# DO STATE-LEVEL RPS POLICIES IN THE U.S. DELIVER ANTICIPATED BENEFITS? EXAMINING THE IMPACT OF FEDERALIZED ENERGY AND ENVIRONMENT POLICY ON ELECTRICITY PRICE AND QUANTITY, USE OF RENEWABLES, AND CARBON EMISSIONS

by

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# ABSTRACT

JOSEPH ALLEYN COCHRAN. Do state-level RPS policies in the U.S. deliver anticipated benefits? Examining the impact of federalized energy and environmental policy on electricity price and quantity, use of renewables, and carbon emissions (Under the direction of DR. PETER SCHWARZ)

In this dissertation, I present the findings of a formative evaluation of the changes in the electricity markets of states that implemented renewable portfolio standards (RPS policies) from 2000 to 2010. The formative evaluation is an assessment of the consequences of RPS policies that I conducted for adopting states that were still implementing their RPS policies. Using governmental data as my primary sources, I estimated the changes in carbon intensity within adopting states. I also examined the changes attributable to RPS policies in electricity prices, electricity revenues, electricity production, carbon dioxide emissions, and renewable electricity production within adopting states in order to gain a more detailed understanding of the changes in the electricity markets of adopting states caused by RPS policies. Using OLS regressions and path analysis models, I found these policies have not yet improved the electricity markets of adopting states by significantly reducing carbon intensity from 2000 to 2010, in sharp contrast with the expectations reported in the professional literature.

# DEDICATION

I wish to dedicate my dissertation to Zaarah, which I could have never finished without her endless patience with my delays and her tireless efforts on my behalf to edit my dissertation.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| C | carbon dioxide emissions |
| CDD | cooling degree-days |
| CI | carbon intensity |
| DGC | Democratic Governor control |
| DHC | Democratic House control |
| DSC | Democratic Senate control |
| DSIRE | Database of State Incentives for Renewables & Efficiency |
| EIA | Energy Information Agency |
| M | conversion from W-h to MW-h |
| MDT | mandatory |
| MW-h | megawatt-hour |
| NG | natural gas generation |
| N.C. | North Carolina |
| OE | other alternative electricity production |
| OLS | ordinary least squares |
| P | electricity price |
| PCA | per capita area |
| PCI | per capita income |
| POP | population |
| Q | electricity quantity |
| R | electricity revenue |

| | |
|---|---|
| RE | renewable electricity index |
| REC | renewable energy credit |
| RPI | RPS index |
| RPP | RPS percentage |
| RPS | renewable portfolio standards |
| RPT | RPS trading |
| RST | RPS stringency |
| SE | solar electricity production |
| VIF | variance inflation factor |
| W-h | watt-hour |
| WE | wind electricity production |

# CHAPTER 1: INTRODUCTION

Renewable portfolio standards (RPS policies) are environmental policies designed to facilitate the adoption of energy efficiency and the production of renewable electricity within adopting states (Brown, Sovacool & Hirsh, 2006). RPS policies are usually mandatory policies that states voluntarily adopt to further their environmental goals (Brown, York & Kushler, 2007). The majority of states adopted RPS policies voluntarily after the passage of the Energy Policy Act (EPAct) of 2005 (Lyon & Yin, 2010; Yin & Powers, 2010).

The central problem addressed in my study is whether RPS policies have had an effect on adopting states during the first years of RPS policy implementation. To investigate the problem, I performed a formative evaluation of the effects of RPS policies on electricity markets of adopting states from 2000 to 2010. A formative evaluation is an assessment that occurs during the implementation of a policy. I examined electricity prices (price), electricity revenues (revenue), electricity production (quantity), carbon dioxide emissions (emissions), and carbon intensity (carbon intensity) as the dependent variables of my study.

I used carbon intensity as the central characteristic of electricity markets to determine the effects of RPS policies on adopting states because it represented the total environment cost attributable to those policies. I measured carbon intensity as the number of metric tons of carbon dioxide generated within a state per MW-h of electricity produced within that state. I present the total environmental cost attributable to RPS policies within adopting states in Chapter 4.

Carbon intensity would decrease if the energy efficiency and the renewable electricity production attributable to the RPS policies replaced the production of electricity from high-carbon emitting sources. While replacing low carbon emitting sources would be marginally beneficial, RPS policies would realize their greatest effectiveness by displacing electricity production from high-carbon emitting sources (Lyon & Yin, 2010). However, states designed RPS policies to facilitate adoption rather than targeted displacement, so their effectiveness is dependent on the demand for electricity rather than the efficacy of energy efficiency or renewable electricity production (Yin & Powers, 2010).

The formative evaluation consists of ordinary least squares (OLS) regressions and path analysis models. I designed the OLS regressions to evaluate the influence of RPS policies on adopting states and to estimate the effect of renewable electricity production on producing states. I created the path analysis models to assess the influence of renewable electricity production and to quantify the effects of energy efficiency within adopting states. The synthesis of these two approaches allowed me to evaluate the results of RPS policies, the influence of renewable electricity production and the effects of energy efficiency within the framework of the dissertation.

The states that adopted RPS policies had already been successful in implementing previous environmental policies that had successfully mitigated emissions (Lyon & Yin, 2010; Yin & Powers, 2010). In 2000, adopting states already possessed lower emissions than non-adopting states, though the majority of them would not adopt RPS policies until after 2005. The previous successes of adopting states might mean that RPS policies may not cause significant reduction in emissions because these states already possessed effective carbon dioxide mitigation policies (Sovacool, 2008). These policies successfully reduced emissions because they promoted energy efficiency and renewable electricity production (DSIRE, 2013; Reddy, 2013). I present the comparison of emissions between adopting and non-adopting states in Figure A4 in Appendix A.

North Carolina (N.C.) portrays one example of a state that adopted an RPS policy. The N.C. RPS policy became law on August 20, 2007. The law required corporate electrical utilities to produce 12.5% of their electricity with renewable energy sources by 2021. Electrical cooperatives and municipal suppliers were required to produce 10% of their electricity with renewable energies by 2018 (DSIRE, 2013; Gaul & Carley, 2012).

Most of the state governments within the United States did not adopt RPS policies until the middle of the 2000s (Yin & Powers, 2010). Early adopting states introduced RPS policies in an attempt to deal with their production of carbon dioxide emissions (Johnson, 2014; Owen, 2004). In 2005, the federal government of the United States passed the Energy Policy Act of 2005 (EPAct). The EPAct of 2005 facilitated the adoption of RPS policies by augmenting the subsidies provided by the states with incentives from the U.S. government (Yin & Powers, 2010).

The U.S. government offered incentives to reduce the effective cost of RPS policy adoption (Carley, 2009; Van Nostrand & Hirschberger, 2010). However, EPAct (2005) did not make the adoption of RPS policies mandatory (Stone, 2009), and left most of the design and the implementation of these policies up to individual adopting states (Carley & Miller, 2012; Motl, 2010). Figure 1.1 shows the extent of RPS adoption in 2010.

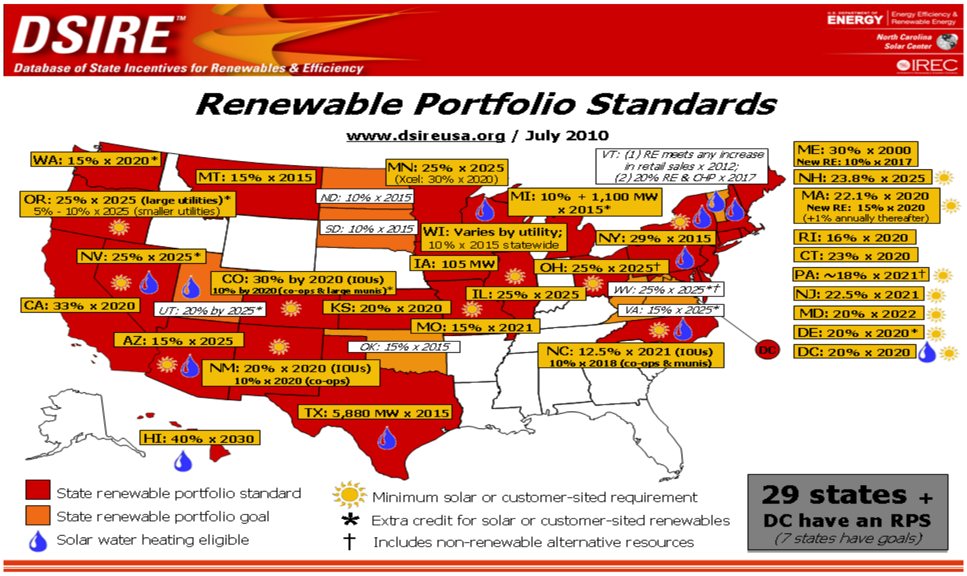


Figure 1.1: Renewable portfolio standards (DSIRE, 2013)

Notes: I treated Oklahoma and West Virginia as states that have adopted mandatory RPS policies because their goals were similar to RPS policies. I treated North Dakota as a non-adopting state because its aims were even weaker than the four voluntary RPS states. I excluded voluntary states from the dataset of the study because their inclusion did not affect the overall results.

In 2010, most of the states that adopted RPS policies were located on the East Coast, around the Great Lakes and on the Pacific Coast. Most of the non-adopting states were Southern states. A few western states did not adopt RPS policies, as did Alaska.

## 1.1: Renewable Portfolio Standards

### 1.1.1: Purpose of RPS Policies

Although the stated aims of RPS policies were to address concerns about climate change by facilitating energy efficiency and renewable electricity production, states adopted RPS policies for a variety of other reasons (Lyon & Yin, 2010; Yin & Powers, 2010). In some cases, states used the promise of increased employment as their primary reason for adopting RPS policies (Leon, 2013). In other cases, states desired to reduce the average cost of energy efficiency and renewable energy by promoting a greater market than would have occurred without them taking action (Buckman, 2011; Tanaka & Chen, 2013). In yet other cases, states adopted RPS policies to force the United States government to adopt stricter environmental standards (Carley & Miller, 2012).

In this study, I consider the stated aims of RPS policies as the primary goals of the states that adopted them, so I focus on the effects of RPS policies on adopting states. Although other important reasons for the adoption of these policies existed, these reasons were secondary to the central focus of the study: a formative evaluation of the consequences of the implementation of the RPS policies. I examined the results of that implementation on the electricity markets and on the renewable electricity production of adopting states from 2000 to 2010.

### 1.1.2: Anticipated Influences of RPS Policies

According to the predictions of the professional literature, I anticipated that RPS policies would affect the electricity markets of adopting states. For example, I expected to see higher price and lower quantity and emissions. First, price would increase because of the added costs of adopting energy efficiency and renewable electricity production (Briggs & Gautam, 2012; Cappers & Goldman, 2010). Subsidies for renewable energy sources would reduce their unit costs; however, the overall cost to society would increase because of the need to address issues of intermittency and non-dispatchability. Second, the associated increase in price and the adoption of energy efficiency would reduce quantity (Carley, 2009; Carley & Miller, 2012). Finally, emissions would decrease because of the associated adoption of energy efficiency and renewable electricity production (Brown et al., 2007; Tra, 2011).

I assessed RPS policies with two other measures: revenue and carbon intensity. Revenue reflected the total economic costs of RPS policies to adopting states. Revenue would increase because of the inelastic nature of electricity demand; price would increase by more than production would decrease (Chen, Wiser, Mills, & Bolinger, 2009). Carbon intensity represented the total environmental costs attributable to RPS policies within adopting states. Carbon intensity would diminish because of the replacement of fossil fuels with energy efficiency or renewable energy production (Adetutu, 2014; Briggs & Gautam, 2012).

I selected carbon intensity as the central characteristic of electricity markets for the purpose of my study. Carbon intensity best reflected the stated intentions of RPS policies to reduce emissions because it represented a reduction in carbon dioxide emissions per unit of electricity production within a state (Briggs & Gautam, 2012; Lyon & Yin, 2010; Yin & Powers, 2010). The replacement of high-carbon carbon emitting sources with energy efficiency or renewable electricity production would decrease carbon intensity and would represent a successful RPS policy. I offer further explanation of the utility of using carbon intensity as the primary focus of the study in Chapter 3.

#### 1.1.2.1: RPS Policies, Renewable Electricity Production, and Energy Efficiency

I anticipated that RPS policies would influence electricity markets by increasing renewable electricity production within adopting states (Buckman, 2011; Kydes, 2007). I also expected that these policies would influence electricity markets by reducing the amount of electricity consumed within adopting states (Adetutu, 2014). The previous literature predicted that the combined effects of these two changes would reduce the consumption of high-carbon emitting sources for electricity production within adopting states (Duane, 2010; Johnson, 2014).

The three types of renewable electricity production facilitated by RPS policies were wind, solar and dispatchable technologies (DSIRE, 2013; EIA, 2013a). Wind included onshore wind and offshore wind (Dong, 2012; Riti, 2010). Solar included photovoltaic and solar thermal (Burns & Kang, 2012; Gaul & Carley, 2012). Dispatchable included biomass and geothermal (Aslani & Wong, 2014; Peterson, 2012). The development of hydroelectric power had reached the maximum production capacity in the United States by the timeframe of the dataset (2000 to 2010), so I excluded it from the study. Tidal energy and wave energy had yet to become economically viable sources of energy by the timeframe of the dataset (2000 to 2010), so I excluded them.

The examination of the effects of RPS policies on adopting states was central to my study. RPS policies functioned through facilitating energy efficiency and renewable electricity production. While a few states allowed their RPS policies to count energy efficiency as a form of renewable electricity production, I discovered that counting energy efficiency as a form of renewable electricity production did not have a significant effect on the results of my study.

My analysis would have to evaluate the effects of energy efficiency as well as those of renewable electricity production in order to understand the influence of RPS policies on adopting states. I designed the methodology of my study to evaluate the influence of renewable electricity production on adopting states and to quantify the effects of energy efficiency on adopting states by using path analysis models. I discuss the path analysis models in detail in Chapter 3.

1.1.2.3: Predicted Influences of RPS Policies

Adopting states developed RPS policies that reflected their underlying political consensuses (Lyon & Yin, 2010). Within my study, adopting states were states that possessed a non-zero value for the RPS variables during any year while non-adopting states were states that possessed a zero value for those variables for every year within the dataset. I attempted to control for the underlying political views of adopting states with the political control variables of my study. I sought to measure the influence of RPS policies on adopting states by testing the three hypotheses of the study. Each hypothesis was a compound of multiple hypotheses designed to examine the relationships between four independent variables and up to five dependent variables.

In the first hypothesis, I examined the results of RPS policies on the electricity markets of adopting states (price, revenue, quantity, emissions, and carbon intensity). The second hypothesis focused on the effects of RPS policies on renewable power production in adopting states (wind, solar, dispatchable, and renewable). I designed the third hypothesis to examine the outcomes of renewable electricity production on the electricity markets of producing states (price, revenue, quantity, emissions, and carbon intensity). I used the second and third hypotheses to create the path analysis models that quantified the influence of renewable electricity production and the effects of energy efficiency attributable to RPS policies. I discuss the variables of the hypotheses in further detail in Chapter 3, but I present an overview below.

The dependent variables of the first and third hypotheses were electricity price (price), electricity revenue (revenue), electricity production (quantity), carbon dioxide emissions (emissions) and carbon intensity (carbon intensity). The dependent variables of the second hypothesis were wind electricity (wind), solar electricity (solar), other alternative electricity (dispatchable), and renewable electricity index (renewable). The dependent variables of the second hypothesis serve as the connection between the first and second stage of the path analysis models.

The independent variables of the first and second hypotheses were RPS percentage (percentage), RPS stringency (stringency), RPS trading (trading) and RPS index (RPI). I tested each of these RPS variables within separate OLS regressions in order to avoid issues of multicollinearity. I operationalized each of the RPS variables in W-h per capita. RPI was the sum of percentage, stringency, and trading, and because there was no variance assumed between the component variables, the component variables of RPI could be included within the same OLS regressions while avoiding multicollinearity.

The independent variables of the third hypothesis were wind, solar, dispatchable, and renewable. I tested each of these renewable electricity production variables within separate OLS regressions to avoid issues of multicollinearity. I measured each of the renewable energy variables in W-h per capita. Renewable was the sum of wind, solar, and dispatchable and allowed for the inclusion of the three component variables within the same OLS regressions without the analysis causing multicollinearity.

The three groups of hypotheses are:

*H1*: The type of RPS policy (percentage, stringency, trading, or RPI) will influence the electricity markets of adopting states in the predicted directions (+price, +revenue, -quantity, -emissions, or -carbon intensity).

$H_2$: The type of RPS policy (percentage, stringency, trading, or RPI) will shape renewable electricity production within adopting states in the predicted directions (+wind, +solar, +dispatchable, or +renewable).

*H3*: Renewable electricity production (wind, solar, dispatchable, or renewable) will influence the electricity markets of producing states in the predicted directions (+price, +revenue, -quantity, -emissions, or -carbon intensity).

1.1.2.4: Path Analysis Models

RPS policies facilitated the adoption of energy efficiency and renewable electricity production in order to reduce carbon dioxide emissions (Fischer, 2009; Lyon & Yin, 2010). I designed the path analysis models of the study to evaluate the influence of renewable electricity production and to quantify to effects of energy efficiency on adopting states, as mentioned above. I found that it was the only way to quantify the changes in the electricity markets of adopting states caused by the energy efficiency attributable to RPS policies.

I divided the path analysis models into three stages. The first stage consisted of the influence of RPS policies on renewable electricity production, represented by the second hypothesis. The second stage comprised the effects of renewable electricity production on electricity markets, represented by the third hypothesis. I multiplied the coefficients of first stage by the coefficient of the second stage to calculate the mediating influence of renewable electricity production on adopting states. Within the third stage, I subtracted that mediating influence from the findings of the first hypothesis to quantify the effects of energy efficiency on adopting states. I discuss the path analysis models in further detail in Chapter 3.

1.1.3: Policies Facilitated by RPS Policies

Some of the professional literature interpreted RPS policies as relatively straightforward environmental policies because they encouraged the adoption of energy efficiency (Fischer, 2006; Fischer, 2009). Other researchers presented RPS policies as energy policies because they encouraged the production of renewable electricity (Lyon & Yin, 2010; Yin & Powers, 2010). Each policy vision appealed to different interest groups, facilitating the spread of these policies throughout the United States (Yin & Powers, 2010).

Table 1.1 shows the adoption dates, the implementation deadlines, and the minimum required renewable electricity production for states that adopted mandatory RPS policies. The adoption dates ranged from 1983 to 2010 and the implementation deadlines ranged from 1999 to 2030. The minimum required renewable electricity production ranged from 10% to 40%. Four of these states also allowed energy efficiency gains or renewable energy credits (RECs) to count towards their goals (Nevada, North Carolina, Oklahoma, and West Virginia). I found that the particular allowances of these four states did not alter the effects of their RPS policies, so I did not differentiate them from other adopting states. I discuss the influence of energy efficiency below.

Table 1.1: Adoption of mandatory RPS policies (DSIRE, 2013)

| State | Mandatory RPS Policy Adoption | Mandatory RPS Deadline | RPS Policy Goal |
|---|---|---|---|
| Arizona | 2007 | 2025 | 15% |
| California | 2003 | 2020 | 33% |
| Colorado | 2004 | 2020 | 30% |
| Connecticut | 1998 | 2020 | 23% |
| Delaware | 2005 | 2025 | 20% |
| District of Columbia | 2005 | 2020 | 20% |
| Hawaii | 2003 | 2030 | 40% |
| Illinois | 2007 | 2025 | 25% |
| Iowa | 1983 | 1999 | 105 MW |
| Kansas | 2009 | 2020 | 20% |
| Maine | 1999 | 2017 | 30% |
| Maryland | 2004 | 2020 | 20% |
| Massachusetts | 2002 | 2020 | 22.1% |
| Michigan | 2008 | 2015 | 10% + 1,100 MW |
| Minnesota | 2007 | 2025 | 25% |
| Missouri | 1998 | 2020 | 15% |
| Montana | 2005 | 2015 | 15% |
| Nevada | 1997 | 2025 | 25% |
| New Hampshire | 2007 | 2025 | 23.8% |
| New Jersey | 1999 | 2021 | 22.5% |
| New Mexico | 2004 | 2020 | 20% |
| New York | 2004 | 2015 | 29% |
| North Carolina | 2007 | 2021 | 12.5% |
| Ohio | 2009 | 2025 | 25% |
| Oklahoma | 2010 | 2025 | 15% |
| Oregon | 2007 | 2025 | 25% |
| Pennsylvania | 2004 | 2020 | 18% |
| Rhode Island | 2004 | 2019 | 16% |
| Texas | 1999 | 2015 | 5,880 MW |
| Washington | 2006 | 2020 | 15% |
| West Virginia | 2001 | 2025 | 25% |
| Wisconsin | 1999 | 2012 | 10% |

Source: Quantitative RPS Data by Database of State Incentives for Renewables & Efficiency (DSIRE), 2013. Retrieved from http://www.dsireusa.org/rpsdata/index.cfm

Table 1.2 shows the progression of implementation of RPS policies within adopting states. Most of them show a zero value because they do not have any firm requirements until after the adopting of EPAct in 2005. The majority of adopting states will not have RPS policies that will reach fruition until 2020.

The OLS regressions that I used for the study used states with ‘0’ values to provide a comparison between adopting and non-adopting states. Most of the cases covered within the timeframe of the dataset would have missing values if the study used a progression analysis. I designed my study to be as comprehensive as possible, so I did not use a progression analysis.

Table 1.2: Progression of RPS policies (DSIRE, 2013)

| State | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AZ | - | - | - | - | - | - | - | 0% | 0% | 2% | 4% |
| CA | - | - | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| CO | - | - | - | - | 0% | 0% | 0% | 3% | 5% | 5% | 5% |
| CT | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 6.5% | 10% | 12% | 14% |
| DE | - | - | - | - | - | 0% | 0% | 2% | 3% | 4% | 5% |
| DC | - | - | - | - | - | 0% | 0% | 4% | 4.5% | 5% | 5.5% |
| HI | - | - | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 10% |
| IL | - | - | - | - | - | - | - | 0% | 0% | 2% | 4% |
| IA | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| KS | - | - | - | - | - | - | - | - | - | 0% | 0% |
| ME | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 2% | 3% |
| MD | - | - | - | - | 0% | 0% | 3.5% | 3.5% | 4.5% | 4.5% | 5.5% |
| MA | 0% | 0% | 0% | 1% | 1.5 % | 2% | 2.5% | 3% | 3.5% | 4% | 5% |
| MI | - | - | - | - | - | - | - | 0% | 0% | 0% | 0% |
| MN | - | - | - | - | - | - | - | 0% | 0% | 0% | 2.5% |
| MO | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| MT | - | - | - | - | - | 0% | 0% | 0% | 5% | 5% | 10% |
| NV | 0% | 0% | 0% | 0% | 0% | 6% | 6% | 9% | 9% | 12% | 12% |
| NH | - | - | - | - | - | - | - | 0% | 4% | 6% | 7.5% |
| NJ | 0% | 0% | 0% | 0% | 0% | 3.2% | 3.5% | 4.5% | 5.6% | 6.5% | 7.4% |
| NM | - | - | - | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| NY | - | - | - | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| NC | - | - | - | - | - | - | - | 0% | 0% | 0% | 0% |
| OH | - | - | - | - | - | - | - | - | - | 0.3% | 0.5% |
| OK | - | - | - | - | - | - | - | - | - | - | 0% |
| OR | - | - | - | - | - | - | - | 0% | 0% | 0% | 0% |
| PA | - | - | - | - | 0% | 0% | 0% | 0% | 5.7% | 6.2% | 6.7% |
| RI | - | - | - | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| TX | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 5% | 7% | 7% |
| WA | - | - | - | - | - | - | 0% | 0% | 0% | 0% | 0% |
| WV | - | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| WI | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% |

Source: Quantitative RPS Data by Database of State Incentives for Renewables & Efficiency (DSIRE), 2013. Retrieved from http://www.dsireusa.org/rpsdata/index/cfm

I chose to use the variables that reflected the components of RPS policies rather than a variable that represented the progress of these policies for four reasons. First, I analyzed the elements of RPS policies to compare the changes that occurred between the electricity markets of adopting states and non-adopting states. Second, using a variable that reflected the progress of the policies would make it impossible to compare the changes in adopting states that occurred before the implementation of RPS policies to the changes that occurred after the implementation of those policies. Third, I used the components of RPS policies to differentiate between the potential effects of the elements of these policies. Finally, a variable representing the progress of the policies was decidedly nonlinear with regard to most of the dependent variables when I tested it for linearity.

1.1.3.1: Energy Efficiency

Energy efficiency was a component of RPS policies because it served as one of the central mechanisms that could change the electricity markets of adopting states by reducing the demand for electricity (Brown et al., 2007). Supporters of RPS policies had promoted energy efficiency as a method to achieve part of the underlying goals of the RPS policies (Adetutu, 2014). The savings attributable to energy efficiency was often so great in comparison to renewable electricity production that producers of electricity gave their customers energy efficient goods for free (Cappers & Goldman, 2010). State and federal government policies promoted energy efficiency because efficiency was affordable when compared to other environmental policies (Brown et al., 2007; Duane, 2010).

