and Policy of Global Change, Report No. 173.

Pollin, R., J. Heintz, and H. Garrett-Peltier. (2009). "The Economic Benefits of Investing in Clean Energy." Department of Economics and Political Economy Research Institute, University of Massachusetts, Amherst.

Ponder, D. J. Tiller and J. Hoyle. (2008). "Secondary Economic Impact Analysis of Greenhouse Gas Mitigation Options for North Carolina." Prepared for the Center for Climate Strategies. The Appalachian State University Energy Center.

Prindle, W. R., A. M. Shipley and R. N. Elliott. (2006). "Energy Efficiency's Role in a Carbon Cap-and-Trade System: Modeling Results from the Regional Greenhouse Gas Initiative." American Council for an Energy-Efficient Economy (ACEEE) Report Number E064, May.

Repetto, R., and D. Austin. (1997). "The Costs of Climate Protection: A Guide for the Perplexed." Washington, DC: World Resources Institute.

Roland-Holst, D. and Karhl, F. (2009). "The Florida Economy and a Federal Carbon Cap: A Quantitative Analysis." Department of Agricultural and Resources Economics Working Paper, University of California, Berkeley.

Rose, A. (1996). "Input-Output Economics and Computable General Equilibrium Models." *Structural Change and Economic Dynamics* 6: 295–304.

Rose, A. and D. Wei. (2006). "The Economic Impacts of Coal Utilization and Displacement in the Continental United States, 2015." The Pennsylvania State University, University Park, PA.

Rose, A. and D. Wei. (2010). "The Economic Impact of the Florida Energy and Climate Change Action Plan on the State's Economy," *Climate Policy,* forthcoming.

Rose, A. and W. Miernyk. (1989). "Input-Output Analysis: The First Fifty Years." *Economic Systems Research* 1(2): 229–271.

Ross, M., B. Murray, R. Beach, and B. Depro. (2008). "State-level Economic Impacts of a National Climate Change Policy." Pew Center on Global Climate Change. White Paper.

Science Applications International Corporation (SAIC) (2008). "Analysis of The Lieberman-Warner Climate Security Act (S.2191) Using The National Energy Modeling System (NEMS/ACCF/NAM)." Prepared for the American Council for Capital Formation and the National Association of Manufacturers.

Tuerck, D., P. Bachman, A. Sanchez-Penalver, and M. Head. (2008). "The Economics of Climate Change: Proposals in South Carolina." The South Carolina Policy Council in cooperation with The Beacon Hill Institute, Suffolk University.