Most of the states adopted energy efficiency resource standards (EERS) by 2010

(EIA, 2013b). These standards often predated the adoption of RPS policies within a state; however, states often did not allow energy efficiency gains to replace the requirement for renewable electricity production. I tested the influence of counting the effects of energy efficiency towards RPS goals in a separate analysis and found that they did not alter the results of the study, so I did not separate those states from other adopting states within my study. I used the path analysis models of the study to quantify the effects of energy efficiency, as discussed in further detail in Chapter 3. Figure 1.2 shows the extent of EERS in 2013.

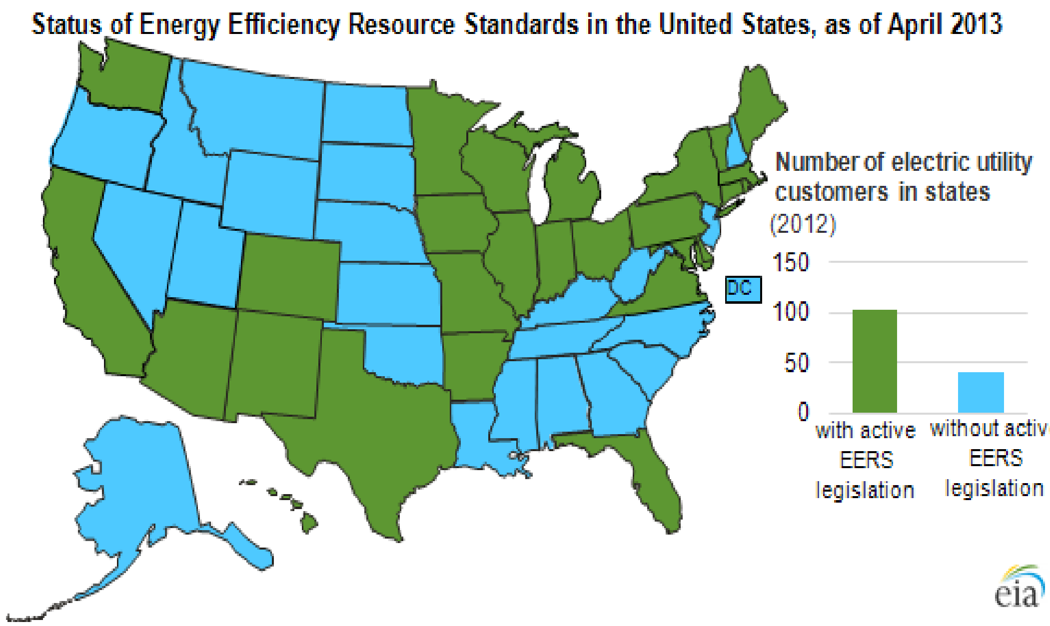


Figure 1.2: Energy efficiency resource standards (EIA, 2013b)

Source: Status of energy efficiency resource standards (EERS) in the United States, by the Energy Information Agency (EIA), 2013, http://www.eia.gov/todayinenergy/detail.cfm?id=12051

While energy efficiency was a desirable goal within RPS policies, some economists and policy-makers were concerned about the effect of rebound and backfire, which would mitigate the effectiveness of energy efficiency as a way to reduce electricity use (Reddy, 2013). A rebound would occur when the adoption of energy efficiency encouraged a minor increase in the consumption of electricity related to a minor reduction in electricity prices, decreasing the actual reduction in electricity consumption by less than what was predicted (Gneezy, Meier & Rey-Biel, 2011). A backfire would occur when the adoption of energy efficiency encouraged a major increase in the consumption of electricity related to a major reduction in electricity prices, allowing groups of consumers to increase their electricity consumption (Fölster & Nyström, 2010).

## 1.2: Statement of the Problem

States created RPS policies to deal with the environmental implications of global climate change without imposing significant economic costs for the adopting states (Carley & Miller, 2012). However, effective public policies require penalties as well as incentives, which the majority of RPS policies lack (DSIRE, 2013). The lack of penalties associated with RPS policies means that their enforcement is uncertain. These policies also have many provisions that moderated the costs to corporations and individuals, such as tax credits and subsidies, so their overall influence may be diminished (Bird, Chapman, Logan, Sumner & Short, 2011). However, if RPS policies work, the policies should change the electricity markets of adopting states, primarily through reducing carbon intensity.

Therefore, the goal of any formative evaluation should be to assess whether RPS policies have had an effect on adopting states during the first years of RPS policy implementation. If these policies have caused a reduction in carbon intensity through displacing high-carbon emitting sources for electricity production with energy efficiency and renewable electricity production, then the adopting states will have received quantifiable benefit from RPS policies. Otherwise, the benefits of RPS policies to adopting states may be questionable.

## 1.3: Previous Research into RPS Policies

Most of the researchers who have examined RPS policies have analyzed the effect of the policies on price (Fischer, 2006; Fischer, 2009). In addition, the majority of the previous literature provided explorations into the consequences of RPS policies on revenue and carbon intensity (Briggs & Gautam, 2012; Tra, 2011). I broadened the scope of the research by an investigation of the overall influence of RPS policies through examining the effects of RPI, percentage, stringency, and trading. I also attempted to quantify the outcomes of energy efficiency attributable to RPS policies on adopting states.

### 1.3.1: Outcomes of RPS Policies

Earlier researchers found that RPS policies significantly increased the price of electricity within adopting states, though the change was less than 1% (Bird et al., 2011). Questions arose from the earlier studies, however, concerning the exact cause of the observed increase in electricity prices (Anthoff & Hahn, 2010; Bernow, Dougherty & Duckworth, 1997). Regulatory costs associated with these policies could be a cause of the increase in electricity prices (Aldy & Stavins, 2012; Cropper & Oates, 1992). The expense associated with the facilitation of renewable electricity production within adopting states could also be a cause of the increase in electricity prices (Carley, 2009; Carley & Miller, 2012).

In the research that predated the adoption of the EPAct of 2005, researchers assumed the U.S. government would follow the example of the European Union (Berry & Jaccard, 2001). The European Union had adopted national RPS policies that used government incentives to expand renewable electricity production (Fan, Akimov & Roca, 2013; Eyckmans & Hagen, 2010). However, the adoption of the EPAct of 2005 meant that the United States was taking a different path (Fischer, 2009).

Existing U.S. laws prohibited the federal government from providing incentives that would favor the products of one state over another (Bloom, Forrester & Klugman, 2011). For example, the U.S. government could not adopt feed-in tariffs, which are standard in the RPS policies of the European Union (Del Río, 2012). Feed-in tariffs allowed the nations of the European Union to promote investment in renewable electricity production by providing cash subsidies to the owners of such production (Knill, Heichel & Arndt, 2012). States were forced be creative in their implementation of RPS policies without similar support from the federal government (Yin & Powers, 2010). Renewable energy credits (RECs) were one of the methods by which the states have avoided these legal issues (Burn & Kang, 2012; Riti, 2010).

RECs were tax credits that compensated electricity producers for the expense of investing in renewable electricity production (Burns & Kang, 2012; Riti, 2010). The purpose of RECs had been to facilitate investment in renewable energy (Motl, 2010). States had complied by giving electricity producers tax credits with a value that approaches or exceeds the cost of investing in renewable electricity production (Burns & Kang, 2012). The U.S. government has offered similar tax credits, called Production Tax Credits, for the past quarter century with the intention of facilitating the adoption of new energy technologies (Riti, 2010). RECs provided a method by which twenty-eight states promoted the trade in renewable power. I captured the influence of the RECs with the independent variable of trading within my study.

## 1.4: Evaluation of RPS Policies

I evaluated the consequences of RPS policies using a three-stage path analysis model, similar to the one used by Matisoff (2008) to explore the adoption of RPS policies. The continuous nature of the dependent variables allowed an efficient utilization of OLS regressions as the statistical method for hypothesis testing. I used the path analysis models to assess the influence of renewable electricity production and to quantify the effects of energy efficiency within adopting states. I verified the path analysis models with the structural equation models (SEMs).

I selected SEMs to test the path analysis models because they are capable of simultaneous examination (Chen & Chang, 2013a; Chen & Chang, 2013b). The analytical capabilities of SEMs facilitated the extraction of the total effects of RPS policies on adopting states. SEMs also enabled the detection of the influence of the unmeasured interaction variables that may be present in my model (Hussey & Egan, 2007). Although I used SEMs to verify the path analysis models, I did not report them because their results matched those of the path analysis models. Therefore, the path analysis models were sufficient to explain the results of the study.

### 1.4.1: Variables

I used two sets of independent variables and two sets of dependent variables, as well as eight control variables and two categorizing variables. I collected data for 46 states (and the District of Columbia) from 2000 to 2010. I excluded four states because they had adopted voluntary RPS policies that lacked any enforcement provisions to facilitate the adoption of energy efficiency or the production of renewable electricity. I describe the variables in detail in Chapter 3; however, I provide an overview in the following paragraphs. I also present an overview of their operationalization in Appendix A.

The first set of independent variables involved the elements of RPS policies. RPI (RPS index) was an index of percentage, stringency, and trading, and as mentioned previously was the sum of the other three RPS variables. Percentage (RPS percentage) measured the amount of renewable electricity production required by an RPS policy. Stringency (RPS stringency) measured the amount of renewable electricity production required from specific power sources within an RPS policy. Trading (RPS trading) measured the amount of renewable electricity production that was satisfied by purchasing renewables from other states. I used these variables as the independent variables of the first and second hypotheses.

The first set of dependent variables deals involved the electricity markets of adopting states. Price measured the price of electricity within a state. Revenue measured the revenue resulting from electricity production within a state. Quantity measured the amount of electricity produced within a state. Emissions measured the carbon dioxide emissions within a state. Carbon intensity measured the amount of carbon dioxide emissions produced per unit of electricity generated within a state. I used these variables as the dependent variables for the first and third hypotheses.

The second set of dependent variables and the second set of independent variables focused on the types of renewable electricity production within a state. Renewable was an index of wind, solar, and dispatchable, and as previously mentioned, was the sum of the three other renewable energy variables.  Wind represented the amount of electricity produced from wind energy sources within a state.  Solar reflected the amount of electricity generated from solar energy sources within a state.  Dispatchable represented the amount of electricity generated from biomass and geothermal energy sources within a state.  I used these variables as the dependent variables of the second hypothesis and the independent variables of the third hypothesis.

I used control variables derived from previous research on the adoption and implementation of RPS policies (Lyon & Yin, 2010; Yin & Powers, 2010).  I divided these control variables into demographic control variables (per capita area [PCA], per capita income [PCI], and population [POP]), energy control variables (cooling degree-days [CDD] and natural gas electricity production [NG]) and political control variables (Democratic Party governorship control [DGC], Democratic Party state house control [DHC], and Democratic Party state senate control [DSC]).

I used two categorizing control variables.  The first represents the state (State), and the second represents the year (Year).  I used fixed effects for State and Year in my initial model.  However, I dropped the two sets of fixed effect variables because they did not change the effect of any of the independent variables on any of the dependent variables.

1.4.2: Data

I used state-year as the unit of analysis.  I collected RPS data from the Database of State Incentives for Renewables & Efficiency (DSIRE), an online database maintained by N.C. State and supported by the U.S. Department of Energy to provide researchers with information on energy policies (DSIRE, 2013). The demographic data came from the U.S. Census, which provides annual estimates of demographic data for each state (U.S. Census, 2013). The energy data came from the U.S. Energy Information Agency, which provides annual reports on energy variables for each state (EIA, 2013a). The political data came from state government organizations (NCSL, 2015; NGA, 2011).

1.4.3: Methodology

I evaluated the outcomes of RPS policies on adopting states by using OLS regressions and path analysis models to create a formative evaluation. I used panel data that represented multiple states over multiple years, which produced a dataset that I used to test comparative changes between adopting and non-adopting states from 2000 to 2010. I structured my hypotheses in accordance with the examples provided by the previous literature to explore four elements of RPS policy.

The first and central element of my study reflected the research of Briggs and Gautam (2012), Carley and Miller (2012), and Yin and Powers (2010) by examining the effects of RPS policies on the multiple components of electricity markets in adopting states (price, revenue, quantity, emissions, and carbon intensity). The second element followed the research of Fischer (2006 & 2009) by testing the changes attributable to RPS percentage. The third element reproduced the research of Carley and Miller (2012) by investigating the changes attributable to RPS stringency. The fourth and final element simulated the research of Fershee (2008) by exploring the changes attributable to RPS trading.

In comparison to the professional literature, I examined the second through fourth elements to provide a detailed understanding of the influences of RPS policies on the electricity markets of adopting states. Previous researchers examined particular aspects of RPS policies, such as their effects on electricity price or carbon intensity (Briggs & Gautam, 2012; Tra, 2011). In contrast, I examined multiple aspects of RPS policies, including their effects on overall electricity markets and renewable electricity production.

I conducted the OLS regressions to test my three hypotheses. I used them to evaluate the influences of RPS policies on adopting states and to create the coefficients for the path analysis models. Path analysis models were superior to OLS regressions for quantifying the effects of energy efficiency on adopting states because I could use them to examine the sequential products of analysis (Duncan, 1966). The sequential products of analysis could quantify the effects of energy efficiency by subtracting the mediating influence of renewable electricity production from the results of RPS policies.

The general equations that I used to derive the effects of energy efficiency were:

(1): RPS Variable Energy Efficiency = (RPS Variable H1 Coefficient) – (Renewable Energy Influence)

(2): Renewable Energy Influence = (RPS Variable H2 Coefficient) * (Renewable Energy H3 Coefficient)

I divided the path analysis model into three stages. The first stage represented the second hypothesis; the second stage reflected the third hypothesis. I derived the path analysis coefficients from the outcomes of those two stages, the product of multiplying the coefficients of the first stage by those of the second stage. With the third stage, I subtracted the influence of that mediation from the findings of the OLS regressions of the first hypothesis, in order to quantify the effects of energy efficiency on adopting states. I present a further discussion of path analysis models in Chapter 3.

Other factors could moderate any observed outcomes, such as the effects of the demographics or political environment of a state. I used the control variables to moderate the influence of RPS policies within the OLS regressions and the path analysis models. I discuss the control variables in further detail in Chapter 3.

The OLS regressions represented the effects of RPS policies on the electricity markets and renewable electricity production of adopting states. They also evaluated the influence of renewable electricity production on producing states. The path analysis models quantified the effects of energy efficiency on adopting states by subtracting the mediation of renewable electricity production within adopting states. I discuss the results of RPS policies, the influence of renewable electricity production and the effects of energy efficiency in further detail in Chapters 4 and 5.

## 1.5: Effectiveness of Energy Policies

During the adoption phase of RPS policies, which occurred primarily between 2000 and 2010, the majority of the experts in the energy industry thought that affordable fossil fuel resources were becoming constrained in the United States (Johnson, 2014). Since then, the development of gas shales and oil shales by fracking technology has reduced this constraint, at least for a few decades (Jenner & Lamadrid, 2013). If more states are to adopt RPS policies, then it is necessary to show that these policies represent an efficient way to transition from fossil fuel energy technologies to energy efficiency and renewable energy production. More importantly, I will need to show that the adoption of RPS policies are connected to a replacement of high emitting fossil fuels instead of low emitting fossil fuels with energy efficiency and renewable electricity production.  I should be able to show such replacement if these policies are associated with a reduction of carbon intensity within adopting states.

I examined the influence of RPS policies on adopting states by using OLS regressions and the path analysis models, as mentioned previously.  As previously noted by Lyon and Yin (2010) and Yin and Powers (2010), these policies are effectively the only national climate change policy in the United States.  If these policies are associated with a reduction of carbon intensity within adopting states, then their results will be a validation of that climate change policy.  If these policies are effective climate change policies, I should be able to determine which elements of these policies were most effective.  Policy-makers from less effective states could then use the findings of this study to tailor their policies to follow the examples of more effective states.

## 1.6: Overview of the Results

I found no evidence that RPS policies were associated with a significant reduction of carbon intensity in adopting states.  However, my analysis reflected only the first decade of RPS performance in adopting states, when their requirements were still small. The effects of RPS policies may change over time, so I would suggest further examination to see if RPS policies may eventually accomplish their stated objectives.  I discuss my findings in detail in Chapters 4 and 5 and present them in Appendixes B and C.

Since I found that RPS policies were unconnected to a significant reduction of carbon intensity within adopting states, I suggest future research will have to confirm my findings involving the evaluation of the outcomes of RPS policies after more years of data become available. I propose that further expansion of these policies would be unwise if further research replicates my findings, though the results of future substantive evaluations will determine the long-term effectiveness of RPS policies. I discuss my conclusions in detail in Chapter 5.

## 1.7: Outline of the Dissertation

In Chapter 1, I introduce the topic of the study and present the statement of the problem and the outline of the research questions and hypotheses. In Chapter 2, I review the literature, including a consideration of the theoretical justifications and empirical findings of previous research. Chapter 3 focuses on the methodology of the study and includes descriptions of the data analysis process, the research questions, and the hypotheses. Chapter 4 is an examination of the results. Chapter 5 is a discussion of the findings, implications, and possible consequences on future energy policy within the United States.

# CHAPTER 2: LITERATURE REVIEW

Although RPS policies have existed since the 1980s, few studies exist that address the changes caused by RPS policies within adopting states. Most of the studies instead examine the adoption of these policies (Lyon & Yin, 2010; Yin & Powers, 2010). The remaining articles are mostly case studies of the changes within the electricity markets of individual states (Fischer, 2006; Fischer, 2009). At the time of my study, the few studies on the national changes in the electricity markets of adopting states are unpublished working papers (Briggs & Gautam, 2012; Tra, 2011).

Policy adoption is different from policy implementation. Studies of policy adoption focus on the circumstances that led to the adoption of RPS policies (Lyon & Yin, 2010). Studies of policy implementation focus on the results of implementing RPS policies (Tra, 2011). The implementation studies show that RPS policies often caused significant changes in the electricity markets or renewable electricity production of adopting states (Briggs & Gautam, 2012; Zhao, Tang, & Wang, 2013).

Previous research into the implementation of RPS policies has contributed to the current understanding of the factors that moderate the influence of RPS policies. Some studies have examined the power of political parties and state demographics (Tra, 2011). Researchers have also evaluated the influence of these factors on the renewable electricity production that arises from RPS policies (Yin & Powers, 2010).

The first half of the literature review is a narrative overview of the historical events that led to the adoption of RPS policies. I discuss the consequences that previous researchers predicted would occur with the implementation of RPS policies. The second half of the literature review is a discussion of the most recent research into the implications of RPS policies for electricity markets and renewable energy production. I also present the contributions of my research in light of the findings of previous literature.

## 2.1: Overview of U.S. Energy Policy

The U.S. government adopted the Public Utility Regulatory Policies Act (PURPA) in 1978 to reduce the energy vulnerability of the United States (Levy & Keegan, 1987). At that time, the United States suffered from market shocks caused by commercial or political interests that monopolized energy sources during the 1970s (O'Callaghan & Greenwald, 1996). The price shocks that destabilized the U.S. economy during the 1970s illustrated the vulnerability caused by its dependence on fossil fuels (Thompson, 1983).

PURPA (1978) improved the methods that electrical utilities used to generate electricity by giving them incentives to modernize their infrastructure. It also provided incentives for utilities to adopt technologies that would improve energy efficiency (Levy & Keegan, 1987). The development of competitive electricity markets would lead to further facilitation of greater energy efficiency (Fox-Penner, 1990). In turn, energy efficiency would benefit the entire energy sector of the United States (Porter & Van Der Linde, 1995).

The U.S. government adopted the Energy Policy Act (EPAct) in 2005 to build on the policies implemented by PURPA (Metcalf, 2007). By that time, evidence of the influence of anthropogenic emissions on global climate was conclusive (Doniger, Herzoq & Lashof, 2006). The intention of EPAct (2005) was to further the energy efficiency gains of PURPA (1978) and to motivate new investment into renewable electricity production (Brown, Sovacool & Hirsh, 2006). Further investment in energy efficiency and renewable electricity production would change electricity markets throughout the United States by displacing fossil fuel utilization (Kelliher & Farinella, 2008). The EPAct of 2005 facilitated the adoption of state RPS policies by offering federal government incentives that would supplement any state government incentives (Lyon & Yin, 2010).

RPS policies allowed state governments to create energy and environmental policies to address concerns about global climate change (McKinstry, Dernbach & Peterson, 2008; Peterson, 2012). However, policy competition among state governments to fulfill the goals of PURPA of 1978 and the EPAct of 2005 resulted in a diverse array of solutions (Anthoff & Hahn, 2010). These solutions addressed the same problem from multiple directions by experimenting with a wide variety of strategies that facilitated energy efficiency and renewable energy production (Horiuchi, 2007). Policy-makers considered the alternatives to RPS policies, such as cap-and-trade or carbon taxation, to be unworkable because they were taxes rather than subsidies (Engel, 2008; Feijoo & Das, 2014).

## 2.2: Proposed Changes

I divided the literature on the effects of RPS policies into two groups: previous literature concerning the changes in the electricity markets of adopting states and previous research concerning the changes in the production of renewable electricity within adopting states (Carley, 2009; Ivanova, 2012). Previous literature concerning changes in characteristics of electricity markets includes literature that examines changes in electricity prices, revenue, production, carbon dioxide emissions, and carbon intensity (Briggs & Gautam, 2012; Tra, 2011). Previous research concerning changes in the production of renewable electricity includes research that examines wind, solar and other alternative energy production (Dong, 2012; Gaul & Carley, 2012; Zhao, Tang & Wang, 2013). In my analysis, I also examined each of these elements, as detailed in Chapters 3 and 4.

### 2.2.1: Market Outcomes of RPS Policies

One of the primary concerns of research into RPS policies was the pressure that they would exert on electricity prices. Although most of the researchers suggested that the adoption of these policies would result in higher electricity prices, some suggested the opposite (Fischer, 2006; Fischer, 2009). For example, Fischer (2006) discussed hypothetical situations that may result in a reduction in electricity prices due to the replacement of fossil fuels with renewable energy. She hypothesized that the elasticities associated with renewable energy were higher than the elasticities associated with fossil fuels. She proposed that the price of renewable energy would fall rapidly as its production increased, which would eventually allow renewable energy to replace fossil fuels. She created an economic model around her assumptions of falling electricity prices caused by increased renewable energy production and suggested that one of the outcomes of RPS policies would be lower electricity prices.

Fischer (2009) suggested the subsequent decrease in natural gas prices would eventually make it a desirable vehicular fuel if petroleum prices remained high and if electricity prices remained low because of renewable energy production. She created an economic model from the findings of her previous research that estimated the elasticities of baseload technologies, natural gas, other fossil fuels, and renewable energy. She found that the elasticity of renewable energy was greater than the elasticity of natural gas, so she concluded that the price of renewable energy would fall below the price of natural gas as renewable electricity production continued to expand. She determined, however, that RPS policies would reduce the use of non-renewable sources of energy rather than resulting in their replacement by renewable sources of energy because energy efficiency is more cost effective than creating new energy infrastructure. I found, however, that the evidence presented within the previous literature was on the side of higher prices, with lower prices serving as a minority view. I will discuss the influence of RPS policies on electricity prices throughout the remainder of Chapter 2.

Previous research examines the effect on electricity prices by the increased regulation of RPS policies (Brown et al., 2007; Felder & Haut, 2008). For example, Felder and Haut (2008) suggested that increased regulation by RPS policies would be the primary cause of higher electricity prices. They surveyed the previous literature and, based on the findings of other researchers, proposed that RPS policies would result in electricity producers adopting expensive technologies and passing on the costs to their consumers. While they also suggested that RPS policies would promote energy efficiency and renewable electricity production, they concluded that RPS policies could only avoid causing excessive increases in electricity prices by allowing for the continued utilization of coal and nuclear energy.

Brown et al. (2007), however, suggested that RPS policies would reduce the cost of fossil fuels by reducing the demand for fossil fuels, which would result in a rebound effect within the electricity markets of adopting states. They surveyed RPS policies throughout the United States and suggested that the promotion of energy efficiency and renewable electricity production by those policies should reduce the demand for fossil fuels. They proposed that the reduction in that demand would significantly reduce the cost of fossil fuels, which would result in an actual reduction in fossil fuel consumption that would be smaller than any predicted reduction originally attributed to the adoption of RPS policies. They suggested that the resulting rebound effect would minimize the efficacy of these policies.

Carley and Miller (2012) and Yin and Powers (2010) assessed the influence of RPS policies by evaluating the results of stringent RPS policies in terms of the types of renewable energy produced by adopting states. They realized that RPS policies did not significantly increase renewable energy production when they controlled for demographic and political factors. They also observed that stringent RPS policies usually promoted wind energy and solar energy at the exclusion of other renewable energy sources (biofuel, geothermal, etc.).

Sovacool (2008, 2011) analyzed the significance of the trading of renewable electricity production allowed by adopting states' RPS policies. In 2008, he examined a survey of the existing literature on the adoption of renewable electricity production and concluded that RPS policies would not be sufficient to deal with the energy challenges of the twenty-first century. In 2011, he reviewed the existing literature on the effects of trading schemes in a variety of markets, from energy to water, and discovered that trading often resulted in inefficiencies that minimized the effectiveness of trading policies. In both cases, he speculated that RPS policies would not significantly increase renewable energy production because the portfolio approach would cause market inefficiencies that would prevent those policies from being effective. He proposed that these inefficiencies would manifest in the form of excess exemptions and subsidizations, which would minimize the effectiveness of RPS policies.

2.2.1.1: Influence of Natural Gas

The previous literature has examined the effect of the expansion of the production of natural gas and the subsequent reduction in natural gas prices on electricity markets throughout the United States. In 2005 and 2008, the price of natural gas plummeted and started a transition from power plants that consumed coal to ones that consumed natural gas (Arora & Cai, 2014). The replacement of coal with natural gas meant that carbon dioxide emissions started to drop due to market forces during the period that the majority of states were adopting RPS policies (Palmer, Burtraw, Woerman, & Beasley, 2012). The influence of natural gas might explain many of the changes in the electricity markets otherwise erroneously attributed to RPS policies (Logan, Lopez, Mai, Davidson, Bazilian, & Arent, 2013).

Arora and Cai (2014) anticipated that the influence of the price of natural gas on the price of electricity would be a moderating factor on the expansion of renewable electricity production. They predicted that declines in the price of natural gas would make the adoption of renewable energy unaffordable by comparison. They used a global multi-sector recursive dynamic computable general equilibrium model to determine the influence of the price of natural gas on the production of renewable electricity. They found that low natural gas prices would negatively influence renewable electricity production.

Lafrancois (2012) suggested that new supplies of natural gas provided by the utilization of fracking technologies caused long-term changes in the economics of electricity markets, resulting in a decrease in the price of electricity. He used a theoretical model to estimate the influence of replacing coal with natural gas for the purpose of electricity production on electricity prices. He predicted that the increased production of natural gas by fracking would decrease the cost of natural gas electricity generation because increasing supplies of natural gas would reduce the cost of that fuel. He also anticipated that the production of natural gas through use of fracking technologies would reduce concern about energy dependence in the United States.

Similarly, Palmer et al. (2012) noted a significant reduction in carbon dioxide emissions caused by the replacement of coal-fired power plants with natural gas power plants. They used a Haiku model, a form of partial equilibrium model, to examine the effect of natural gas production on electricity prices. They discovered that the expansion of natural gas production reduced electricity prices and allowed for the replacement of coal with natural gas. They attributed the reduction in carbon dioxide emissions primarily to the expansion of natural gas.

Logan et al. (2013) predicted that long-term changes to the electricity market due to natural gas production would reduce carbon dioxide emissions more than would RPS policies. They predicted a future in which RPS policies would be uneconomical because of the relative cost efficiency of reducing carbon dioxide emissions by natural gas consumption. They used two models, one for natural gas supply cost variations and one for natural gas demand variations, and found that increasing natural gas consumption reduced electricity prices below the point at which the majority of renewable sources became economically viable.

2.2.2: Influence of Renewable Energy Sources

Aslani and Wong (2014) used a system dynamics model to examine the cost of renewable electricity production. They found that the availability of renewable energy sources contributes to the potential effectiveness of RPS policies because states prefer to develop renewable energy sources for which they have comparative advantages in resource availability. In particular, they suggested that states that possessed more hours of sunlight would develop solar power while states that possessed higher wind speeds would develop wind energy.

Brown et al. (2007) had a particular interest in the interaction of RPS policies with the availability of economically viable solar and wind energy. Based on their survey of previous literature, they thought that RPS policies would only be effective where renewable energy sources are affordable because of issues of intermittency and non-dispatchability. When they analyzed electricity markets throughout the U.S., they found that the majority of states were more able to make effective use of energy efficiency than renewable electricity production.

Gaul and Carley (2012) argued that solar resources were abundant in the Southwest of the United States, allowing for greater investment in solar than in the rest of the nation. Based on the descriptive statistics of their dataset and on the interviews that they conducted with the leaders of the energy industry, they proposed that producers within that region would preferentially exploit solar energy. They investigated the adoption of renewable energy throughout the United States and found that the states that had the greatest success in producing solar energy were those that possessed the highest solar intensity.

Similarly, Dong (2012) claimed that wind resources were abundant in the Midwest and along the coasts of the United States. Based on his regression analysis of the effects of energy policies throughout fifty-three developed nations, he suggested that energy producers within the Midwest and along the coasts of the United States would preferentially exploit wind energy. Within his analysis, he found that the nations that achieved the best results in producing wind energy were those that possessed the greatest wind potential.

Chien and Hu (2008) suggested that the availability of solar and wind resources would determine the renewable energy investments of individual nations. Based on their regression analysis of the expansion of renewable energy within 116 economies, they predicted that nations would facilitate the development of renewable sources prevalent in their regions in attempts to reduce carbon dioxide emissions. They found that nations that possessed higher solar intensities preferentially invested in solar energy while those that possessed greater wind potential preferentially invested in wind energy.

Yin and Powers (2010) examined the effects of the adoption of RPS policies on renewable electricity production within the United States before 2010. They maintained that RPS policies functioned by increasing renewable electricity production. Based on their regression analysis of RPS policies adopted within the United States up to 2008, they suggested that the reductions in cost associated with the scaling up of the production of renewable energy would further increase renewable electricity production. They used a changes-in-changes approach with state and year fixed effects to do their analysis and found that RPS policies increased renewable energy production.

Buckman (2011) theorized that the effectiveness of these policies would be more constrained within states bounded by geographical limitations. Based on his regression analysis of the promotion of specific renewable energy sources within RPS policies adopted by 2010, he anticipated that states that lacked economically viable solar and wind resources would not be able to develop effective RPS policies. He compared the renewable electricity production of adopting states and found that states that adopted stringent policies produced less renewable electricity than states that did not adopt stringent policies.

Similarly, Wiser, Barbose, and Holt (2011) advanced the idea that states located outside of the optimal areas for wind and solar power could have less effective RPS policies. Based on their regression analysis of the energy trading that existed before 2010, they suggested that such states would develop open RPS policies that would allow trading of renewable energy with producing states. They surveyed adopting states and discovered that the production of solar energy was greater in states that had plentiful solar resources. They found that the facilitation of solar electricity production required subsidization by adopting states.

### 2.2.3: State Policy Experimentation

Carley and Miller (2012) proposed that RPS policies represented one of the purest examples of policy competition within the United States. They claimed that states competed to create RPS policies that would allow them to acquire a competitive economic advantage over other states by reducing carbon intensity at the lowest possible cost because of the potential threat of future environmental policies to the economies of states. They used a two-stage analysis for their model: the first stage was a logit model that assessed the probability of the adoption of RPS policies and the second stage was a multinomial model that examined the discrete outcomes of RPS policies. They found that weak RPS policies were unlikely to expand renewable electricity production and that strong RPS policies were more useful for expanding renewable electricity production.

Davies (2012) reviewed the legal mechanisms used by governments to incentivize the production of renewable electricity. He suggested that governments compete by creating RPS policies according to their individual needs by combining economic and environmental factors. He concluded that governments that were successful in balancing economic and environmental goals would become prosperous while localities that failed to achieve this balance would become impoverished because of the potential threat of future carbon taxes to their future prosperity.

Yin and Powers (2010) claimed that the adoption of these policies reflected a progressive trend in environmental policies. Based on their analysis of the influence of political factors on the adoption of RPS policies within the United States, they suggested that the adoption of RPS policies represented the shifting of the political ideologies of adopting states to a more progressive ideology. They concluded that political factors had more influence than economic factors on the adoption of RPS policies that promoted renewable electricity production.

Mahone, Woo, Williams, & Horowitz (2009) assessed California's RPS policies as a case study and compared the effectiveness of its renewable electricity production to the effectiveness of its energy efficiency programs. Based on their examination of the energy market of California, they claimed that the basic premise of RPS policies--that renewable energy can replace fossil fuels--might not be correct. In fact, they suggested that renewable electricity production was only part of the solution to replace fossil fuels, as increased energy efficiency was also necessary to reduce energy demands to the point at which renewable energy could replace fossil fuels. They found that the cost effectiveness of RPS policies was dependent on properly balancing the investments in renewable electricity production with those in energy efficiency and that increased energy efficiency was more effective in reducing carbon dioxide emissions than increased renewable energy production.

Adetutu (2014) examined the effect of energy efficiency gains on the electricity markets of four OPEC countries from 1972-2010. He predicted that renewable electricity production was an ineffective way to reduce carbon dioxide emissions because of the resource expenditures needed to encourage people to change their energy preferences. He used an econometric model with a translog functional form to calculate the second order effects of energy efficiency. He discovered that investment in energy efficiency was more effective in reducing carbon dioxide emissions than was investment in renewable electricity production and found that governments that facilitated energy efficiency with their environmental policies benefited more than those did that encouraged renewable energy production.

Brown et al. (2007) proposed that large-scale investment in renewable electricity production only occurred if there was an equally widespread subsidization by governmental entities. Based on their survey of the previous literature, they suggested that states' subsidization of the costs of renewable energy production was required if they wished for renewable energy production to be competitive with fossil fuel electricity production. They asserted that the influence of RPS policies might therefore be relatively modest in comparison to the predictions of the policies' proponents. They also found that the emphasis on replacing fossil fuels with renewable energy meant that RPS policies did not reduce the production of carbon dioxide. They suggested that RPS policies did not achieve a reduction in carbon dioxide emissions because these policies distorted state energy markets by excessive subsidization of renewable electricity production.

2.2.4: Popularity of RPS Policies

Fershee (2008) examined the effects of the recent actions of the U.S. Congress on the effectiveness of RPS policies. He surveyed legislation passed by the U.S. Congress during the period around the passage of EPAct (2005). He suggested that, although RPS policies have been controversial because of political arguments over environmental goals, the U.S. Congress supported RPS policies because most American citizens supported the adoption of renewable electricity production. He discovered that the perception that RPS policies were minimally disruptive probably caused this support within the U.S. Congress because these policies did not assign a cost to carbon dioxide emissions.

Brown et al. (2007) proposed that the popularity of RPS policies came from the subsidies that accompanied them. They argued that the adoption of RPS policies for environmental policy purposes had proven to be to relatively attractive because of the low costs of those policies to the people who would be affected by them. The attractiveness of RPS policies made competing environmental policies (like cap-and-trade and carbon trading) seem unfeasible by comparison.

Lyon and Yin (2010) suggested that concerns about fossil fuel dependency led to the popularity of RPS policies. They used a proportional odds model to assess the factors that led to the adoption of RPS policies and found that political factors influenced the probability of adoption. They performed a mutinomial logit model to evaluate whether the popularity of RPS policies increased the popularity of in-state renewable electricity production and discovered that in-state electricity production was not nearly as popular as RPS policies.

## 2.3: Predicted Influences of RPS Policies

Lyon and Yin (2010) and Yin and Powers (2010) proposed that examining the factors leading to the adoption of RPS policies offered insight into their potential consequences. According to Lyon and Yin (2010), Republican administrations in adopting states produced programs that reduced costs to electricity producers while Democratic administrations reduced costs to electricity consumers. According to Yin and Powers (2010), states were able to adopt RPS policies that were more stringent when they naturally benefited from abundant renewable energy sources.

Fischer (2006) predicted that RPS policies would reduce electricity prices for developed nations by reducing dependency on expensive fossil fuels. Her hypothetical model suggested that fossil fuels would become less economically viable as demand for fossil fuels continued to increase. She proposed that developing nations would then suffer further competitive disadvantages compared to their more developed peers because they would be incapable of affording the infrastructure investments required to utilize renewable energy sources.

Fischer (2009) further suggested that the increased regulatory burden imposed by RPS policies might not increase overall electricity costs. Her economic model predicted that the cost of renewable electricity production would continue to decrease as it continued to benefit from economies of scale. She also claimed the reduction in the demand for natural gas, which was not readily exportable, would reduce the overall cost of electricity production, which would more than offset the regulatory costs of RPS policies.

### 2.3.1: The Reduction of Carbon Dioxide Emissions

Jenner, Groba, and Indvik (2013) examined the effects of RPS policies within the European Union. They suggested that the European Union's willingness to support dramatic changes in the energy industry differentiated it from the United States. In particular, the United States attempted to make marginal changes while the European Union decided to make transformational changes. Through use of OLS random effect models, they analyzed the influence of feed-in-tariffs (i.e., direct payments from governments to utilities producers for producing electricity from specific renewable energy sources) on the electricity markets of the European Union. They discovered that feed-in-tariffs were effective policies for reducing carbon dioxide emissions and suggested that feed-in-tariffs should be included in RPS policies.

Costantini and Crespi (2008) used a gravity equation to evaluate the effects of trade flows within the energy markets of 148 nations. They suggested that the desire of the members of the European Union to develop new renewable energy technologies and to create new export markets distorted their trade flows. However, they discovered that nations that possessed stricter environmental regulations were able to expand their energy export markets. They found that stricter environmental regulations reduced carbon dioxide emissions and concluded that the environmental and economic goals of the members of the European Union were actually achievable.

Arora and Cai (2014) claimed that the development of new fossil fuel resources has allowed the United States to be more sanguine in its approach towards energy security than the European Union has been. They believed that this change in attitude was mainly because of the expansion of the production of natural gas within the United States since the adoption of the EPAct of 2005. They proposed that the United States achieved greater carbon dioxide emission reductions from the expansion of natural gas production than the European Union enjoyed from the expansion of renewable electricity production.

Lafrancois (2012) claimed that the replacement of coal-fired electricity production with natural gas electricity production facilitated a greater decline in carbon dioxide emissions than did the modest renewable energy production investments in the United States since 2005. He used a theoretical model to estimate the influence of replacing coal with natural gas for the purpose of electricity production on carbon dioxide emissions. He found that the growth in natural gas electricity production dwarfed the growth in non-hydroelectric renewable energy from 2000 to 2010. After he examined the historical evidence provided by the EIA, he suggested that natural gas electricity production was more effective at reducing carbon dioxide emissions than renewable electricity production.

Wang, Chen, Jha, and Rogers (2014) surveyed the existing literature and asserted that the expansion of the production of natural gas allowed the United States to end the decade with reductions in carbon dioxide emissions. Based on the historical evidence that they examined, they discussed the influence of the increase in natural gas production and found that the production corresponded with a significant decrease in carbon dioxide emissions. Their evaluation of the information provided by the EIA suggested that U.S. carbon dioxide emission reductions were comparable to those experienced by the European Union because of the expansion of natural gas production within the United States.

## 2.4: Recent RPS Policy Research

Although the examination of the outcomes of RPS policies is a relatively new topic of exploration, a few comparative studies have focused on the consequences of RPS policies on adopting states. While most of these studies have drawn attention to the aftermath within individual states, two have broadened the examination to the national-level. In the first study, Tra (2011) examined the outcomes of RPS policies in retail electricity markets. In the second study, Briggs and Gautam (2012) evaluated the influence of RPS policies on carbon intensity, the amount of carbon dioxide produced per unit of electricity generated.

2.4.1: Changes in Electricity Prices

Tra (2011) produced a working paper that may be the first detailed examination of the national outcomes of RPS policies on state electricity markets. He explicitly compared the consequences of RPS policies on retail electricity prices within adopting states to non-adopting states. Using data from 1990 to 2006, he examined the effects of RPS policies on retail electricity prices in 20 states and the District of Columbia. His data came from the Energy Information Administration (EIA), which reported information related to all of the electrical distribution utilities in the United States. He noted a limitation of the study was that the data came from electrical distribution utilities that were not required to report information for each year. He also noted that missing data, specifically that none of the utilities were capable of providing information for every year of operation, could bias his findings.

Tra (2011) found that RPS policies increased retail electricity prices within adopting states when compared to non-adopting states. Although he touched upon the potential effects of RPS policies on electricity production and carbon dioxide emissions, as well as on the facilitation of renewable energy production, the total effects of RPS policies were not the primary focus. In fact, he did not measure anything beyond the effects of RPP on retail electricity prices, meaning that there might have been unaccounted for policy influences on retail electricity prices, such as the influences of other aspects of RPS policy. For example, the effects of RPS stringency and RPS trading were two factors that he did not address.

2.4.2: Effect of RPS Policies on Carbon Intensity

Briggs and Gautam (2012) produced a working paper focused on the influence of RPS policies on electricity markets within adopting states, as represented by carbon intensity changes. Certain aspects of RPS policies, such as renewable energy credits (RECs), served as a mechanism for proving that electricity producers fulfilled the renewable energy requirements of the RPS policies of adopting states by trade. The trade of these mechanisms allowed these policies to reduce their effective carbon dioxide emissions. Although unpublished, their work is one of the few examples of an examination of the effect of RPS policies on carbon intensity.

Briggs and Gautam (2012) specifically examined the effects of the RPS policies percentage requirement on the carbon intensity of a state. They operationalized the dependent variable as the natural logarithm of carbon intensity. This dependent variable ranged from a value of zero to a value of negative infinity, which magnified the apparent change in the dependent variable. They also presented a probit model for RPS policy selection in a state. RPS percentage reduced carbon intensity in comparison to non-adopting states.

However, the effect of RPS percentage on carbon intensity became insignificant with the inclusion of year fixed effects. They used year fixed effects to control for the normal growth in electricity markets that occurred as economies grew from year to year. They used RPS percentage as their primary independent variable, which was constant within adopting states after adoption. RPS percentage did not change after adoption because it represented the goal of the policy rather than the effect of the policy. Over time, they excluded the changes in electricity production from their model; in other words, they did not account for the influence of changes in electricity demand on carbon intensity.

2.4.3: Development of Renewable Electricity Production

A number of researchers that have found notable changes in renewable electricity production that may be attributable to RPS policies. In general, the researchers found that these policies increase renewable electricity production by facilitating private sector investment (Carley, 2009). However, some researchers found situations in which these policies do not function as anticipated because of the diminishing returns of additional environmental policies (Zhao, Tang & Wang, 2013).

Carley (2009) concluded that the implementation of RPS policies did not initially improve renewable electricity production. However, RPS policies significantly increased such production year over year within adopting states after a few years' delay. However, she did not compare the growth of renewable electricity production within adopting states to the growth in non-adopting states.

Yin and Powers (2010) found that RPS policies had a positive influence on the development of in-state renewable electricity production. States with RPS policies that restricted trading increased the development of renewable energy more than did states that did not restrict trading. States that allowed renewable energy trading did not offer the same level of incentives as did states that did not allow trading.

Zhao, Tang, and Wang (2013) found that multiple environmental regulations had diminishing returns. Increasing the number of regulations, year over year, reduced the individual policies' outcomes until additional ones provided no discernable changes.

Thus, governments that have already adopted robust regulations would not experience further improvements with the adoption of RPS policies.

## 2.5: Contribution of the Dissertation

The majority opinion within the previous literature indicated that RPS policies should result in higher electricity prices and lower carbon intensity for adopting states (Briggs & Gautam, 2012; Tra, 2011). Previous researchers have suggested that these policies should also increase renewable electricity production within these states (Yin & Powers, 2010). Although recent studies indicated there were in fact modest improvements in renewable electricity production attributable to RPS policies, these improvements seemed to occur years after the adoption of RPS policies (Carley, 2009; Carley & Gaul, 2012). With a few exceptions, these studies have largely excluded the consequences of the stringency and trading requirements of these policies (Carley & Miller, 2012; Marriott & Matthews, 2005; Yin & Powers, 2010). In addition, researchers have mostly ignored any potential mediating influences, such as the independent expansion of renewable electricity production due to market forces or to national policies, on the effectiveness of RPS policies (Burns & Kang, 2012; Riti, 2010).

In this study, I assessed the changes in the electricity markets of adopting states attributable to RPS policies within the United States from 2000 to 2010. I examined the results of these policies on the electricity markets and renewable electricity production of adopting states. I also investigated the influence of the change of renewable energy development on the electricity markets within adopting states. Finally, I used path analysis models to evaluate the mediating influence of renewable electricity production and to quantify the effects of energy efficiency on adopting states.

I built upon the previous studies by offering a detailed examination of the changes in electricity markets and renewable electricity production attributable to RPS policies by broadening the examination. In relation to electricity markets, I expanded upon previous research by including changes in revenue, quantity, and emissions. In relation to renewable electricity production, I built upon previous research by examining the specific relationship between RPS policies and the production of wind, solar, dispatchable, and renewable.

# CHAPTER 3: THE METHODOLOGY

I used OLS regressions to test the three hypotheses presented in Chapter 1. As previously stated, I predicted that states that adopt RPS policies should have a significant reduction in carbon intensity. Furthermore, states that adopt RPS policies should have a significant increase in renewable electricity production. In turn, states that produce renewable electricity production should have a significant reduction in carbon intensity.

Within my study, adopting states were states that possessed a non-zero value for the RPS variables during any year while non-adopting states were states that possessed a zero value for those variables for every year within the dataset. I used OLS regressions to evaluate the changes in the electricity markets of adopting states. I predicted that the adoption of RPS policies would be associated with higher price and revenue and with lower quantity, emissions, and carbon intensity. I used the path analysis models to quantify the effects of energy efficiency on adopting states.

I multiplied the coefficients of the OLS regressions of the second hypothesis by those of the OLS regressions of the third hypothesis to assess the mediation of renewable electricity production on adopting states. I subtracted that mediation from the findings of the OLS regressions of the first hypothesis to quantify the effects of energy efficiency on adopting states. The quantification of the effects of energy efficiency would allow me to determine whether renewable electricity production or energy efficiency caused the outcomes of RPS policies.

The general equations that I used to derive the effects of energy efficiency were:

(1): RPS Variable Energy Efficiency = (RPS Variable H1 Coefficient) – (Renewable Energy Influence)

(2): Renewable Energy Influence = (RPS Variable H2 Coefficient) * (Renewable Energy H3 Coefficient)

I chose structural equation models (SEMs) to verify the path analysis models because SEMs are capable of addressing any issues relating to simultaneity and latent variables. However, they proved to be redundant. They duplicated the results of the path analysis models because the simultaneous effects of RPS policies did not differ significantly from their sequential effects.

## 3.1: Explaining the Characteristics of Electricity Markets

In Chapter 1, I briefly discussed the characteristics of electricity markets that I used to assess the consequences of RPS policies. The characteristics of electricity markets that I used were price, revenue, quantity, emissions, and carbon intensity. I now discuss them in further detail.

I investigated the changes in carbon intensity, where RPS policies being associated with a reduction in carbon intensity within adopting states represented a successful outcome. In effect, I assumed that RPS policies facilitated the replacement of high-carbon emitting fossil fuels with renewable power production and energy efficiency. In addition, I explored the changes in price, revenue, quantity and emissions within the electricity markets of adopting states to further illustrate the influence of RPS policies.

Although evaluating the changes in carbon intensity associated with RPS policies was my primary purpose, there were four secondary explorations. The first area involved price, which I anticipated would increase within adopting states because of the costs of adopting energy efficiency and renewable power production. Second, I expected revenue to rise in adopting states because of the relative inelasticity of the demand for electricity; as price rises, quantity decreases by a smaller percentage. Third, I assumed that quantity would decline in adopting states because of the facilitation of energy efficiency by RPS policies. Finally, I anticipated emissions to fall within adopting states because of energy efficiency and renewable electricity production gains. I found that these secondary explorations allowed for the investigation of the electricity markets within adopting states in further detail than could be accomplished by only examining the changes in carbon intensity.

## 3.2: Methodology of the Study

For consistency with the literature, I first present the OLS regressions models and then the path analysis models. Although the OLS regressions were quite robust, I was unable to use them to evaluate the mediating influence of renewable electricity production or to quantify the results of energy efficiency because they were unable to create a sequential analysis. I constructed the pathways of influence within the path analysis models in order to perform a sequential analysis.

As mentioned before, the general equations that I used to derive the effects of energy efficiency were:

(3): RPS Variable Energy Efficiency = (RPS Variable H1 Coefficient) –

(Renewable Energy Influence)

(4): Renewable Energy Influence = (RPS Variable H2 Coefficient) * (Renewable Energy H3 Coefficient)

I calculated the changes attributable to the effects of energy efficiency promoted within RPS policies by using path analysis models. I measured the effects of energy efficiency by subtracting the renewable energy measure from the coefficients of the OLS regressions of the first hypothesis. I derived the renewable energy measure by multiplying the RPS variable coefficients of the OLS regressions of the second hypothesis by the renewable energy coefficients of the OLS regressions of the third hypothesis.

I attempted to account for the influence of the preexisting political tendencies of states by examining the differences that existed between adopting and non-adopting states before 2000. The preferences of the citizens of adopting states created the political consensuses that formed RPS policies (Lyon & Yin, 2010; Yin & Powers, 2010). Although this political consensus was unique to each state, the consensus presumably changed the electricity markets of adopting states by influencing the design of the adopted RPS policies. In 2000, for example, it was evident that adopting states had different electricity markets than non-adopting states, as discussed below. I present this information in Figures A1 through A5 in Appendix A.

I interpreted that information as indicating that adopting states were already different from non-adopting states before they implemented their RPS policies. Previous researchers have examined the consequences of RPS policies after adoption (Briggs & Gautam, 2012; Tra, 2011). These researchers, however, did not account for the political tendencies that existed in adopting states before the passage of RPS policies. The political tendencies of states affected electricity markets because states controlled by the Democratic Party before 2000 tended to have higher price and revenue and lower quantity, emissions, and carbon intensity than states controlled by the Republican Party.

While adopting states possessed higher price and revenue and lower quantity, emissions, and carbon intensity than non-adopting states, I discovered that the differences between the two types of states were insignificant. I performed robustness checks to verify the validity of the results of my study and found that the differences were accounted for when I used political control variables. Therefore, I discovered that the differences between adopting and non-adopting states before 2000 were attributable to political differences. I present the political control variables in Section 3.2.5.

3.2.1: Research Questions and Hypotheses

I will answer three research questions within my study. First, what effect did RPS policies have on the electricity markets of adopting states? Second, what influence did RPS policies have on the production of renewable electricity in adopting states? Third, what effect did the production of renewable electricity have on the electricity markets of producing states?

Each research question had a corresponding hypothesis related to the influence of RPS policies on electricity markets in adopting states. Each hypothesis contained multiple components. I tested each component with OLS regressions. I present the three hypotheses in Equations 1, 2 and 3. I discuss the variables of the equations in Section 3.2.5.

The equations are:

(5): Electricity Market (price, revenue, quantity, emissions, carbon intensity) = $\alpha + \beta_1$RPS Policy (RPI, percentage, stringency, or trading) + $\beta_2$POP + $\beta_3$PCI + $\beta_4$PCA + $\beta_5$CDD + $\beta_6$NG + $\beta_7$DGC + $B_8$DHC + $\beta_9$DSC +$\varepsilon$.

(6): Renewable Electricity (renewable, wind, solar, Alternative) = $\alpha + \beta_1$RPS Policy (RPI, percentage, stringency, or trading) + $\beta_2$POP + $\beta_3$PCI + $\beta_4$PCA + $\beta_5$CDD + $\beta_6$NG + $\beta_7$DGC + $B_8$DHC + $\beta_9$DSC +$\varepsilon$.

(7): Electricity Market (price, revenue, quantity, emissions, carbon intensity) = $\alpha + \beta_1$Renewable Electricity (renewable, wind, solar, or dispatchable) + $\beta_2$POP + $\beta_3$PCI + $\beta_4$PCA + $\beta_5$CDD + $\beta_6$NG + $\beta_7$DGC + $B_8$DHC + $\beta_9$DSC +$\varepsilon$.

I explain the influence of RPS policy on electricity markets within adopting states with the first equation. I explore the effect of RPS policies on renewable electricity production within adopting states with the second equation. I represent the influence of renewable electricity production on electricity markets within adopting states with the third equation. I control for the effects of population (POP), per capita income (PCI), per capita area (PCA), cooling degree-days (CDD), natural gas consumption (NG), Democratic Party governorship control (DGC), Democratic Party state house control (DHC), and Democratic Party state senate control (DSC) within each of the equations. I provide details on these variables in Appendix A.

The coefficient expectations are:

*H1*: The type of RPS policy (percentage, stringency, trading, or RPI) will influence the electricity markets of adopting states in the predicted directions (+price, +revenue, -quantity, -emissions, or -carbon intensity).

*H2*: The type of RPS policy (percentage, stringency, trading, or RPI) will shape renewable electricity production within adopting states in the predicted directions (+wind, +solar, +dispatchable, or +renewable).

*H3*: Renewable electricity production (wind, solar, dispatchable, or renewable) will influence the electricity markets of producing states in the predicted directions (+price, +revenue, -quantity, -emissions, or -carbon intensity).

### 3.2.2: Goal of the Evaluation

The goal of the evaluation is to examine the effect of RPS implementation. The previous research had already fully explained the factors that led to the adoption of RPS policies, so I focused on the outcomes of RPS policies. I also examined the results of renewable electricity production on adopting states so I could evaluate their influence on the effects of RPS policies.

The four components that comprised RPS policies are percentage, stringency, trading, and RPI. If they have produced the intended results, then they should show a significantly negative association with carbon intensity. Any connected change in carbon intensity would decrease the amount of carbon dioxide produced per unit of electricity generated by adopting states, which would represent an improvement in the electricity markets. If I do not find that result, the four elements of RPS policies could still have a discernable relationship with the other four characteristics of electricity markets (price, revenue, quantity, or emissions).

### 3.2.3: Assumption of the Hypotheses

The underlying assumption of the hypotheses was that RPS policies altered the electricity markets of adopting states. The influence of RPS policies was a combination of the results of renewable electricity production and the effects of energy efficiency. Demographic variables, energy variables, and political variables potentially moderated the performance of RPS policies.

I found that the most relevant demographic variables within the professional literature were PCA, PCI, and POP. I operationalized PCA as the amount of land, in square meters, per capita of a state. PCA served as a proxy for the solar and wind intensity variables from the previous literature because it was highly correlated with both solar intensity and wind intensity (Burns & Kang, 2012; Riti, 2010). I formulated PCI as the GDP of a state divided by its population in thousands of dollars per capita. PCI represented the wealth effects found within each state (Yi & Feiock, 2012). I created POP as the population in millions of residents. POP quantified the absolute population of a state, which directly affected the electricity markets of adopting states.

The energy variables found to be the most pertinent in the previous literature were CDD and NG. I operationalized CDD as the number of average cooling degree-days recorded in a particular state during a given year. CDD reflected the electricity demand created by the requirements for cooling within a state during the warmest months of the year. I explain my reasons for using CDD instead of using a measure for heating degree-days below. I created NG as W-h of electricity produced from natural gas per capita per year. NG captured the environmental effects associated with replacing coal consumption with natural gas consumption.

I found that the most suitable political variables within the existing literature involved the party control of a state: DGC, DHC, and DSC. DGC was a dichotomous variable that represented whether the Democratic Party controlled the governorship of a state. DHC was a dichotomous variable that reflected whether the Democratic Party controlled the house of representatives of a state. DSC was a dichotomous variable that captured whether the Democratic Party controlled the senate of a state. Previous researchers had found the Democratic Party was more sympathetic to passing environmental policies than the Republican Party (Lyon & Yin, 2010; Yin & Powers, 2010). In the case of Nebraska, the only state with a unicameral legislature, I made DHC and DSC equal.

3.2.4: Data

I constructed a dataset from publicly available data. The dataset consisted of panel data from every U.S. state (and Washington, DC) for each year from 2000 to 2010. The dataset, however, excluded states that had voluntary RPS policies. I found that their inclusion prevented a clear distinction between states that had adopted mandatory RPS policies and states that had not adopted any RPS policies. In particular, I excluded the states of South Dakota, Utah, Vermont, and Virginia because of the voluntary nature of their policies. I also omitted a variable that differentiated between adopting states and non-adopting states, as explained below.

I collected my data primarily from U.S. government sources such as DSIRE (2013), the EIA (2013a), and U.S. Census (2013). The N.C. Clean Energy Technology Center at N.C. State University operates DSIRE (Database of State Incentives for Renewables & Efficiency) while the U.S. Department of Energy funds DSIRE. I collected the data concerning the state political variables from their national organizations (NCSL, 2015; NGA, 2011). However, I found some uncertainties regarding the classification of some states during years of divided government and years of independent party governance. If the governor was a member of the Democratic Party during an era of divided government, I considered the Democratic Party to be in charge of the chamber of the legislature in question during a given year.

I used state-year as my unit of analysis. Each state-year represented the intersection of one of the forty-six states (plus Washington, D.C.) with one of the 11 years (2000 to 2010). The dataset comprised 517 cases, which I analyzed for the effects of RPS policies on the electricity markets in adopting states. The utilization of per capita measures prevented some issues involving error terms in spatial and temporal autocorrelation that would have otherwise occurred. I verified the appropriateness of the per capita measures when state and year fixed effect models did not add any explanatory power to the study.

3.2.4.1: Explaining the Exclusion of Control Variables

I decided against using a variable that differentiated between adopting states and non-adopting states when I discovered that any such variable was highly correlated with the RPS variables. Outside of the quantitative models that used the RPS variables, I found that such a variable was universally insignificant. Since the inclusion of such a variable either invalidated the models through producing high levels of multicollinearity or was simply insignificant, I omitted such a variable from my quantitative models.

I initially included nonprofit data that I collected indirectly from the IRS under the auspices of the National Center of Charitable Statistics. I had intended to use those data to illustrate with a fine degree of granulation the consequences of the political tendencies of the citizens of a state. While the variables derived from the nonprofit data could have had an effect, they were highly correlated with PCI, so I eventually excluded them from the final study.

I also originally included a number of energy control variables from the Energy Information Administration (EIA). I found that these variables correlated with one of the other control variables or dependent variables. For instance, the measures for coal and petroleum electricity generation were highly correlated with NG. Thus, I dropped them in favor of NG because of the anticipated environmental effect of increased electricity production by natural gas on adopting states. Similarly, the measures of potential solar and wind energy capacity were highly correlated with PCA. I found that areas of greater wind capacity (i.e., plains) and greater solar capacity (i.e., deserts) tended to have more land area per resident. Therefore, I dropped these variables in favor of PCA because these variables were highly correlated with land area and each other. In addition, there was an inverse correlation between the measure of average heating degree-days per year and CDD. The summation of heating degree-days per year and cooling degree-days produced insignificant results because of the inverse correlation between the two measures. I excluded average heating degree-days per year from the final analysis because there are methods of heating that do not require the use of electricity, while cooling requires air conditioning.

3.2.4.2: Explaining the Exclusion of the Fixed Effect Variables

A fixed effect model would have been more conventional than the model that I used. I eliminated the fixed effect variables from my model because I found them to be unnecessary or invalid. Specifically, I showed the fixed effect variables to be unnecessary because they had no effect on the model or invalid because they had high

Variance Inflation Factors (VIF), which indicated high levels of multicollinearity (O'Brian, 2007).

After I discovered that the fixed effect variables were unnecessary or invalid, I sought to gain similar outcomes using robust clustered errors for State and Year. The difference between the models that included standard errors and those that included robust clustered errors was insignificant. There was no evidence that the errors were suffering from serial or spatial clustering. I concluded that it would be better for ease of interpretation to use standard errors for my analysis.

3.2.5: Constructing the Variables of the Study

I constructed the variables to align with previous research into the outcomes of RPS policies on the electricity markets in adopting states. I expanded upon previous studies by examining the results of the components of these policies (RPI, percentage, stringency, and trading) and of the types of renewable electricity production (renewable, wind, solar, and dispatchable). I explain the variables below and offer an expanded discussion in Appendix A.

I created the RPS variables to be the independent variables of the first and second hypotheses. The RPS variables were percentage, stringency, trading, and RPI. Because percentage, stringency, and trading were capturing similar phenomena, I used RPI to represent the totality of the effects of RPS policies. I operationalized the percentage, stringency, and trading variable in W-h per capita to allow for their inclusion in the RPI variable.

The equations I used to formulate the RPS variables are:

(8) percentage = (MW-h * RPS percentage) / (POP * 1,000,000).

(9) stringency = (MW-h * RPS stringency) / (POP * 1,000,000).

(10) trading = (MW-h * RPS trading) / (POP * 1,000,000).

(11) RPI = (percentage) + (stringency) + (trading).

I derived the RPS variables from information obtained from DSIRE (2013), the EIA (2013a), and the U.S. Census (2013). I changed the operationalization of these variables from W-h per capita per year to MW-h per capita per year within models that had price or carbon intensity as the dependent variable. This transformation was necessary in order to create coefficients that were large enough for interpretation.

I generated carbon intensity, price, revenue, quantity, and emissions to be the dependent variables of the first and third hypotheses. I explored the results of RPS policies and renewable electricity production through analyzing their relationships to the five dependent variables. While carbon intensity was the primary dependent variable within the first and third hypotheses, I used the other four dependent variables to evaluate the secondary outcomes of RPS policies on adopting states and renewable electricity production on producing states.

The equations I used to generate the dependent variables are:

(12) carbon intensity = (Metric Tons of $CO_2$/Year) / (MW-h/Year).

(13) price = ($/MW-h).

(14) revenue = ([$/MW-h] * [MW-h/Year]) / (POP * 1,000,000).

(15) quantity = (MW-h/Year)/ (POP * 1,000,000).

(16) emissions = (Metric Tons of $CO_2$/year * 1,000,000 grams/metric ton) / (POP * 1,000,000).

I was unable to standardize the dependent variables into one type of measure, so I uniquely operationalized each of them. Carbon intensity is measure in grams of carbon dioxide emissions per W-h, price in $ per MW-h, revenue in $, quantity in W-h per capita, and emissions in grams of carbon dioxide emissions per capita. I produced the electricity market variables from information obtained from DSIRE (2013), the EIA (2013a), and the U.S. Census (2013).

I formulated renewable, wind, solar, and dispatchable to be the dependent variables of the second hypothesis and the independent variables of the third hypothesis. The renewable electricity production variables were renewable, wind, solar, and dispatchable. Because wind, solar, and dispatchable proved to be highly correlated, I used renewable to represent the total renewable electricity production within a state. I formulated the wind, solar, and dispatchable variables in W-h per capita to allow for their inclusion in the renewable variable.

The equations that I used to create the renewable energy production variables are:

(17) wind = (MW-h/year * wind percentage) / (POP * 1,000,000).

(18) solar = (MW-h/year * solar percentage) / (POP * 1,000,000).

(19) dispatchable = (MW-h/year * other alternative energy percentage) / (POP * 1,000,000).

(20) renewable = (wind + solar + dispatchable).

I constructed the renewable electricity production variables from information obtained from DSIRE (2013), the EIA (2013a), and the U.S. Census (2013). I changed the operationalization of these variables from W-h to MW-h per capita per year within models that had price or carbon intensity as the dependent variable, again for ease of interpretation.

### 3.2.6: Three-Stage Model

In the first stage of the model, I evaluated the effects of RPS policies on adopting states. The second stage focused on the influence of RPS policies on renewable electricity production within adopting states. In the third stage, I examined the effects of renewable electricity production on producing states.

I explored all of the potential pathways of influence; however, I only focused on the significant pathways. These significant pathways possessed three stages. In the first stage, the independent variable was required to have a significant effect on the dependent variable (which was also the independent variable of the second state). The independent variable for the second stage needed to have a significant influence on the dependent variable of the second stage (which was also the independent variable of the third phase). Finally, the independent variable of the third stage was required to have a significant relationship with the dependent variable of the third stage. Since each stage used the same control variables, I did not investigate the pathways of influence for the control variables.

## 3.3: Explanation of the Path Analysis Models

I used path analysis models to evaluate the mediation of renewable electricity production and to quantify the effects of energy efficiency within adopting states. I present the structure of the path analysis models in Figures C1 through C4 in Appendix C. The figures show the pathways of the influence of the independent variables through each of the three hypotheses. I used renewable electricity production as a mediating variable within the path analysis models. A meditating variable changes the influence of an independent variable on a dependent variable by intervening in the pathway of influence.

The first hypothesis determined the overall influence of RPS policies on electricity markets. The second and third hypotheses assessed the mediation of renewable power production so that I could quantify the effects of energy efficiency on adopting states by using the path analysis models. I grouped the pathways of influence into sequences, and each sequence contained path analysis models that shared the same primary independent variable.

3.3.1: Path Analysis Sequences

The RPI, percentage, stringency, and trading sequences represented the pathways of influence of the RPS variables. These pathways evaluated the effects of the RPS variables on the electricity markets of adopting states, as represented by price, revenue, quantity, emissions, and carbon intensity. I traced the pathways of influence through the four variables that represented the potential mediation caused by renewable electricity production, as represented by wind, solar, dispatchable, and renewable.

I divided the path analysis sequences into three stages. In the first stage, I examined the coefficients of the OLS regressions of the second hypothesis to assess the influence of RPS policies on renewable electricity production within adopting states. I divided the first stage into four partial models, each of which centered on one of the four dependent variables of the second hypothesis (wind, solar, dispatchable, or renewable).

In the second stage, I estimated the coefficients of the OLS regressions of the third hypothesis to evaluate the effects of renewable electricity production on producing states. I divided the second stage into four partial models, each of which centered on one of the four of the third hypothesis (wind, solar, dispatchable, and renewable). I present the sequences in Figures C1 through C4 of Appendix C.

3.3.2: Structural Equation Models

I used structural equation models (SEMs) to verify the outcomes of the path analysis models because of the weaknesses of those models in respect to simultaneous effects. The SEMs accounted for these influences by running multiple regression equations and by controlling for the simultaneous influence of each the independent variables on the other independent variables regression equations within the same model (Chen & Chang, 2013a & 2013b). I dropped the SEMs from the model after their outcomes were identical to the results of the path analysis models.

## 3.4: Policy Analysis Model

After I tested the path analysis models, it was possible to compare the influences attributable to the RPS policies of adopting states. I was able to assess the overall influence of RPS policies, the consequences of renewable electricity production and the effects of energy efficiency. If I detected any benefit derived from the adoption of RPS policies, I might have also been able to make a conclusion concerning which types of RPS policies might have produced the largest beneficial effect on adopting states. I would have quantified that beneficial effect through a policy effect variable derived from the policy analysis model.

I would calculate the magnitude of the effects of RPS policies by creating a policy effect variable. I would derive one policy variable for each of the four types of RPS policies (i.e., RPI, percentage, stringency, and trading). I would also derive each policy variable by calculating the cost of reducing carbon intensity in adopting states by dividing the change in revenue by the change in carbon intensity. If the quotient had been negative, I would have been able to derive a cost associated with the reduction of carbon intensity for each type of RPS policy.

I anticipated that if I were able to derive a policy variable from the results of the study, then the findings regarding that policy variable could guide policy-makers seeking to improve RPS policies. The resulting outcome of the policy analysis model was not significant, however, meaning that I was unable to assess the cost associated with the reduction of carbon intensity for each type of RPS policy. The primary reason why I was unable to provide a policy variable was due to the lack of significant reductions in carbon intensity within adopting states associated with RPS policies. I discuss the failure to create the policy effect variable in further detail in Chapter 4.

## 3.5: Limitations of the Evaluation

I discovered that my analysis suffered from several limitations. In particular, the evaluation was limited to path analysis models to quantify the effects of energy efficiency on adopting states. The evaluation was also restricted to 2000 to 2010. In addition, the model may not be generalizable beyond the United States.

I used a dataset that encompassed 2000 to 2010. The results of the evaluation were formative, so the passage of time could change the outcomes of RPS policies. In fact, since the enforcement of the RPS mandates occurred after 2010 in most of the adopting states, I consider the results of my study to be preliminary. The effects of these policies could grow over time if policy-makers learn from outcomes. The influence of these policies could also increase over time if renewable energy sources become more affordable as economies of scale reduce costs.

The average adopting state had these policies for four years during the timeframe of the dataset, meaning that cumulative effects may not have appeared significant before 2010. Future researchers should be able to observe some effect once RPS requirements exceed zero, but the full effects will be unknown until the maximum requirement is in place (preferable for several years).

Further, I question the generalizability of my outcomes beyond the policy environment of the United States. Other nations may be able to adopt national-level RPS policies that are more effective than the state-level RPS policies implemented in the United States. The United States, however, is constrained by particular legal restrictions that prevent the federal government from providing direct forms of financial support through RPS policies. For example, the United States is unable to provide feed-in tariffs, because that practice would favor one form of electricity production over another (Bloom, Forrester & Klugman, 2011). These particular legal restrictions do not hamper the policies of other nations (Cowart & Neme, 2013).

# CHAPTER 4: RESULTS OF THE ANALYSIS

Chapter 4 presents the results of my analysis. The goal of the analysis was to evaluate the effect of RPS policies on electricity markets within adopting states. Carbon intensity was the central measure of assessment. I measured carbon intensity as the ratio of grams of carbon dioxide emissions produced per W-h of electricity produced within adopting states. An associated reduction in carbon intensity would provide support for the first hypothesis, indicating evidence of an improvement in the electricity markets of adopting states.

I used ordinary least square (OLS) regressions to test the three hypotheses of the dissertation. I tested for autocorrelation with Durbin-Watson tests and for multicollinearity with variance inflation factor (VIF) tests. I found Durbin-Watson statistics between 1.4 and 2.0 and VIF scores between 1.0 and 1.9, indicating no major autocorrelation or multicollinearity issues.

I found no evidence of a reduction in carbon intensity within adopting states in connection to RPS policies. This finding motivated me to seek possible evidence of mediation by renewable electricity production in Hypotheses 2 and 3. If RPS policies increased renewable electricity production, I would find support for Hypothesis 2 and partial evidence of mediation. If renewable electricity production improved electricity markets by reducing carbon intensity, I would find support for Hypothesis 3 and partial evidence of mediation.

If I did not find support for Hypothesis 2, this would mean that RPS policies were not associated with an increase in renewable electricity production. If I did not find support for Hypothesis 3, this would mean that renewable electricity production did not have the significant relationship to the electricity markets of producing states that the previous literature had predicted. If I found no evidence to support the mediation of the effects of RPS policies, then their effects on adopting states would be completely dependent on their facilitation of energy efficiency. That is, within adopting states RPS policies most likely influence the electricity markets of adopting states because they directly facilitate energy efficiency.

## 4.1: Overview of the Variables

First, I present the summary statistics of the variables I used in the analysis, which are the averages for 2000 to 2010. Table 4.1 shows an overview of the differences between the average values of adopting states and non-adopting states. Figures A1 through A9 in Appendix A are a visual depiction of the average differences between adopting states and non-adopting states, as discussed in the following paragraphs.

In general, adopting states had lower carbon intensity than the non-adopting states 2000; the differences between the two types of states did not change from 2000 to 2010. When examining Figures A1 through A4, I noticed equivalent differences when I examined price, quantity, revenue, and emissions. Adopting states had higher price, lower quantity, higher revenue, and lower emissions than non-adopting states. Figures A1 through A5 indicated that the adoption of RPS policies was not associated with any significant changes in the electricity markets of adopting states.

Table 4.1: Comparison of variables between adopting and non-adopting states

| Variable | Overall Mean | Adopting Mean | Non-adopting Mean |
|---|---|---|---|
| N | 517 | 352 | 165 |
| RPI | 4,148,000 | 6,092,000 | 0 |
| percentage | 1,918,000 | 2,817,000 | 0 |
| stringency | 534,400 | 784,900 | 0 |
| trading | 1,696,000 | 2,491,000 | 0 |
| renewable | 433,500 | 401,000 | 503,700 |
| wind | 171,800 | 147,000 | 224,600 |
| solar | 880.3 | 1279 | 29.03 |
| dispatchable | 260,800 | 252,800 | 278,100 |
| price | 84.56 | 91.43 | 69.89 |
| revenue | 1,282,000,000 | 1,145,000,000 | 1,575,000,000 |
| quantity | 17,270,000 | 13,860,000 | 24,550,000 |
| emissions | 12,210,000 | 8,996,000 | 19,070,000 |
| carbon intensity | 0.6376 | 0.6256 | 0.6632 |
| DGC | 0.5000 | 0.6000 | 0.3000 |
| DHC | 0.5700 | 0.6200 | 0.4700 |
| DSC | 0.5200 | 0.6100 | 0.3100 |
| CDD | 96.50 | 83.93 | 123.3 |
| NG | 2,410,000 | 2,338,000 | 2,563,000 |
| PCA | 104,500 | 44,390 | 232,900 |
| PCI | 42.55 | 44.67 | 38.03 |
| POP | 6.044 | 6.786 | 4.461 |

Notes: I operationalized RPI, percentage, stringency, trading, renewable, wind, solar, and dispatchable in W-h per capita. Price is measured in $ per MW-h, revenue in $ per capita, quantity in W-h per capita, emissions in grams per W-h, and carbon intensity in grams per W-h. I operationalized CDD in days per year, NG in W-h per capita, PCA in square meters per capita. I measured PCI in $1,000 per capita and POP in millions of people per state.

When I examined Figures A6 through A9, I found that the influence of RPS policies on the production of renewable electricity was more complicated than I had initially hypothesized. Non-adopting states dominated the production of wind from 2000 to 2010. Adopting states consistently increased the production of solar from 2000 to 2010. Non-adopting states produced higher levels of dispatchable in 2000, but adopting states produced higher levels of dispatchable by 2010.

I discovered that the adoption of RPS policies was unconnected to the differences between these two types of states. Adopting states possessed significantly higher prices and revenues and significantly lower quantity, emissions, and carbon intensity than non-adopting states before they adopted RPS policies. Non-adopting states also possessed significantly higher levels of wind and renewables than adopting states from 2000 to 2010.

## 4.2: Results of the OLS Regressions

### 4.2.1: OLS Regressions

I discussed the model of my analysis in depth in Chapter 3; however, it is necessary to consider the nature of the OLS regressions before discussing the outcomes. I used panel data for the OLS regressions. I was interested in comparing the differences between states that had adopted mandatory RPS policies and states that had adopted no RPS policies, so I excluded states that adopted voluntary RPS policies from the dataset. I tested the data with state and year fixed effects before using it in my study. Using state and year fixed effects made no difference in the outcomes of the OLS regression regressions, so I excluded them.

The nature of the independent variables required that I test each independent variable separately to avoid issues of multicollinearity. When testing Hypotheses 1 and 2, I tested each of the RPS variables (RPI, percentage, stringency, and trading) separately to avoid multicollinearity. When testing Hypothesis 3, I tested each of the renewable energy variables (renewable, wind, solar, and dispatchable) separately because of similar concerns.

I operationalized my independent variables in W-h per capita per year whenever possible. When the dependent variables were price or carbon intensity, I transformed the independent variables into MW-h per capita per year because the coefficients were undetectable when I measured them in W-h. I also transformed NG and POP by a similar magnitude to make their coefficients detectable when I used price or carbon intensity as the dependent variables.

I discuss the overall results of the OLS regressions in detail in Sections 4.2.3 through 4.2.5. Table 4.2 shows an overview of the outcomes. The independent variables are in the columns, and the dependent variables in the rows. I show the differences in the dependent variables of the study, between adopting states and non-adopting states, in Figures A1 through A9 in Appendix A.

Table 4.2: Formative evaluation overview results (N=517)

| *Hypothesis 1* | *RPI* | *percentage* | *stringency* | *trading* |
|---|---|---|---|---|
| price (M) | 0.000 | 1.972** | -1.248 | 0.019 |
| revenue | 34.162*** | 81.52*** | 130.595*** | 75.861*** |
| quantity | 0.519*** | 0.967** | 2.455*** | 1.119*** |
| emissions | 0.492*** | 0.910** | 2.504*** | 0.946** |
| carbon intensity (M) | 0.005** | 0.013** | 0.023*** | 0.010* |
| *Hypothesis 2* | *RPI* | *percentage* | *stringency* | *trading* |
| renewable | -0.009 | -0.011 | -0.051** | -0.017 |
| wind | -0.005 | -0.012 | -0.007 | -0.022 |
| solar | 0.000 | 0.000 | 0.000 | 0.000 |
| dispatchable | -0.003 | 0.000 | -0.043** | 0.005 |
| *Hypothesis 3* | *renewable* | *Wind* | *solar* | *dispatchable* |
| price (M) | 0.000 | -4.949* | -0.000 | 0.074*** |
| revenue | 511.329*** | 693.368*** | -2,925.161 | 84.393 |
| quantity | 7.229*** | 11.586*** | 82.654 | -2.275 |
| emissions | 6.737*** | 12.410*** | 108.820 | -4.420** |
| carbon intensity (M) | -0.002 | 0.074*** | 1.040 | -0.129*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million.

4.2.2: Results of the Three Hypotheses

I present an overview of the direction, magnitude, and significance of each of the OLS regressions in Table 4.2, although the coefficients for the control variables are not included. I present the coefficients of the control variables in Appendix B. I discuss the direction and significance of the variables in each OLS regression in further detail in Sections 4.2.3 through Sections 4.2.5. I also give the exact figures for the model summaries of the OLS regressions in Tables B1 through B20 of Appendix B.

While I did find substantial differences between adopting states and non-adopting states within the summary statistics, I discovered that they did not significantly affect the outcomes of RPS policies. I tested the validity of my results by controlling for the status of a state (adopting versus non-adopting). I excluded the status of a state from the final analysis when I realized that it was statistically insignificant throughout the OLS regressions and the path analysis models.

4.2.3: Findings of the First Hypothesis

The first hypothesis was a compound hypothesis in which I proposed that RPS policies would be significantly negative in relation to carbon intensity. RPS policies would be significantly positive in respect to price and revenue. RPS policies would also be significantly negative in connection to quantity and emissions.

In the first hypothesis, I examined the effects of RPS policies on adopting states. The components of RPS policies included RPI, percentage, stringency, and trading. Percentage represented the minimum amount of electricity produced by renewable sources to fulfill the specifications of an RPS policy. Stringency measured the minimum amount of electricity from specific renewable sources to meet the requirements of an RPS policy. Trading quantified the maximum amount of electricity production that was importable from other states to satisfy an RPS policy. RPI summed the cumulative influence of an RPS policy, the combined effects of percentage, stringency, and trading, as explained in Chapter 3.

The nature of the first hypothesis required multiple OLS regressions to explore the relationship between RPS policies and their consequences for state electricity markets. Therefore, I used multiple OLS regressions to examine the first hypothesis and the multiple intersections between independent and dependent variables. I evaluated the results of Hypothesis 1 according to the criteria that I presented in Chapters 1 and 3. I report the results of the OLS regressions of the first hypothesis in Tables B1 through B8 in Appendix B.

4.2.3.1: Independent Variables

The results of the RPS variable regressions were contrary to the predictions of the first hypothesis. Although the RPS variables were significantly positive in relation to revenue, there was no corresponding relationship with price, except in the case of the percentage model. The RPS variables were also significantly positive in respect to quantity, emissions, and carbon intensity. However, I could not use the results of the OLS regressions to support the first hypothesis, as they did not show any decrease in carbon intensity. I present the findings of these OLS regressions in Tables B1 through B8 of Appendix B.

4.2.3.2: Control Variables

In the first hypothesis, the direction and significance of the control variables were generally stable regardless of the independent variable. I present the results of the control variables on the dependent variables of the first hypothesis in Tables B1 through B8. I expected the control variables, with the exception of PCA, to be significantly positive in respect to price and revenue and significantly negative in relation to quantity, emissions, and carbon intensity. I expected PCA to be significantly positive in association with price, revenue, quantity, emissions, and carbon intensity.

The existence of a state's senate controlled by the Democratic Party was the most influential factor among the political control variables. DGC was significantly negative in relation to price and was insignificant in relation to revenue, quantity, emissions, and carbon intensity. DSC was significantly positive in respect to price and significantly negative in association with revenue, quantity, emissions, and carbon intensity. DHC was significantly positive in connection to price and was insignificant in respect to revenue, quantity, emissions, and carbon intensity.

Higher production of electricity from natural gas was the more influential factor among the energy control variables. CDD was significantly positive in relation to revenue and emissions and was insignificant in association with price, quantity, and carbon intensity. NG was significantly positive in respect to price, significantly negative in connection to emissions and carbon intensity, and was insignificant in association with revenue and quantity. I discuss the seemingly counterintuitive effects of NG on price in Chapter 5.

A high population was the most influential factor among the demographic control variables. PCA was significantly positive in connection to price, quantity, emissions, and carbon intensity and was insignificant in relation to revenue. PCI was significantly positive in respect to price and carbon intensity and significantly negative in association with quantity, revenue, and emissions. POP was significant positive in relation to price and significantly negative in connection to quantity, revenue, emissions, and carbon intensity.

4.2.3.3: Final Thoughts Concerning the First Hypothesis

The relative lack of significant outcomes in the predicted direction in the first hypothesis indicated there was possibly something amiss with the design or implementation of RPS policies. While the OLS regressions showed the RPS policies were significantly positive in relation to revenue, they were not significantly positive in respect to price or significantly negative in connection to quantity, emissions, or carbon intensity. The lack of the predicted association between carbon intensity and RPS policies suggests that RPS policies have had no discernable benefits for adopting states.

Therefore, I explored the second hypothesis and the third hypothesis to ascertain the reasons for the lack of significant outcomes. I also explored the path analysis models to assess the mediation of renewable electricity production and to quantify the effects of energy efficiency on adopting states. My results suggested that one of those two factors were preventing RPS policies from being effective.

4.2.4: Findings of the Second Hypothesis

The second hypothesis was a compound hypothesis that I used to discover the association between RPS policies and renewable electricity production within adopting states. I predicted that RPS policies would have a significantly positive connection to wind, solar, dispatchable, and renewable. I report the results of the OLS regressions of the second hypothesis in Tables B9 through B12 in Appendix B.

In addition, the second hypothesis represented the multiple pathways of influence for the path analysis models. Within the path analysis models, I evaluated every potential pathway traceable through the independent and dependent variables of the second and third hypotheses. The RPI pathways were RPI-wind, RPI-solar, RPI-dispatchable, and RPI-renewable. The percentage pathways were percentage-wind, percentage-solar, percentage-dispatchable, and percentage-renewable. The stringency pathways were stringency-wind, stringency-solar, stringency-dispatchable, and stringency-renewable. The trading pathways were trading-wind, trading-solar, trading-dispatchable, and trading-renewable. Since RPS policies facilitated energy efficiency as well as renewable electricity production, these pathways were essential for assessing the mediation of renewable electricity production and the effects of energy efficiency within adopting states. The results of the second hypothesis would serve as the first stage of the path analysis models.

4.2.4.1: Independent Variables

The results of the OLS regressions were inconsistent with the predictions of the second hypothesis. The OLS regressions showed that the independent variables appeared to have no significant relationships with the dependent variables, with the exception of stringency. Therefore, I could not use the OLS regressions to support the second hypothesis because they were insignificant. I present the findings of the OLS regressions in Tables B9, B10, and B12 in Appendix B.

With the exception of stringency, RPS policies did not appear to have a significant connection to renewable electricity production. Even stringency did not align with the predictions of the second hypothesis either, as the OLS regressions showed that it was significantly negative in relation to some types of renewable electricity production.

Stringency was not significant in respect wind or solar, but it was significantly negative in connection to dispatchable and renewable. However, I could not use the OLS regressions to support the second hypothesis because they revealed that stringency was not significantly positive in association with renewable electricity production. I present the findings of the OLS regressions in Table B11 of Appendix B.

4.2.4.2: Control Variables

The results of the OLS regressions of the second hypothesis indicate that the control variables did not strongly influence renewable electricity production (wind, solar, dispatchable, or renewable). Specifically, none of the political control variables or the demographic control variable appeared to possess a high magnitude within the OLS regressions, even if they were statistically significant. I present the results of the control variables on the dependent variables of the second hypothesis in Tables B13 through B16 in Appendix B. I had anticipated that the control variables would increase the production of renewable electricity, but they did not.

None of the political control variables appeared to possess a high magnitude, even if they were significant. DGC was significantly positive in relation to renewable and wind, but significantly negative in relation to solar and insignificant in connection to dispatchable. DHC was significantly positive in respect to dispatchable, but significantly negative in connection to wind and insignificant in association with renewable and solar. DSC was significantly positive in relation to dispatchable, but insignificant in respect to renewable, wind, and solar.

The two energy control variables were equally influential factors. CDD was significantly negative in relation to renewable, wind, solar, and dispatchable. NG was significantly positive in respect to renewable, solar, and dispatchable, but it was insignificant in connection to wind. The circumstances that led to increased CDD also seemed to lead to decreased renewable electricity production while those that led to increased NG also appeared to lead to increased renewable electricity production. In effect, the same policy factors that led to an increase in renewable electricity production within a state also led to an increase in NG.

I found that none of the demographic control variables possessed a high magnitude, even if they were significant. PCA was significantly negative in connection to renewable and dispatchable and insignificant in association with wind and solar. PCI was significantly negative in relation to dispatchable and insignificant in respect to renewable, wind, and solar. POP was significantly positive in connection to solar, but significantly negative in association with renewable and dispatchable and insignificant in relation to wind.

4.2.4.3: Final Thoughts Concerning the Second Hypothesis

In the second hypothesis, I predicted that RPS policies would be significantly positive in relation to renewable electricity production; however, the OLS results indicated that none of the RPS policies was significantly positive in respect to that production. In fact, stringency appeared to be significantly negative in connection to dispatchable and renewable. The results of the OLS regressions indicated that the path analysis models could only potentially mediate the findings of the first hypothesis concerning stringency. Even though the results of the OLS analyses did not reveal support for the second hypothesis, the path analysis models would detect if renewable electricity production mediated the influence of stringency.

4.2.5: Findings of the Third Hypothesis

The third hypothesis was a compound hypothesis in which I proposed that the production of renewable electricity would have a significant relationship with the electricity markets of producing states. I suggested that the production of renewable electricity would be significantly positive in relation to price and revenue. I also proposed that the production of renewable electricity would be significantly negative in respect to quantity, emissions, and carbon intensity.

The third hypothesis served as the second part of the path analysis models. The nature of the third hypothesis required multiple OLS regressions to explore these relationships. I report the outcomes of the OLS regressions of the third hypothesis in Tables B13 through B20 in Appendix B.

4.2.5.1: Independent Variables

The results of the renewable electricity production OLS regressions did not appear to support the predictions of the third hypothesis, with the exception of OLS regressions relating to dispatchable. Although the renewable electricity variables were significantly positive in connection to price and revenue, they were also significantly positive in association with quantity, emissions, and carbon intensity. Therefore, I could not use the OLS regressions to support the third hypothesis because renewable electricity production did not appear to decrease carbon intensity. I present the findings of these OLS regressions in Tables B13 through B18 of Appendix B.

When dispatchable was the independent variable, however, I discovered that the results of the OLS regressions were consistent with the predictions of the third hypothesis. Although dispatchable was insignificant in respect to revenue or quantity, it was significantly positive in connection to price and significantly negative in association with emissions and carbon intensity, all of which were in the predicted directions. Therefore, the findings of the OLS regressions in relation to dispatchable partially supported one of the hypothesis of my study. I present the findings of these models in Tables B19 and B20 in Appendix B.

4.2.5.2: Control Variables

The results of the OLS regressions of the third hypothesis indicated that the control variable strongly influenced the dependent variables (price, revenue, quantity, emissions, and carbon intensity). Specifically, the energy control variables and the demographic control variables appeared to be a strong influence on the dependent variables. I present the effects of the control variables on the dependent variables of the third hypothesis in Tables B13 through B20 in Appendix B. I anticipated the control variables to be significantly positive in connection to price and revenue and to be significant negative in association with quantity, emissions, and carbon intensity.

The dominance of a state's senate by the Democratic Party was the most influential factor among the political control variables. DGC was significantly negative in relation to price and insignificant in respect to revenue, quantity, emissions, and carbon intensity. DHC was significantly positive in connection to price, but insignificant in association with revenue, quantity, emissions, and carbon intensity. DSC was significantly positive in relation to price, but significantly negative in respect to revenue, quantity, emissions, and carbon intensity.

Higher production of electricity from natural gas was the more influential factor among the energy control variables. CDD was significantly positive in connection to revenue, quantity, emissions, and carbon intensity, but insignificant in association with price. NG was significantly positive in relation to price, but significantly negative in respect to quantity, emissions, and carbon intensity and insignificant in respect to revenue. I explain the counterintuitive relationship between NG and price in Chapter 5.

The population of a state was the most influential factor among the demographic control variables. PCA was significantly positive in connection to price, revenue, quantity, emissions, and carbon intensity. PCI was significantly positive in association with price and carbon intensity, but insignificant in relation to revenue, quantity, and emissions. POP was significantly positive in respect to price, but significantly negative in connection to revenue, quantity, emissions, and carbon intensity.

4.2.5.3: Final Thoughts Concerning the Third Hypothesis

The lack of significant results in the predicted direction in most of the OLS regressions indicated that the third hypothesis was unsupported. Although wind was significantly positive in relation to revenue, it was nonetheless significantly negative in respect to price. Wind was also significantly positive in connection to quantity and emissions, contrary to the predicted behavior. The insignificance of solar made it impossible to assess its utility because of the small numbers associated with the production of solar from 2000 to 2010. Dispatchable was the only renewable source with significant relationships in the prediction directions within the OLS regressions. The findings of the third hypothesis indicated a need for further research into the outcomes of renewable electricity production within producing states.

The examination of the results of renewable electricity production in relation to producing states allowed the path analysis models to assess the influence of renewable electricity production and to quantify the effects of energy efficiency. However, I discovered that I could derive only five pathways of influence from the findings of the third hypothesis, which meant the renewable electricity production did not generally contribute the outcomes of RPS policies. The results of RPS policies, positive or negative, were generally attributable to the influence of energy efficiency, as explained below. Nonetheless, renewable electricity production might have mediated the effect of stringency on adopting states.

4.2.6: Influence of the Control Variables

The control variables comprised most of the explanatory factors within the majority of the OLS regressions. In each of the three hypotheses, the control variables accounted for more of the variance in the dependent variables than did the independent variables. The strength of the control variables relative to the independent variables indicated that I might not find support for the three hypotheses, even after assessing the mediation of renewable electricity production and quantifying the effects of energy efficiency in connection to adopting states with the path analysis models. The control variables provided more of an explanation for the changes in the electricity markets and the renewable electricity production of adopting states than did their RPS policies. The results of the three hypotheses suggested that changing the control variables would have more influence on electricity markets and renewable electricity production than changing RPS policies.

## 4.3: Outcomes of the Path Analysis Models

### 4.3.1: Results of the Path Analysis Models

The path analysis models examined the influence of renewable electricity production on the outcomes of RPS policies. They showed that renewable electricity production did not significantly mediate the results of RPS policies. The findings of my analysis suggested that the results of RPS policies were attributable to energy efficiency, rather than renewable electricity production, as explained below. I present the simplified path analysis models in Figures C1, C2, C3, and C4 in Appendix C.

The general equations that I used to derive the effects of energy efficiency were:

(1): RPS Variable Energy Efficiency = (RPS Variable H1 Coefficient) – (Renewable Energy Influence)

(2): Renewable Energy Influence = (RPS Variable H2 Coefficient) * (Renewable Energy H3 Coefficient)

The reason why renewable electricity production did not mediate the results of RPS policies was probably that RPS policies did not facilitate the development of renewable electricity production. For example, the mediation that would have occurred because of wind and solar did not manifest because RPS policies did not facilitate their development within adopting states. RPS policies, with the exception of stringency, also did not appear to have any effect on the development of dispatchable or renewable. I observed significant mediation only in connection to the pathways of stringency-dispatchable and stringency-renewable.

In assessing the results of the path analysis models, I ignored the effects of wind and solar because the findings of the second hypothesis indicated that RPS policies did not facilitate their production within adopting states. I observed mediation within the pathways of stringency-dispatchable that affected emissions and carbon intensity. I also discovered mediation within the pathways of stringency-renewable that affected revenue, quantity, and emissions.

In the case of stringency-dispatchable, I observed that mediation was significantly positive in relation to emissions and significantly negative in respect to carbon intensity. In the case of stringency-renewable, I discovered that mediation was significantly negative in connection to revenue, emissions, and carbon intensity. I subtracted the outcomes of the mediation from the coefficients of the first hypothesis, in association with the relevant dependent variable, in order to quantify the influence of energy efficiency within the RPS policies of adopting states.

Stringency-dispatchable-emissions represented the effects of stringency on emissions meditated by dispatchable. The coefficient of the observed mediation was 0.190 grams of carbon dioxide per capita per year. When added to the results of stringency on emissions of the first hypothesis, the mediation increased the effect of stringency on emissions to 2.694 grams of carbon dioxide per capita per year for every W-h of stringency per capita per year.

Stringency-dispatchable-carbon intensity reflected the influence of stringency on carbon intensity meditated by dispatchable. The coefficient of the mediation was -0.006 grams of carbon dioxide per MW-h. When added to the results of stringency on carbon intensity of the first hypothesis, the mediation decreased the effect of stringency on carbon intensity to 0.017 grams of carbon dioxide for every MW-h per MW-h of stringency per capita per year.

Stringency-renewable-revenue represented the influence of stringency on revenue meditated by renewable. The coefficient of the mediation was -$26.10 per capita per year. When added to the results of stringency on revenue of the first hypothesis, the mediation decreased the effect of stringency on revenue to $104 per capita per year for every W-h of stringency per capita per year.

Stringency-renewable-quantity reflected the influence of stringency on quantity meditated by renewable. The coefficient of the mediation was -0.369 W-h per capita per year. When added to the results of stringency on quantity of the first hypothesis, the mediation decreased the effect of stringency on quantity to 2.086 W-h per capita per year for every W-h of stringency per capita per year.

Stringency-renewable-emissions represented the influence of stringency on carbon intensity meditated by emissions. The coefficient of the mediation was -0.344 grams of carbon dioxide per capita per year. When added to the results of stringency on emissions of the first hypothesis, the mediation decreased the effect of stringency on emissions to 2.160 grams of carbon dioxide per capita per year for every W-h of stringency per capita per year.

The results of the path analysis model were not strong enough to change the direction of the results of the first hypothesis, so I accepted the findings of the first hypothesis with only minor modifications. I found that energy efficiency, in relation to RPS policies, did not provide any discrete benefits to adopting states. I present the effects of the path analysis models in Table C1 in Appendix C.

The consistent results of the path analysis models and the OLS regressions showed that RPS policies did not affect the electricity markets of adopting states by creating sufficient adoption of energy efficiency or renewable electricity production. The effects of renewable electricity attributable to RPS policies were minor and were restricted to the stringency pathways of influence. The influence of energy efficiency, rather than that of renewable electricity production, was sufficient to explain the results of the OLS regressions and the effects of RPS policies.

## 4.4: Results of the Dissertation

The results of the study indicated that RPS policies did not perform in accordance with their predicted outcomes. RPS policies did not have the predicted relationship with carbon intensity. Instead, RPS policies were significantly positive in respect to quantity, revenue, and emissions within the electricity markets of adopting states. The lack of the predicted relationship between carbon intensity and RPS policies suggests that these policies have not yet achieved their states goals of replacing fossil fuels with renewable electricity production and energy efficiency.

Although RPS policies were insignificant in connection to price within adopting states, they were significantly positive in association with quantity. Since renewable electricity production did not have a significant effect on the results of RPS policies, these findings indicated that energy efficiency, in respect to RPS policies, was ineffective in reducing quantity. If energy efficiency had been effective, then RPS policies would have been significantly negative in connection to quantity, representing consumers receiving help to purchase energy efficient goods so they could adapt to rising electricity prices.

The positive relationship of RPS policies to quantity corresponded with a similar positive connection to emissions within adopting states. If the renewable electricity production elements of RPS policies had been effective, then the higher quantity would have been associated with lower carbon intensity within adopting states. Instead, I discovered that RPS policies were unrelated to a reduction in carbon intensity, indicating that the renewable electricity production was ineffective, with the exception of dispatchable.

The lack of the predicted relationship to carbon intensity within adopting states shows that RPS policies have not yet succeeded because of failures associated with energy efficiency and the renewable electricity production. I suggest that the continued improvement in technology may address the failures in connection to energy efficiency; however, the failures in association with renewable electricity production may be attributable to fundamental issues of intermittency and non-dispatchability. I discuss the results of the study in detail in Chapter 5.

#### 4.4.1: Influence of Natural Gas

Within the results of the study, I found that NG was significantly positive in relation to price within the OLS regressions of the first and third hypotheses. While my findings may seem counterintuitive, I suggest that the relationship may simply be associated with an increase in the demand for natural gas to produce electricity. The increase in demand would have resulted in higher natural gas prices, which would have pushed up electricity prices.

## 4.5: Findings of the Policy Model

In Chapter 3, I raised the possibility that the results of these analyses could contribute to the development of a policy model. The policy model would have evaluated the cost-benefit ratio of RPS policies within adopting states. The results of my analyses, however, make it impossible to develop a cost-benefit ratio for RPS policies with the data I used. Nonetheless, the outcomes of the study indicate that it is premature to make any suggestions for improving RPS policies because their observed effects to date appear to be negative. The findings of my analysis thus made it impossible to derive a policy model for a variety of reasons including a) negative results from this study, b) quality of data used and collected, and c) absence of full implementation of RPS policies.

## 4.6: Considerations for Future Research

### 4.6.1: Considerations for Future Research Concerning RPS Policies

Future researchers may wish to replicate this study when more data become available over the next decade. My findings indicate that RPS policies may be an ineffective governmental policy for dealing with the production of carbon dioxide emissions by reducing carbon intensity. RPS policies within the United States are not associated with a reduction in the carbon intensity of adopting states within the timeframe of the dataset. Although RPS policies appear to be ineffective, the policies may prove to be effective in reducing carbon intensity after they have come to fruition.

One possible reason for the observed ineffectiveness may be that RPS policies did not promote sufficient energy efficiency, which should have mitigated the increasing demand for electricity within a developed society. While only four states counted energy efficiency as a form of renewable electricity production, every state that adopted RPS policies used them to facilitate energy efficiency. Energy efficiency was an affordable alternative to renewable electricity production, as mentioned previously. States encouraged electricity producers and consumers to adopt behaviors that reduced electricity consumption. Another possible reason might be that these policies depended too much on the promotion of renewable electricity production from wind and solar.

My findings indicate that RPS policies are not yet associated with a reduction of carbon intensity within adopting states. These policies were also unconnected to an increase in renewable electricity production within adopting states. In effect, I have found that these policies have yet to be successful.

# CHAPTER 5: CONCLUSION

I examined the consequences of RPS policies within the United States on electricity markets within adopting states from 2000 to 2010. Using data from governmental sources, I tested three hypotheses with OLS regressions to provide a detailed picture of the outcomes of these policies on carbon intensity within adopting states. I then used path analysis models to evaluate the mediating influence of renewable electricity production and to quantify the effects of energy efficiency on adopting states.

Overall, my OLS results did not support any of the three hypotheses. I did not find support even when I further investigated the OLS results with path analysis models. In accordance with the previous research presented by Briggs and Gautam (2012), I found no evidence that RPS policies were associated with a decrease in carbon intensity within adopting states. The lack of an associated decrease in carbon intensity related to RPS policies meant that there was no discernable benefit from adoption when comparing adopting states to non-adopting states from 2000 to 2010.

The findings of my first hypothesis showed that RPS policies had significant effects within adopting states. The direction of the outcomes, however, was not in the predicted directions. RPS policies did not decrease the carbon intensity of those states, which would have provided environmental benefits to adopting states.

Beyond the consequences of RPS policies on carbon intensity, the findings of the first hypothesis indicated that these policies were significantly positive in relation to revenue, which was in the predicted direction. However, the OLS results did not show that RPS policies had the predicted relationships in connection to quantity or emissions. I discovered that RPS policies did not appear to provide any direct benefits to adopting states; thus, I found no support for my first hypothesis.

The conclusions of my second hypothesis indicated that the overall outcomes of RPS policies in association with renewable electricity production were mostly statistically insignificant. In particular, these policies had an insignificant effect in relation to wind and solar. They also had a mixed though mostly insignificant influence in respect to dispatchable and renewable. I found that RPS policies were unconnected to an increase in renewable electricity production within adopting states; thus, I found no support for my second hypothesis.

The results of my third hypothesis indicated that the results of renewable electricity production within producing states from 2000 to 2010 were not statistically significant. If they had small substantive contribution, it was not discernable. Renewable electricity production had no significant effect on producing states from 2000 to 2010: it was not associated with a reduction in carbon intensity within those states. Beyond its apparent lack of influence on carbon intensity, the findings of the OLS regressions showed that renewable electricity production was significantly positive in relation to revenue within those states, representing an effect in the predicted direction. It was also significantly positive in respect to quantity and emissions, which were outcomes in the opposite of the predicted direction. In general, I found no evidence that, to date, renewable electricity production provides any direct benefits to producing states in the form of carbon intensity reduction connected to that production, with dispatchable being the one exception to that conclusion. I found that dispatchable was significantly positive in connection to price and significantly negative in association with emissions and carbon intensity.

## 5.1: Interpretation

### 5.1.1: Effects of RPS Policies on the Electricity Markets

I did not find any evidence of an association between implementation of RPS policies and changes in the electricity markets of adopting states in the predicted directions. I found no support for the first hypothesis because these policies unconnected to a reduction of carbon intensity within adopting states. I found that the implementation of RPS policies did not benefit adopting states when compared to non-adopting states from 2000 to 2010. In sum, my analysis did not show that the implementation of RPS policies was associated with differences in carbon intensity between the states that did and did not implement the RPS policies.

### 5.1.2: Consequences of RPS Policies on Renewable Electricity Production

I did not find any evidence of a connection between RPS policies and an increase in the production of renewable electricity within adopting states. I did find that states that had higher levels of stringency were associated with significant changes renewable and dispatchable, but the direction of the related changes was in the opposite of the expected direction. My findings suggest that no production of renewable electricity is attributable to the adoption of RPS policies from 2000 to 2010.

5.1.3: Effects of Renewable Electricity Production on Electricity Markets

I did not find any evidence of a relationship between the production of renewable electricity and a corresponding reduction in carbon intensity; thus, I found no support for the third hypothesis. Renewable electricity production was also unrelated to a decrease in quantity or emissions within producing states. My results suggested that no states that produced renewable electricity gained any benefits, in the form of lower quantity, emissions, or carbon intensity, from 2000 to 2010.

I found one exception to the above examination: dispatchable (the renewable energy variable that represented biomass and geothermal). In the case of dispatchable, it was significantly negative in respect to emissions and carbon intensity. Thus, I discovered that dispatchable produce some of the predicted results.

5.1.4: Path Analysis Models

I used the path analysis models of my study to evaluate the mediating influence of renewable electricity production and to quantify the effects of energy efficiency on adopting states. While there were multiple pathways of influence, I explored the five possible pathways that could have potentially changed some of the results of the first hypotheses. I selected these because they both of their stages were statistically significant. However, I found that the results of the exploration of the five pathways concurred with the conclusions of the first hypothesis.

The results of the path analysis models suggest that the effects of RPS policies are attributable to energy efficiency rather than renewable electricity production. Since the facilitation of energy efficiency and renewable electricity production is the purpose of RPS policies, the lack of significant effects associated with renewable electricity production leaves only energy efficiency to explain the results associated with these policies. Thus, I found that energy efficiency portions sufficiently explained the outcomes of RPS policies observed within the formative analysis because, without the explanatory power of renewable electricity production, energy efficiency was the only causal mechanism left to explain the effects of energy efficiency.

### 5.1.5: Final Interpretations

I found that the results of my analysis supported none of the three hypotheses. In the case of the first hypothesis, I discovered no significantly negative relationship between RPS policies and carbon intensity within adopting states. In the case of the second hypothesis, I did not find significantly positive relationships between RPS policies and renewable electricity production within adopting states. In the case of the third hypothesis, I found only one significantly negative relationship between renewable electricity production and carbon intensity within producing states, with dispatchable being significantly negative in respect to carbon intensity.

## 5.2: Policy Implications

The results of the formative evaluation indicate that RPS policies have yet to achieve the desired outcomes. During the period that this study covers, 2000 to 2010, RPS policies did not have the predicted relationships in connection with carbon intensity or renewable electricity production. In addition, renewable electricity production did not have the predicted relationships to the electricity markets of producing states during the same period.

In addition to the findings that address the three hypotheses, the results indicate three additional findings. First, trading was not significant in relation to carbon intensity within adopting states. Second, wind was not significant in the predicted direction in respect to carbon intensity within producing states. Third, solar production did not have the predicted relationship in connection to carbon intensity within producing states. In the next sections, I discuss the policy implications of these three additional findings.

### 5.2.1: Policy Implications of RPS Trading

Previous researchers argued that interstate electricity trading was an essential component of electricity production, because it had served as an affordable way to increase electricity supply without excessive investment (Marriott & Matthews, 2005). The inclusion of provisions within RPS policies that allowed for renewable electricity production trading was consistent with the way the majority of electricity utilities managed their electricity supplies in the United States, by selling electricity when they had excessive supply and by buying electricity when they had excessive demand (Feijoo & Das, 2014). The prevention of disruptions in the electricity markets of adopting states was the goal of the trading provisions of RPS policies (Marriott & Matthews, 2005).

Although a thorough discussion of trade provisions is beyond the scope of this dissertation, I note that the inclusion of trade provisions in RPS policies allows electricity producers in exporting states to charge a premium for renewable electricity production because it is no longer homogenous with non-renewable electricity production (Ivanova, 2012). Under conditions of homogeneity, electricity producers cannot charge a premium price to consumers (Joskow & Kahn, 2001). Producers would require compensation from government subsidies for any excessive costs that are associated with renewable electricity production (Borenstein, 2012). Under conditions of non-homogeneity, however, electricity producers can charge a premium price to capture any of the economic gains created by trading.

The results of this study indicate that trading in renewable electricity production produces no benefits for importing states. Trading does not appear to have the predicted relationship in connection to carbon intensity any more than any other element of RPS policies. I tentatively explain the apparent counterintuitive findings by suggesting that differentiating renewable electricity production from non-renewable electricity production violates the economic assumption of homogeneity. In effect, because renewable electricity becomes a different commodity from non-renewable electricity, its producers may charge their consumers a premium. Their consumers would be willing to be pay a premium to avoid penalties for not meeting their quota. My conclusions also imply that the trading in renewable electricity production has no significant effect on the internal renewable electricity production of adopting states.

I suggest that my results indicate that the trade in renewable electricity production represents a potential market failure. Under the normal assumptions of microeconomics, the trade in renewable electricity production should have been associated with a decrease in carbon intensity within importing states. The trade in renewable electricity production would have allowed importing states to replace high-carbon emitting electricity production with low-carbon emitting electricity production. The importing states would produce lower quantities of electricity and, because that trade would replace high-carbon emitting electricity production, the importing states would have had a connected decrease in carbon intensity.

In the dataset I examined, I discovered that this replacement did not appear to occur. The apparent lack of replacement may mean that any RPS policy that allows trading produces a similar market failure because it violates the assumption of homogeneity. However, I suggest that definitive conclusions concerning the policy implications of the trade in renewable electricity production will have to wait until a substantive examination of existing RPS policies after these policies reach fruition in 2025.

5.2.2: Policy Implications of Wind

The outcomes of the study indicate that the performance of wind energy is much different from that predicted by the third hypothesis. I predicted that wind energy would be associated with a reduction in carbon intensity within producing states. However, my analysis shows that wind energy did not have the predicted relationship in connection to carbon intensity. I consider that outcome significant because wind energy is a mature technology. The United States has produced wind energy since the 1890s, though it did not start to promote it for urban electrification until the 1980s (Office of Energy Efficiency & Renewable Energy, 2015). However, the relationship of wind to the electricity markets of producing states should be more easily detectable by future researchers as wind energy continues to expand. If future research confirms the findings of my evaluation, then I tentatively suggest it is unlikely that there will be significant improvements in the effectiveness of wind energy because it is a mature technology.

I touched upon the issues concerning wind in Chapter 4, but I will briefly discuss them again. One reason why wind did not have the predicted relationship in connection to carbon intensity may be that it is non-dispatchable electricity production. Another reason why wind did not have the predicted relationship in association with carbon intensity may be because it is a form of intermittent electricity production.

Non-dispatchable production may result in higher levels of carbon intensity because fossil fuels produce electricity when wind sources are unavailable to supply electricity (Kydes, 2007). Intermittent production may result in higher levels of carbon intensity because fossil fuels produce electricity when wind sources are insufficient to supply electricity (Riti, 2010). The combination of non-dispatchable and intermittent production may mean that using wind sources for electricity production may result in higher levels of carbon intensity than using natural gas.

Regardless, the findings indicate that the most widespread form of renewable electricity may not produce the predicted outcomes. My results indicate that one of the central concepts underlying RPS policies--the idea that increasing renewable electricity production will be associated with decreased levels of carbon intensity within producing states--may be incorrect. Future research into this question is necessary to confirm my conclusions concerning wind before using them to shape future policy.

5.2.3: Potential Policy Implications of Solar

Although the non-dispatchable and intermittent nature of solar may have effects similar to those associated with wind, the amount of solar from 2000 to 2010 only averaged 880 W-h per capita. That means that its influence on producing states was so minor that it may have been undetectable because of the statistical noise created by every other form of electricity production. Future researchers may be able to determine whether solar yields the same counterintuitive results as did wind, as the literature expects solar to continue to expand (Burns & Kang, 2012).

## 5.3: Policy Recommendations

The findings of this study indicate that state governments should avoid adopting new RPS policies until future researchers can assess the efficacy of these policies. If future research shows that my findings are accurate, then state governments may wish to begin to augment their current RPS policies with other strategies to mitigate emissions and reduce carbon intensity.

The outcomes of my investigation suggest two policy recommendations. First, RPS adopting states already have effective environmental policies that have improved their electricity markets. I suggest that policy-makers in non-adopting states carefully examine the environmental policies implemented by adopting states before 2000. Thus, policy-makers may be able to implement effective environmental policies to improve the quality of their electricity production to the levels enjoyed by adopting states without using RPS policies. Second, there is no particular reason why policy-makers cannot investigate the potential of expanding programs that facilitate biomass and geothermal electricity production within states that possess those energy sources. My findings indicate those forms of renewable electricity production may be effective in reducing carbon intensity, as they reduce carbon intensity, which is the purpose of renewable electricity production.

## 5.4: Recommendations for Future Research

I previously presented a few considerations for future research; however, I offer a few additional suggestions. First, policy researchers should reexamine my findings after another five years of data are available. The researchers may find that some of the long-term consequences of RPS policies will become more obvious as time progresses. Second, future policy researchers should do a formative evaluation of the results of the European Union's RPS policies. Researchers may find that some of the conclusions of my analysis will not apply outside of the unique circumstances of the United States. Third, researchers should undertake a comparative formative evaluation between the results of the RPS policies of the United States and the RPS policies of the European Union.

## 5.5: Concluding Comment

Although human civilization possesses limited energy resources, policy solutions exist to mitigate the consequences of that scarcity (Stern & Kander, 2012). The results of this formative evaluation, however, provide no evidence that RPS policies are an effective policy solution. If future research confirms my findings, policy-makers may wish to reconsider the adoption and implementation of RPS policies. Until then, I suggest that policy-makers from non-adopting states examine the earlier environmental policies of adopting states on how to address the issue of carbon dioxide emissions. I also suggest that policy-makers from adopting states examine the existing environmental policies that differentiated them from non-adopting states and expand upon their earlier successes.

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# APPENDIX A: VARIABLE DEFINITIONS AND GRAPHS

Table A1: State-level RPS variables

| | | |
|---|---|---|
| RPI (RPI) | RPS Index | Continuous variable that measured the W-h per capita per year of electricity that is an index of the state-level RPS requirements. |
| percentage (RPP) | RPS Percentage | Continuous variable that measures the W-h per capita per year of electricity produced to meet the RPS mandate. |
| stringency (RST) | RPS Stringency | Continuous variable that measured the W-h per capita per year of electricity produced from specific renewable sources to meet the RPS mandate. |
| trading (RPT) | RPS Trading | Continuous variable that measured the W-h per capita per year of electricity traded by electrical utilities to meet the RPS mandate. |

Table A2: Renewable energy variables

| | | |
|---|---|---|
| dispatchable (OE) | Other Alternative Electricity Production | Continuous variable that measures the W-h per capita per year of other alternative electricity produced within a state. |
| renewable (RE) | Renewable Electricity Index | Continuous variable that measured the W-h per capita per year of renewable electricity produced within a state. |
| solar (SE) | Solar Electricity Production | Continuous variable that measured the W-h per capita per year of solar electricity produced within a state. |
| wind (WE) | Wind Electricity Production | Continuous variable that measured the W-h per capita per year of wind electricity produced within a state. |

Table A3: Electricity market variables

| Abbreviation | Variable | Operationalization |
|---|---|---|
| price (P) | Electricity Price | Continuous variable that measures the total price of electricity in $ per MW-h. |
| revenue (R) | Electricity Revenue | Continuous variable that measures the $ per million people per year earned by electricity production per year. |
| quantity (Q) | Electricity Quantity | Continuous variable that measures the W-h of electricity per capita per year produced with a state. |
| emissions (C) | Emission Quantity | Continuous variable that measures the grams of carbon dioxide emissions per capita per year. |
| carbon intensity (CI) | Carbon Intensity | Continuous variable that measures carbon intensity (the metric tons of carbon dioxide generated per MW-h of electricity produced). |

Table A4: Demographic control variables

| Abbreviation | Variable | Operationalization |
|---|---|---|
| PCA | Per Capita Area | Continuous variable that measures the per capita area, in square meters, of a state. |
| PCI | Per Capita Income | Continuous variable that measures the average per capita income of a state, in thousands of $. |
| POP | Population | Continuous variable that measures the population of a state in millions of people. |

Table A5**:** Energy control variables

| Abbreviation | Variable | Operationalization |
|---|---|---|
| CDD | Cooling Degree-days | Continuous variable measuring the average number of cooling degree-days for a given state for a given year. |
| NG | Natural Gas Generation | Continuous variable measuring natural gas consumption for electricity generation within a given state for a given year, converted into W-h per capita per year. |

Table A6: Political control variables

| Abbreviation | Variable | Operationalization |
|---|---|---|
| DGC | Governor Democratic Control | Dichotomous variable measuring whether or not a state had a Democratic governor. |
| DHC | House Democratic Control | Dichotomous variable measuring whether or not a state's house of representatives was controlled by the Democratic Party. |
| DSC | Senate Democratic Control | Dichotomous variable measuring whether or not a state's senate was controlled by the Democratic Party. |

Table A7: Unique control variables

| Abbreviation | Variable | Operationalization |
|---|---|---|
| STATE | State | Nominal variable indicating the state that was the source of the data. |
| YEAR | Year | Nominal variable indicating the year that was the source of the data. |

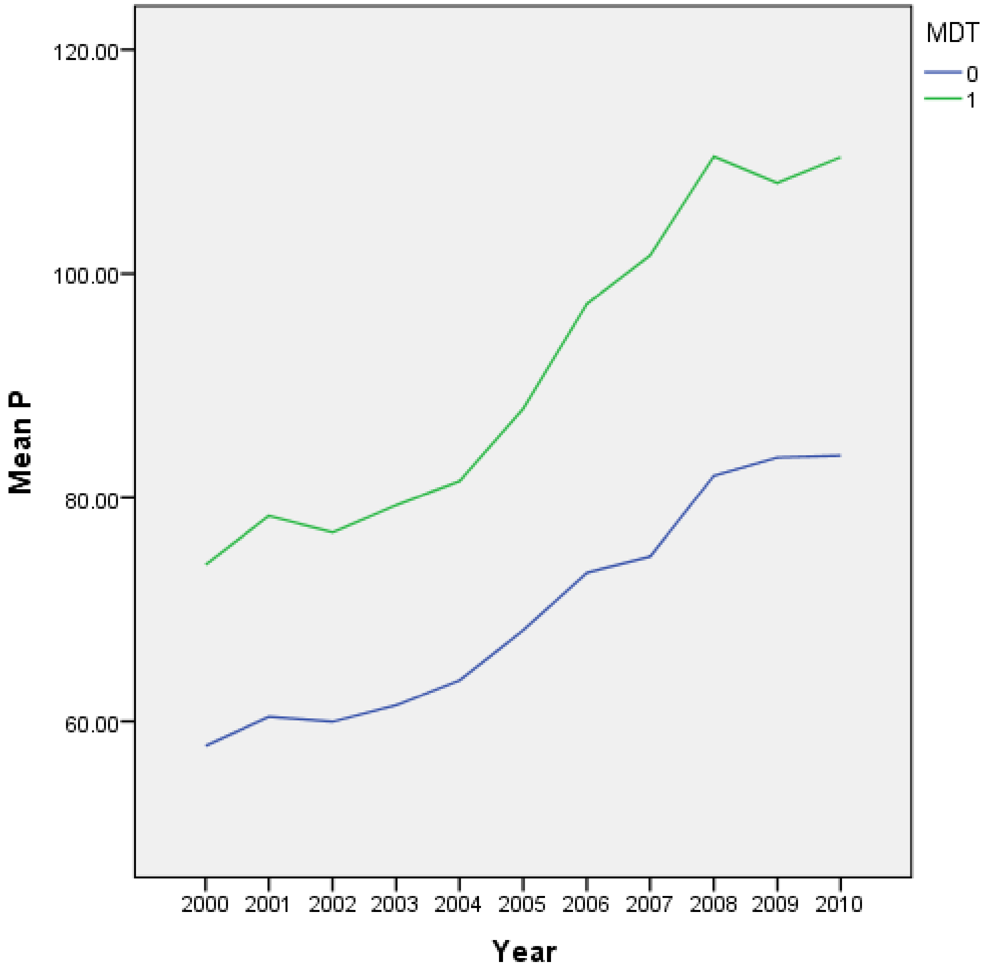


Figure A1: Comparative changes in electricity prices

Notes: When MDT is equal to ‘1’, it represents an adopting state. When MDT is equal to ‘0’, it represents a non-adopting state.

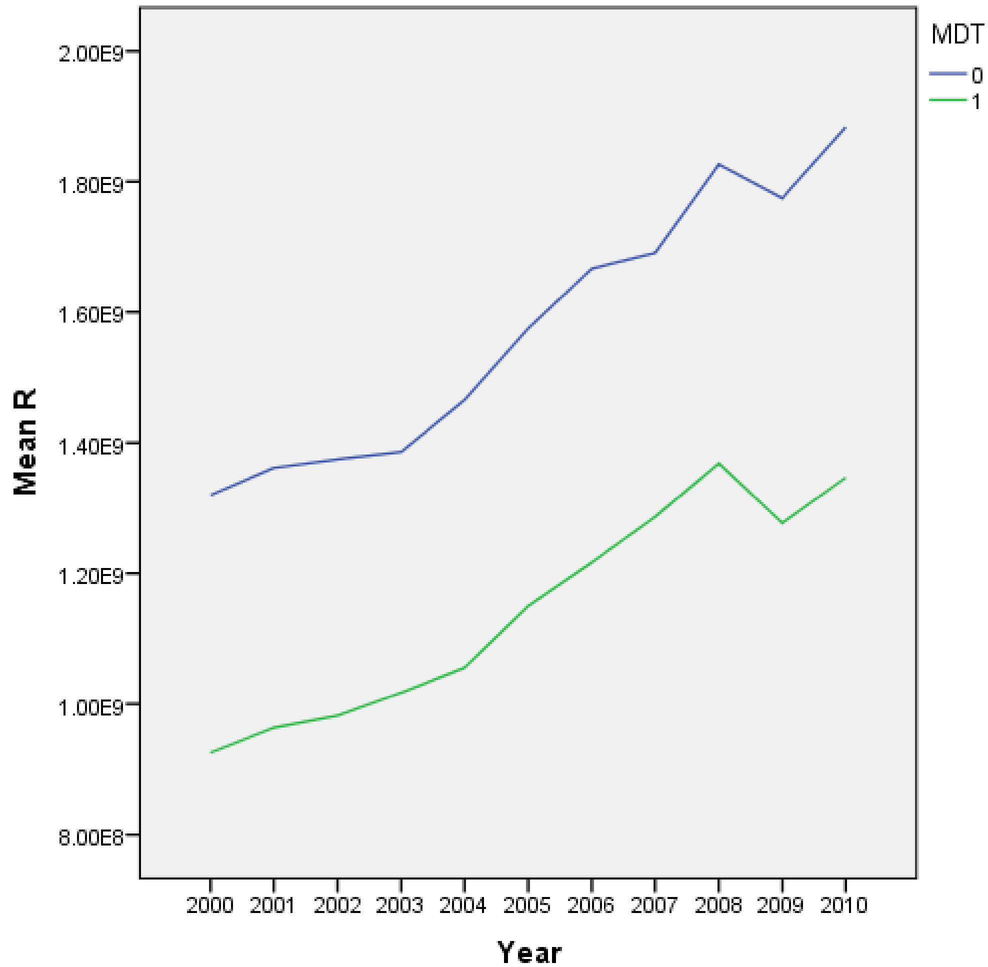


Figure A2: Comparative changes in electricity revenues

Notes: When MDT is equal to '1', it represents an adopting state. When MDT is equal to '0', it represents a non-adopting state.

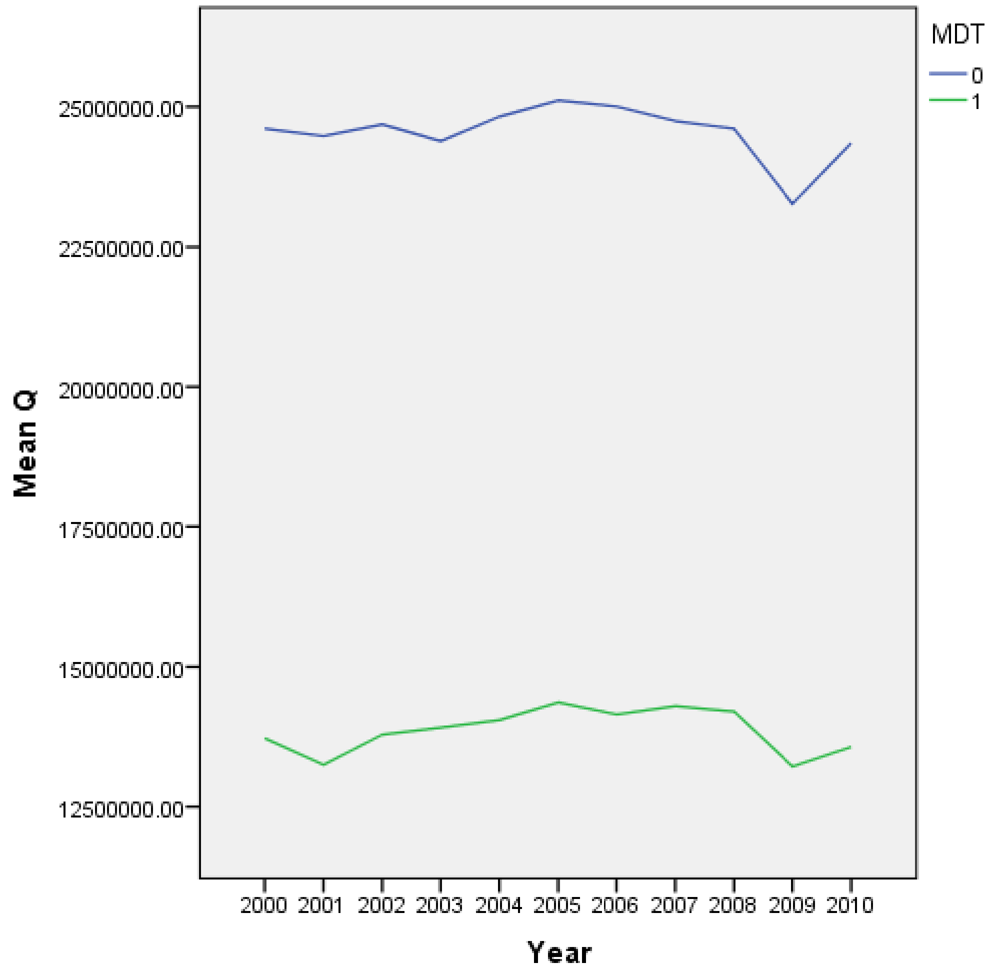


Figure A3: Comparative changes in electricity production

Notes: When MDT is equal to ‘1’, it represents an adopting state. When MDT is equal to ‘0’, it represents a non-adopting state.

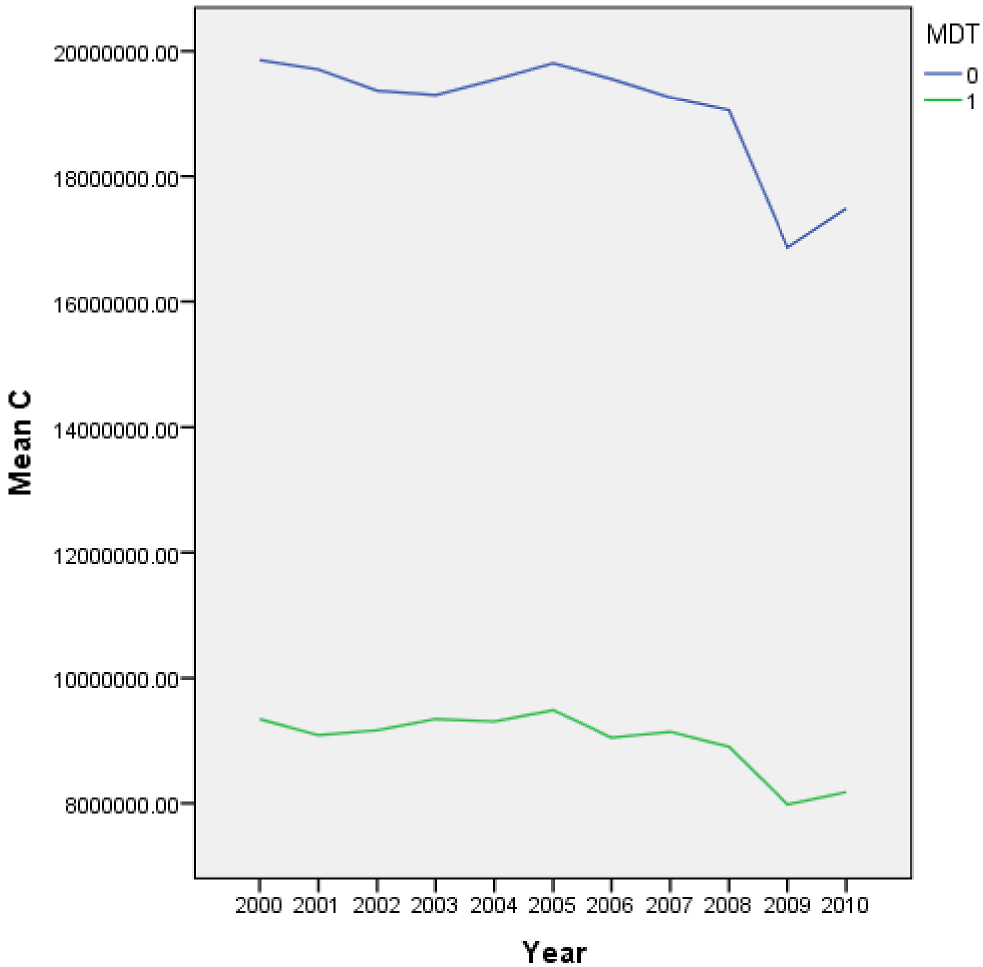


Figure A4: Comparative changes in carbon dioxide emissions

Notes: When MDT is equal to ‘1’, it represents an adopting state.  When MDT is equal to ‘0’, it represents a non-adopting state.

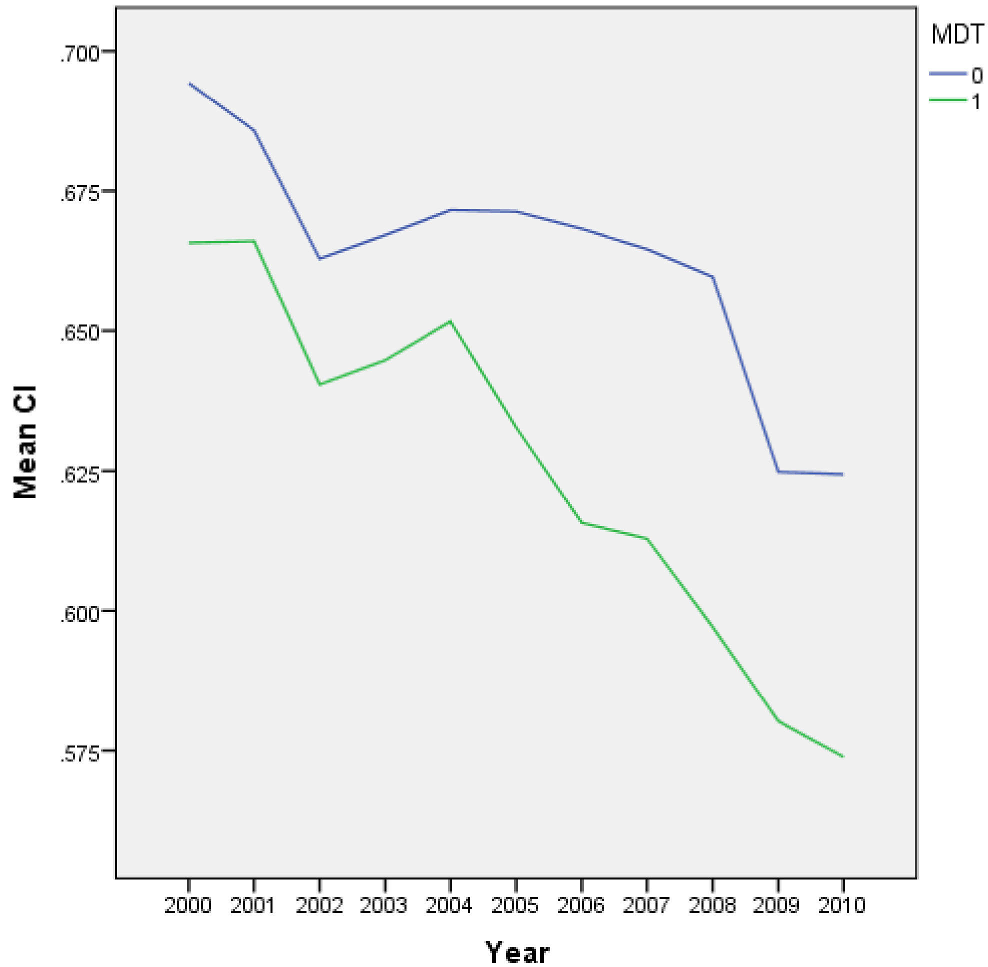


Figure A5: Comparative changes in carbon intensity

Notes: When MDT is equal to '1', it represents an adopting state. When MDT is equal to '0', it represents a non-adopting state.

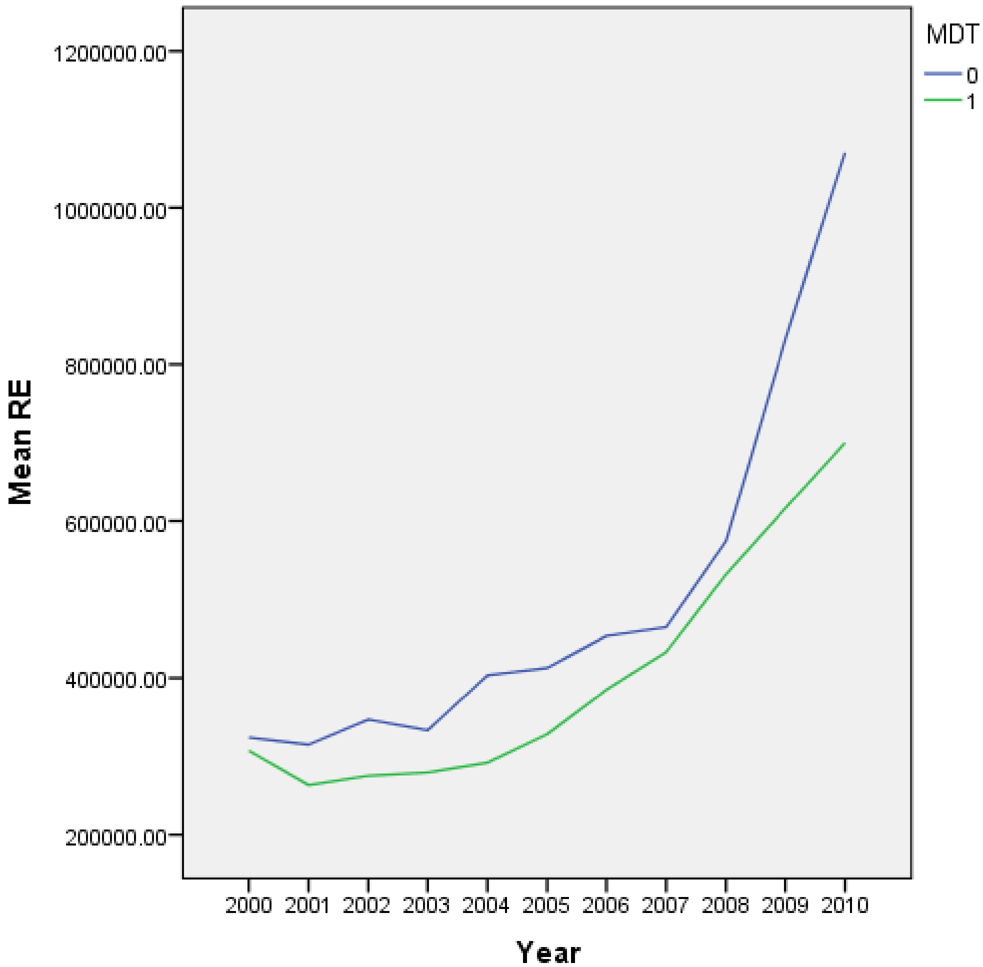


Figure A6: Changes in renewable

Notes: When MDT is equal to ‘1’, it represents an adopting state. When MDT is equal to ‘0’, it represents a non-adopting state.

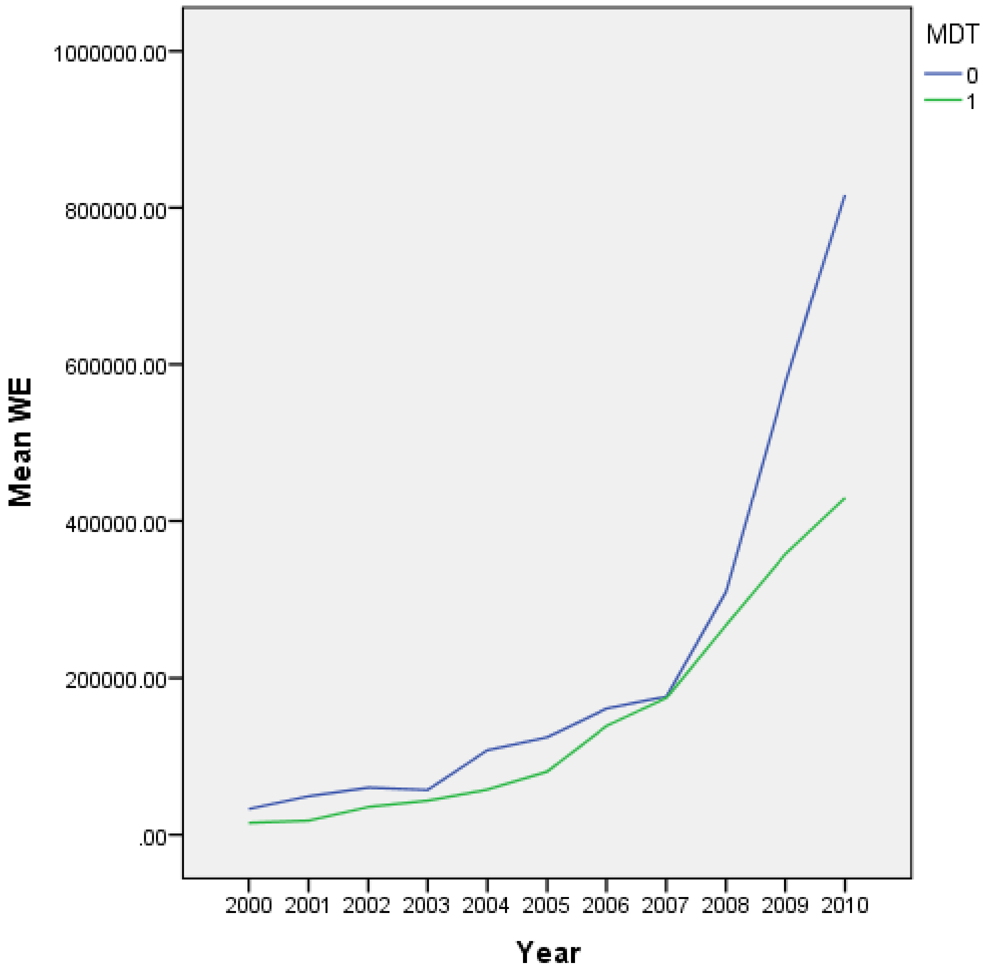


Figure A7: Changes in wind

Notes: When MDT is equal to ‘1’, it represents an adopting state. When MDT is equal to ‘0’, it represents a non-adopting state.

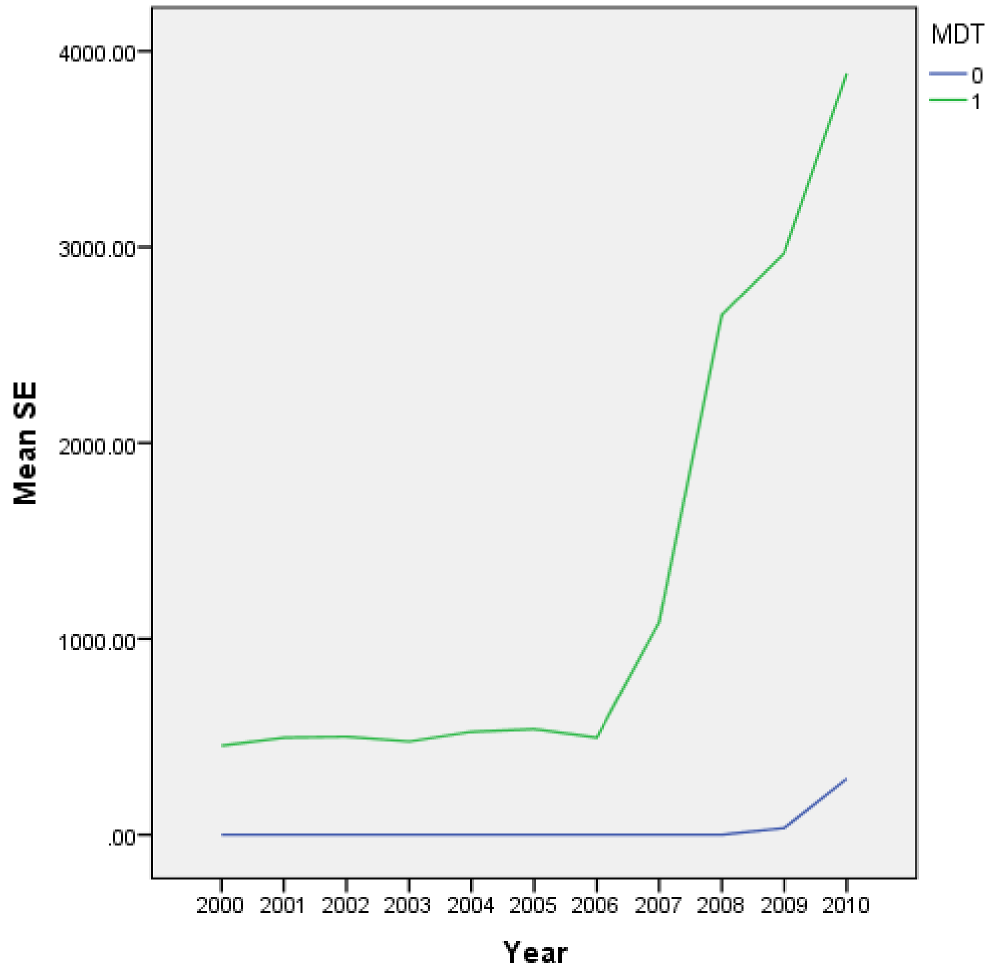


Figure A8: Changes in solar

Notes: When MDT is equal to '1', it represents an adopting state. When MDT is equal to '0', it represents a non-adopting state.

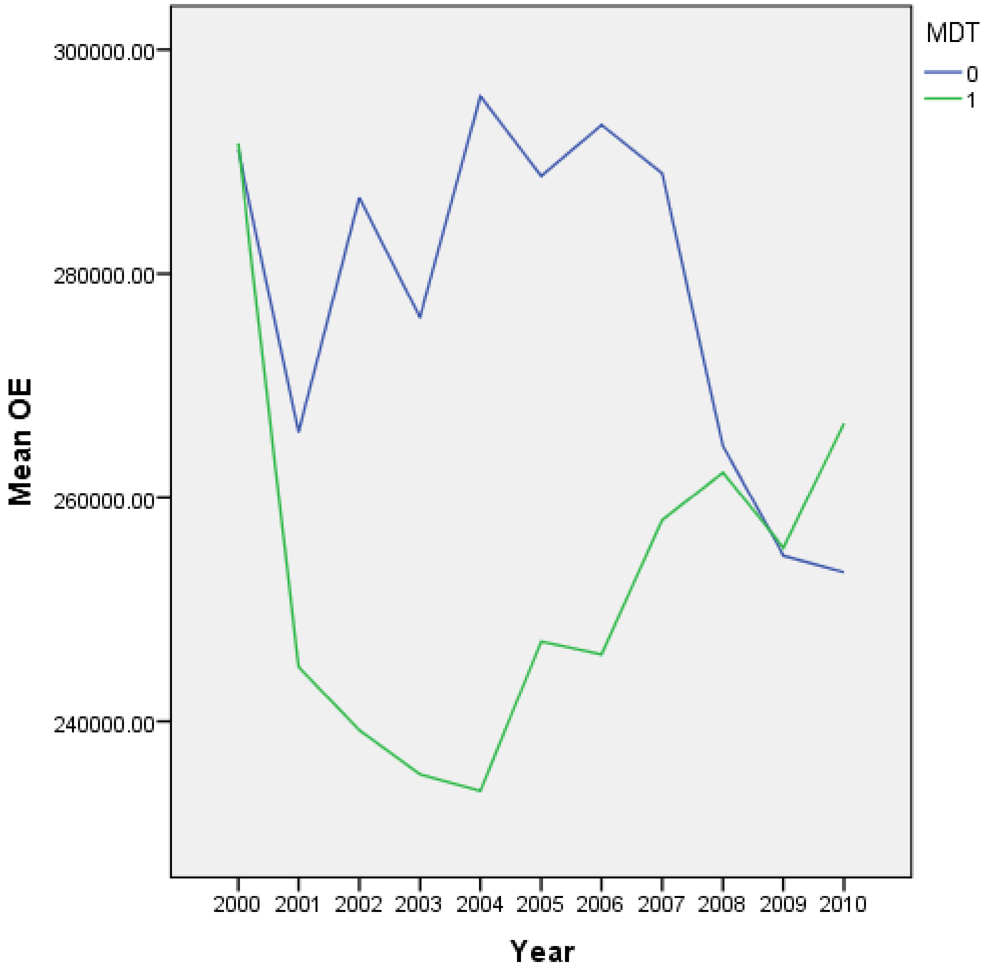


Figure A9: Changes in dispatchable

Notes: When MDT is equal to '1', it represents an adopting state. When MDT is equal to '0', it represents a non-adopting state.

# APPENDIX B: QUANTITATIVE OUTPUT TABLES

Table B1: The influences of RPI on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 38.688***<br>(4.809) | 0.499***<br>(0.037) |
| RPI (M) | 0.168<br>(0.232) | 0.005**<br>(0.002) |
| DGC | -7.749**<br>(2.602) | 0.022<br>(0.020) |
| DSC | 8.592**<br>(3.178) | -0.070**<br>(0.024) |
| DHC | 11.628***<br>(3.093) | 0.001<br>(0.024) |
| CDD | 0.000<br>(0.022) | 0.001***<br>(0.000) |
| NG (M) | 1.673**<br>(0.512) | -0.032***<br>(0.004) |
| PCA (M) | 13.290**<br>(4.340) | 0.116**<br>(0.033) |
| PCI | 0.640***<br>(0.077) | 0.003***<br>(0.001) |
| POP | 0.882***<br>(0.194) | -0.010***<br>(0.001) |
| Adjusted R-Square | 0.264*** | 0.262*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B2: The effects of RPI on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,433,009,037***<br>(117,882,108.3) | 25,670,206.36***<br>(2,207,121.431) | 19,601,236.80***<br>(2,363,928.680) |
| RPI | 34.162***<br>(5.678) | 0.519***<br>(0.106) | 0.492***<br>(0.114) |
| DGC | 42,047,094.57<br>(63,777,705.15) | 1,136,795.236<br>(1,194,117.936) | 606,467.422<br>(1,278,955.293) |
| DSC | -285,979,642.0***<br>(77,896,857.98) | -5,402,305.901***<br>(1,458,472.597) | -5,518,667.823***<br>(1,562,091.307) |
| DHC | -9,317,796.635<br>(75,820,397.86) | -1,400,827.549<br>(1,419,594.775) | -1,249,120.723<br>(1,520,451.370) |
| PCI | -4,583,195.948*<br>(1,888,830.701) | -128,012.316***<br>(35,364.813) | -78,638.662*<br>(37,877.343) |
| CDD | 1,079,885.669*<br>(539,681.317) | 15,416.649<br>(10,104.521) | 17,034.930<br>(10,822.407) |
| POP | -23,569,208.91***<br>(4,766,911.343) | -489,905.302***<br>(89,251.476) | -479,311.412***<br>(95,592.441) |
| NG | 15.679<br>(12.539) | -0.461<br>(0.235) | -0.932***<br>(0.251) |
| PCA | 330.067**<br>(106.395) | 4.746*<br>(1.992) | 6.416**<br>(2.134) |
| Adjusted R-Square | 0.164*** | 0.184*** | 0.170*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B3: The consequences of percentage on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 34.009***<br>(4.800) | 0.501***<br>(0.037) |
| percentage (M) | 1.972**<br>(0.607) | 0.013**<br>(0.005) |
| DGC | -8.889**<br>(2.582) | 0.022<br>(0.020) |
| DSC | 7.395*<br>(3.149) | -0.069**<br>(0.024) |
| DHC | 11.605***<br>(3.062) | 0.000<br>(0.024) |
| CDD | 0.014<br>(0.022) | 0.001***<br>(0.000) |
| NG (M) | 1.516**<br>(0.509) | -0.033***<br>(0.004) |
| PCA (M) | 14.818**<br>(4.312) | 0.117**<br>(0.034) |
| PCI | 0.682***<br>(0.076) | 0.003***<br>(0.001) |
| POP | 0.865***<br>(0.193) | -0.010***<br>(0.001) |
| Adjusted R-Square | 0.278*** | 0.259*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B4: The outcomes of percentage on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,444,324,251***<br>(119,615,865.5) | 26,664,340.63***<br>(2,251,133.124) | 20,561,675.28***<br>(2,405,280.796) |
| percentage | 81.52***<br>(15.12) | 0.967**<br>(0.284) | 0.910**<br>(0.304) |
| DGC | 43,555,502.99<br>(64,336,615.53) | 1,358,849.725<br>(1,210,794.953) | 821,334.314<br>(1,293,704.854) |
| DSC | -281,178,182.7***<br>(78,463,440.73) | -5,117,401.312**<br>(1,476,,657.379) | -5,243,938.273**<br>(1,577,772.366) |
| DHC | 426,511.046<br>(76,292,146.90) | -1,240,311.356<br>(1,435,794.309) | -1,096,677.915<br>(1,577,772.366) |
| PCI | -4,904,128.727*<br>(1,898,611.203) | -140,592.235***<br>(35,731.268) | -90,733.083*<br>(38,177.988) |
| CDD | 1,010,108.118<br>(543,583.244) | 11,953.178<br>(10,230.066) | 13,698.947<br>(10,930.576) |
| POP | -24,375,650.34***<br>(4,799,965.146) | -499,954.271***<br>(90,333.841) | -488,789.642***<br>(96,519.504) |
| NG | 11.310<br>(12.682) | -0.504*<br>(0.239) | -0.972***<br>(0.255) |
| PCA | 349.076**<br>(107.462) | 4.641*<br>(2.022) | 6.312**<br>(2.161) |
| Adjusted R-Square | 0.153*** | 0.165*** | 0.155*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B5: The influences of stringency on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 41.444***<br>(4.562) | 0.511***<br>(0.035) |
| stringency (M) | -1.248<br>(0.757) | 0.023***<br>(0.006) |
| DGC | -7.064**<br>(2.574) | 0.024<br>(0.020) |
| DSC | 9.510**<br>(3.157) | -0.070**<br>(0.024) |
| DHC | 12.176***<br>(3.099) | -0.009<br>(0.024) |
| CDD | -0.060<br>(0.021) | 0.001***<br>(0.000) |
| NG (M) | 1.580**<br>(0.514) | -0.030***<br>(0.004) |
| PCA (M) | 13.002**<br>(0.000) | 0.105**<br>(0.033) |
| PCI | 0.602***<br>(0.076) | 0.003***<br>(0.001) |
| POP | 0.865***<br>(0.194) | -0.010***<br>(0.001) |
| Adjusted R-Square | 0.267*** | 0.272*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B6: The effects of stringency on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,534,315,487***<br>(110,631,294.7) | 26,650,044.10***<br>(2,044,511.264) | 20,319,552.25***<br>(2,188,536.038) |
| stringency | 130.595***<br>(18.367) | 2.455***<br>(0.339) | 2.504***<br>(0.363) |
| DGC | 62,871,631.41<br>(62,406,588.20) | 1,308,763.800<br>(1,153,299.100) | 715,139.262<br>(1,234,542.791) |
| DSC | -278,730,825.2***<br>(76,551,044.65) | -5,511,098.142***<br>(1,414,694.400) | -5,704,122.287***<br>(1,514,351.979) |
| DHC | -46,249,767.10<br>(75,140,381.71) | -2,143,358.355<br>(1,388,624.776) | -2,021,124.214<br>(1,486,445.891) |
| PCI | -4,677,722.049*<br>(1,848,542.372) | -120,357.525***<br>(34,161.814) | -67,964.205<br>(36,568.329) |
| CDD | 524,991.445<br>(517,796.893) | 7,820.062<br>(9,569.097) | 10,148.586<br>(10,243.188) |
| POP | -22,043,550.91***<br>(4,710,958.489) | -460,705.514***<br>(87,060.429) | -449,371.600***<br>(93,193.363) |
| NG | 29.455*<br>(12.467) | -0.212<br>(0.230) | -0.681**<br>(0.247) |
| PCA | 259.002*<br>(104.445) | 3.650<br>(1.930) | 5.372*<br>(2.066) |
| Adjusted R-Square | 0.185*** | 0.226*** | 0.213*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B7: The consequences of trading on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 39.890***<br>(4.944) | 0.505***<br>(0.038) |
| trading (M) | 0.019<br>(0.627) | 0.010*<br>(0.005) |
| DGC | -7.463**<br>(2.612) | 0.024<br>(0.020) |
| DSC | 8.913**<br>(3.181) | -0.066**<br>(0.025) |
| DHC | 11.695***<br>(3.093) | 0.001<br>(0.024) |
| CDD | -0.003<br>(0.023) | 0.001***<br>(0.000) |
| NG (M) | 1.685**<br>(0.514) | -0.033***<br>(0.004) |
| PCA (M) | 12.981**<br>(4.368) | 0.116**<br>(0.034) |
| PCI | 0.627***<br>(0.077) | 0.003***<br>(0.001) |
| POP | 0.881***<br>(0.195) | -0.010***<br>(0.001) |
| Adjusted R-Square | 0.263*** | 0.255*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B8: The outcomes of trading on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,438,428,834*** (122,532,035.3) | 25,867,729.61*** (2,287,352.051) | 20,167,316.41*** (2,451,079.560) |
| trading | 75.861*** (15.550) | 1.119*** (0.290) | 0.946** (0.311) |
| DGC | -46,304,681.90 (64,751,797.76) | 1,227,494.321 (1,208,746.407) | 777,919.857 (1,295,267.867) |
| DSC | -274,830,324.8** (78,834,874.57) | -5,206,735.672*** (1,471,640.552) | -5,247,456.139** (1,576,979.842) |
| DHC | 6,979,054.404 (76,669,932.38) | -1,154,386.432 (1,431,640,552) | -1,019,778.518 (1,533,673.245) |
| PCI | -4,992,804.736** (1,913,745.305) | -135,251.846*** (35,724.611) | -88,833.894* (38,281.760) |
| CDD | 1,237,871.669* (564,018.168) | 17,385.580 (10,528.741) | 17,477.546 (11,282.383) |
| POP | -2,374,291.79*** (4,822,220.749) | -492,597.572*** (90,018.227) | -481,814.566*** (96,461.686) |
| NG | 12.517 (12.733) | -0.507* (0.238) | -0.966*** (0.255) |
| PCA | 342.611** (108.271) | 4.900* (2.021) | 6.444** (2.166) |
| Adjusted R-Square | 0.144*** | 0.170*** | 0.155*** |

Notes: *p<0.05; **p<0.01; ***p<0.001.  The standard errors are in parentheses.

Table B9: The influences of RPI on renewable/wind/solar/dispatchable

| Variable | Coefficients (renewable) | Coefficients (wind) | Coefficients (solar) | Coefficients (dispatchable) |
|---|---|---|---|---|
| N | 517 | 517 | 517 | 517 |
| Constant | 677,479.937***<br>(108,929.806) | 295,664.066**<br>(90,420.614) | -1,396.052<br>(964.766) | 383,211.922***<br>(69,698.674) |
| RPI | -0.009<br>(0.005) | -0.005<br>(0.004) | 0.000<br>(0.000) | -0.003<br>(0.003) |
| DGC | 146,491.760*<br>(58,934.245) | 96,491.790*<br>(48,920.225) | -1,036.223*<br>(521.967) | 51,036.192<br>(37,709.043) |
| DSC | 69,336.203<br>(71,981.149) | -25,857.354<br>(59,750.218) | 529.161<br>(637.520) | 94,664.397*<br>(46,057.097) |
| DHC | -29,435.269<br>(70,062.381) | -137,346.842*<br>(58,157.485) | 532.942<br>(620.526) | 107,378.631*<br>(44,829.374) |
| PCI | -3,035.022<br>(1,745.388) | 1,972.519<br>(1,448.814) | 20.443<br>(15.458) | -5,027.984***<br>(1,116.785) |
| CDD | -2,591.784***<br>(498.696) | -1,195.240**<br>(413.959) | -11.959**<br>(4.417) | -1,384.585***<br>(319.091) |
| POP | -10,173.557*<br>(4404.899) | -4,370.975<br>(3,656.425) | 202.541***<br>(39.013) | -6,005.122*<br>(2,818.472) |
| NG | 0.069***<br>(0.012) | 0.000<br>(0.010) | 0.000***<br>(0.000) | 0.068***<br>(0.007) |
| PCA | -0.247*<br>(0.098) | -0.013<br>(0.082) | 0.000<br>(0.001) | -0.233***<br>(0.063) |
| Adjusted R-Square | 0.101*** | 0.051 | 0.105*** | 0.228*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B10: The effects of percentage on renewable/wind/solar/dispatchable

| Variable | Coefficients (renewable) | Coefficients (wind) | Coefficients (solar) | Coefficients (dispatchable) |
|---|---|---|---|---|
| N | 517 | 517 | 517 | 517 |
| Constant | 646,935.610*** (110,025.377) | 290,235.496** (91,193.458) | -1,343.086 (972.867) | 358,043.200*** (70,323.914) |
| percentage | -0.011 (0.014) | -0.012 (0.012) | 0.000 (0.000) | 0.000 (0.009) |
| DGC | 139,405.696* (59,178.273) | 95,373.154 (49,049.333) | -1,025.083 (523.266) | 45,057.625 (37,824.436) |
| DSC | 60,985.750 (72,172.446) | -27,556.757 (59,819.427) | 545.398 (638.163) | 87,997.109 (46,129.802) |
| DHC | -32,319.452 (70,175.241) | -138,953.039* (58,164.063) | 546.865 (620.504) | 106,086.721* (44,853.267) |
| PCI | -2,694.480 (1,746.385) | 2,057.595 (1,447.475) | 19.652 (15.442) | -4,771.727*** (1,116.221) |
| CDD | -2,493.222*** (500.000) | -1,173.530** (414.420) | -12.164** (4.421) | -1,307.528*** (319.581) |
| POP | -10,043.791* (4,415.116) | -4,252.320 (2,659.426) | 10.134*** (5.812) | -5,993.008* (2,821.970) |
| NG | 0.069*** (0.012) | 0.001 (0.010) | 0.000*** (0.000) | 0.068*** (0.007) |
| PCA | -0.240* (0.099) | -0.013 (0.082) | 0.000 (0.001) | -0.226*** (0.063) |
| Adjusted R-Square | 0.097*** | 0.050*** | 0.104*** | 0.226*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B11: The consequences of stringency on renewable/wind/solar/dispatchable

| Variable | Coefficients (renewable) | Coefficients (wind) | Coefficients (solar) | Coefficients (dispatchable) |
|---|---|---|---|---|
| N | 517 | 517 | 517 | 517 |
| Constant | 672,890.162***<br>(102,958.780) | 263,638.515**<br>(86,081.708) | -1,132.723<br>(918.009) | 410,384.370***<br>(65,311.820) |
| stringency | -0.051**<br>(0.017) | -0.007<br>(0.014) | 0.000<br>(0.000) | -0.043***<br>(0.011) |
| DGC | 146,655.309*<br>(58,078.559) | 89,073.152<br>(48,558.283) | -975.552<br>(517.845) | 58,557.709<br>(36,842.087) |
| DSC | 75,733.481<br>(71,242.067) | -33,224.779<br>(59,564.020) | 587.743<br>(635.214) | 108,370.517*<br>(45,192.349) |
| DHC | -13,276.126<br>(69,929.237) | -136,604.241*<br>(58,466.390) | 522.536<br>(623.509) | 122,805.578*<br>(44,359.556) |
| PCI | -3,352.885<br>(1,720.342) | 2,245.525<br>(1,438.342) | 18.294<br>(15.339) | -5,616.704***<br>(1,091.298) |
| CDD | -2,482.823***<br>(481.887) | -1,083.084**<br>(402.895) | -12.906**<br>(4.297) | -1,386.833***<br>(305.684) |
| POP | -10,785.672*<br>(4,484.244) | -4,443.477<br>(3,665.575) | 203.298***<br>(39.091) | -6,545.494*<br>(2,781.141) |
| NG | 0.064***<br>(0.012) | -0.001<br>(0.010) | 0.000***<br>(0.000) | 0.064***<br>(0.007) |
| PCA | -0.228*<br>(0.097) | -0.002<br>(0.081) | -0.001<br>(0.001) | -0.225***<br>(0.062) |
| Adjusted R-Square | 0.111*** | 0.048*** | 0.103*** | 0.250*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B12: The outcomes of trading on renewable/wind/solar/dispatchable

| Variable | Coefficients (renewable) | Coefficients (wind) | Coefficients (solar) | Coefficients (dispatchable) |
|---|---|---|---|---|
| N | 517 | 517 | 517 | 517 |
| Constant | 668,054.404*** (112,072.440) | 329,140.354*** (92,719.416) | -1,667.913 (990.113) | 340,585.963*** (71,657.185) |
| trading | -0.017 (0.014) | -0.022 (0.012) | 0.000 (0.000) | 0.005 (0.009) |
| DGC | 143,597.715* (59.224.446) | 103,561.298* (48,997.382) | -1,093.398* (523.223) | 41,129.815 (37,867.089) |
| DSC | 64,689.928 (72,105.362) | -19,854.407 (59.653.980) | -481.183 (523.223) | 84,063.182 (46,102.924) |
| DHC | -33,470.514 (70,125.224) | -140,330.443* (58,015.778) | 558.446 (619.527) | 106,301.484* (44,836.858) |
| PCI | -2,860.510 (1,750.384) | 1,735.701 (1,448.122) | 22.338 (15.464) | -4,618.549*** (1,119.165) |
| CDD | -2,601.530*** (515.872) | -1,349.474** (426.790) | -10.692* (4.558) | -1,241.364*** (329.840) |
| POP | -10,129.511* (4,410.586) | -4338.163 (2,648.952) | 202.260*** (38.966) | -5,993.608* (2,820.052) |
| NG | 0.069*** (0.012) | 0.002 (0.010) | 0.000*** (0.000) | 0.067*** (0.007) |
| PCA | -0.247* (0.099) | -0.026 (0.082) | -0.000 (0.001) | -0.221** (0.063) |
| Adjusted R-Square | 0.098*** | 0.055*** | 0.107*** | 0.227*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B13: The influences of renewable on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 38.312***<br>(4.633) | 0.540***<br>(0.036) |
| renewable (M) | 2.681<br>(1.953) | -0.002<br>(0.015) |
| DGC | -7.800**<br>(2.578) | 0.032<br>(0.020) |
| DSC | 8.788**<br>(3.141) | -0.059*<br>(0.024) |
| DHC | 11.783***<br>(3.088) | 0.000<br>(0.024) |
| CDD | 0.003<br>(0.022) | 0.001***<br>(0.000) |
| NG (M) | 1.504**<br>(0.527) | -0.032***<br>(0.004) |
| PCA (M) | 13.577**<br>(4.334) | 0.105***<br>(0.034) |
| PCI | 0.633***<br>(0.075) | 0.003***<br>(0.001) |
| POP | 0.908***<br>(0.195) | -0.010***<br>(0.002) |
| Adjusted R-Square | 0.266*** | 0.249*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B14: The effects of renewable on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,377,046,215*** (104,652,284.6) | 25,152,896.35*** (2,041,176.576) | 19,181,786.26*** (2,210,884.886) |
| renewable | 511.329*** (44.113) | 7.229*** (0.860) | 6.737*** (0.932) |
| DGC | 36,099,553.90 (58,234,728.18) | 1,117,728.634 (1,135,831.516) | 603,577.478 (1,230,267.269) |
| DSC | -244,436,337.2** (70,963,510.17) | -4,742,410.549** (1,384,098.353) | -4,887,041.389** (1,499,175.605) |
| DHC | 20,921,732.06 (69,762,406.70) | -959,008.559 (1,360,671.590) | -834,075.091 (1,473,801.085) |
| PCI | -5,994,841.890*** (1,694,563.884) | -150,762.953*** (33,051.396) | -100,481.370** (35,799.368) |
| CDD | 1,514,809.199** (493,234.390) | 20,725.791* (9,620.225) | 21,790.850* (10,420.073) |
| POP | -18,531,414.08*** (4,409,673.709) | -418,840.353*** (86,007.895) | -413,115.452*** (93,158.797) |
| NG | -16.417 (11.916) | -0.912*** (0.232) | -1.352*** (0.252) |
| PCA | 380.689*** (97.907) | 5.390** (1.910) | 7.001** (2.068) |
| Adjusted R-Square | 0.292*** | 0.250*** | 0.220*** |

Notes: *p<0.05; **p<0.01; ***p<0.001.  The standard errors are in parentheses.

Table B15: The consequences of wind on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 41.215***<br>(4.504) | 0.520***<br>(0.034) |
| wind (M) | -4.949*<br>(2.349) | 0.074***<br>(0.018) |
| DGC | -7.019**<br>(2.567) | 0.025<br>(0.020) |
| DSC | 8.746**<br>(3.133) | -0.056*<br>(0.024) |
| DHC | 11.004***<br>(3.097) | 0.011<br>(0.024) |
| CDD | -0.009<br>(0.021) | 0.001***<br>(0.000) |
| NG (M) | 1.686**<br>(0.509) | -0.032***<br>(0.004) |
| PCA (M) | 12.950**<br>(4.300) | 0.106**<br>(0.033) |
| PCI | 0.638***<br>(0.075) | 0.003**<br>(0.001) |
| POP | 0.860***<br>(0.194) | -0.010***<br>(0.001) |
| Adjusted R-Square | 0.270*** | 0.273*** |

Notes: *p<0.05; **p<0.01; ***p<0.001 M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B16: The outcomes of wind on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,513,554,616***<br>(98,375,462.56) | 26,559,657.39***<br>(1,868,319.670) | 20,146,182.49***<br>(2,001,556.792) |
| wind | 693.368***<br>(51.308) | 11.586***<br>(0.974) | 12.410***<br>(1.044) |
| DGC | 42,936,724.58<br>(56,059,621.06) | 1,036,200.131<br>(1,064,668.871) | 409,495.497<br>(1,140,594.538) |
| DSC | -192,353,712.9**<br>(68,425,230.18) | -3,930,723.788**<br>(1,299,513.112) | -4,080,595.351**<br>(1,392,186.432) |
| DHC | 100,846,203.3<br>(67,642,027.38) | 457,335.462<br>(1,284,638.740) | 675,784.992<br>(1,376,251.311) |
| PCI | -8,864,396.381***<br>(1,635,677.959) | -196,238.711***<br>(31,064.345) | -146,117.376***<br>(33,279.664) |
| CDD | 1,033,324.733*<br>(467,877.435) | 16,115.719<br>(8,885.799) | 18,950.284*<br>(9,519.480) |
| POP | -20,699,980.81***<br>(4,236,518.689) | -440,569.176***<br>(80,458.795) | -427,448.772***<br>(86,196.624) |
| NG | 18.392<br>(11.122) | -0.420*<br>(0.211) | -0.893**<br>(0.226) |
| PCA | 264.934**<br>(93.912) | 3.759*<br>(1.784) | 5.484**<br>(1.911) |
| Adjusted R-Square | 0.341*** | 0.339*** | 0.327*** |

Notes: *p<0.05; **p<0.01; ***p<0.001.  The standard errors are in parentheses.

Table B17: The influences of solar on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 39.861***<br>(4.489) | 0.540***<br>(0.035) |
| solar (M) | -89.379<br>(221.219) | 1.040<br>(1.714) |
| DGC | -7.534**<br>(2.578) | 0.033<br>(0.020) |
| DSC | 8.983**<br>(3.148) | -0.059*<br>(0.024) |
| DHC | 11.744***<br>(3.095) | 0.000<br>(0.024) |
| CDD | -0.005<br>(0.022) | 0.001***<br>(0.000) |
| NG (M) | 1.728**<br>(0.000) | -0.032***<br>(0.004) |
| PCA (M) | 12.914**<br>(0.000) | 0.106**<br>(0.033) |
| PCI | 0.628***<br>(0.075) | 0.003***<br>(0.001) |
| POP | 0.899***<br>(0.200) | -0.010***<br>(0.002) |
| Adjusted R-Square | 0.263*** | 0.249*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B18: The effects of solar on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,693,219,908***<br>(113,836,423.0) | 29,665,772.15***<br>(2,106,280.0001) | 23,420,885.17***<br>(2,244,176.558) |
| solar | -2,925.161<br>(5,609.807) | 82.654<br>(103.797) | 108.820<br>(110.592) |
| DGC | 105,886,834.0<br>(65,375,931.30) | 2,143,658.188<br>(1,209,630.565) | 1,590,006.053<br>(1,288,824.162) |
| DSC | -219,629,961.0**<br>(79,827,736.05) | -4,417,435.126**<br>(1,477,027.822) | -4,603,961.201**<br>(1,573,727.715) |
| DHC | 2,516,743.914<br>(78,486,615.36) | -1,241,974.056<br>(1,452,213.482) | -1,115,321.523<br>(1,547,288.800) |
| PCI | -7,256,310.021***<br>(1,904,123.747) | -169,292.200***<br>(35,231.411) | -118,285.826**<br>(37,537.984) |
| CDD | -329,753.144<br>(546,678.706) | -4,511.070<br>(10,115.026) | -7,093.477<br>(10,777.250) |
| POP | -24,306,503.66***<br>(5,061,701.414) | -508,840.233***<br>(93,655.090) | -503,425.897***<br>(99,786.618) |
| NG | 16.957<br>(13.237) | -0.460<br>(0.245) | -0.945***<br>(0.291) |
| PCA | 264.828*<br>(109.538) | 3.774<br>(2.027) | 5.511*<br>(2.159) |
| Adjusted R-Square | 0.105*** | 0.147*** | 0.141*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

Table B19: The consequences of dispatchable on price and carbon intensity

| Variable | Coefficients (price) | Coefficients (carbon intensity) |
|---|---|---|
| N | 517 | 517 |
| Constant | 34.600*** (4.507) | 0.585*** (0.035) |
| dispatchable (M) | 14.927*** (2.990) | -0.129*** (0.023) |
| DGC | -8.124** (2.513) | 0.037 (0.019) |
| DSC | 7.611* (3.082) | -0.047* (0.024) |
| DHC | 10.111*** (3.036) | 0.014 (0.023) |
| CDD | 0.016 (0.021) | 0.001*** (0.000) |
| NG (M) | 0.677 (0.539) | -0.023*** (0.004) |
| PCA (M) | 16.345*** (4.270) | 0.076* (0.033) |
| PCI | 0.698*** (0.750) | 0.002*** (0.001) |
| POP | 0.971*** (0.191) | -0.011*** (0.001) |
| Adjusted R-Square | 0.298*** | 0.292*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized the NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita. The standard errors are in parentheses.

Table B20: The outcomes of dispatchable on revenue/quantity/emissions

| Variable | Coefficients (revenue) | Coefficients (quantity) | Coefficients (emissions) |
|---|---|---|---|
| N | 517 | 517 | 517 |
| Constant | 1,659,896,353*** (116,943,538.7) | 30,365,613.23*** (2,161,708.110) | 24,892,744.03*** (2,290,673.529) |
| dispatchable | 84.393 (77.587) | -2.275 (1.434) | -4.420** (1.520) |
| DGC | 99,284,720.92 (65,193,304.40) | 2,167,800.763 (1,205,100.172) | 1,686,201.935 (1,276,995.285) |
| DSC | -225,249,167.0** (79,972,836.09) | -4,165,382.760** (1,478,302.523) | -4,146,522.558** (1,566,496.624) |
| DHC | -4,824,162.975 (78,786,504.02) | -955,012.358 (2,456,373.106) | -586,377.936 (1,543,258.919) |
| PCI | -6,893,819.762*** (1,935,894.250) | -178,770.192*** (35,785.118) | -137,570.441*** (37,920.023) |
| CDD | -402,117.578 (550,728.745) | -454.144 (10,180.253) | -113.082 (10,787.597) |
| POP | -23,209,003.84*** (4,950,234.836) | -505,747.031* (91,505.379) | -507,888.204*** (96,964.501) |
| NG | 12.640 (13.977) | -0.267 (0.258) | -0.595* (0.274) |
| PCA | 282.422* (110.805) | 3.215 (2.048) | 4.452* (2.170) |
| Adjusted R-Square | 0.106*** | 0.150*** | 0.154*** |

Notes: *p<0.05; **p<0.01; ***p<0.001. The standard errors are in parentheses.

# APPENDIX C: PATH ANALYSIS MODELS

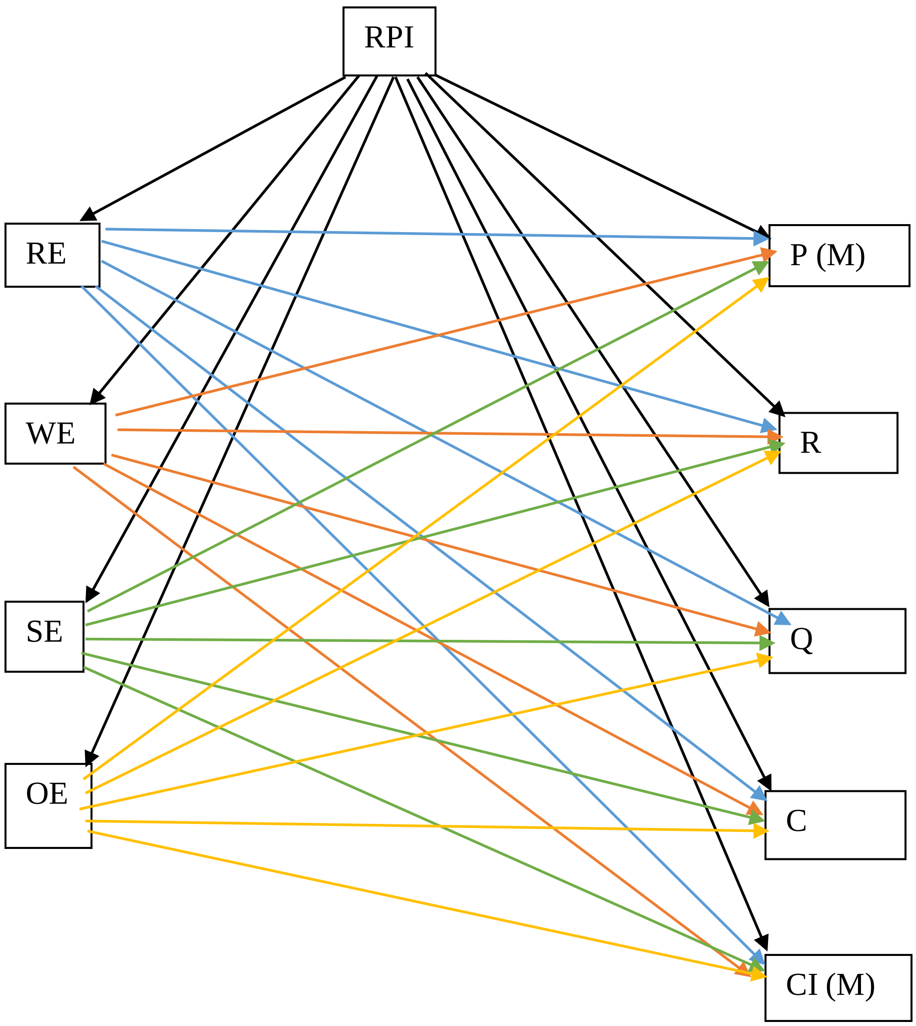


Figure C1: Simplified path analysis model of RPI

Notes: M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I found no significant pathways that began with the RPI independent variable.

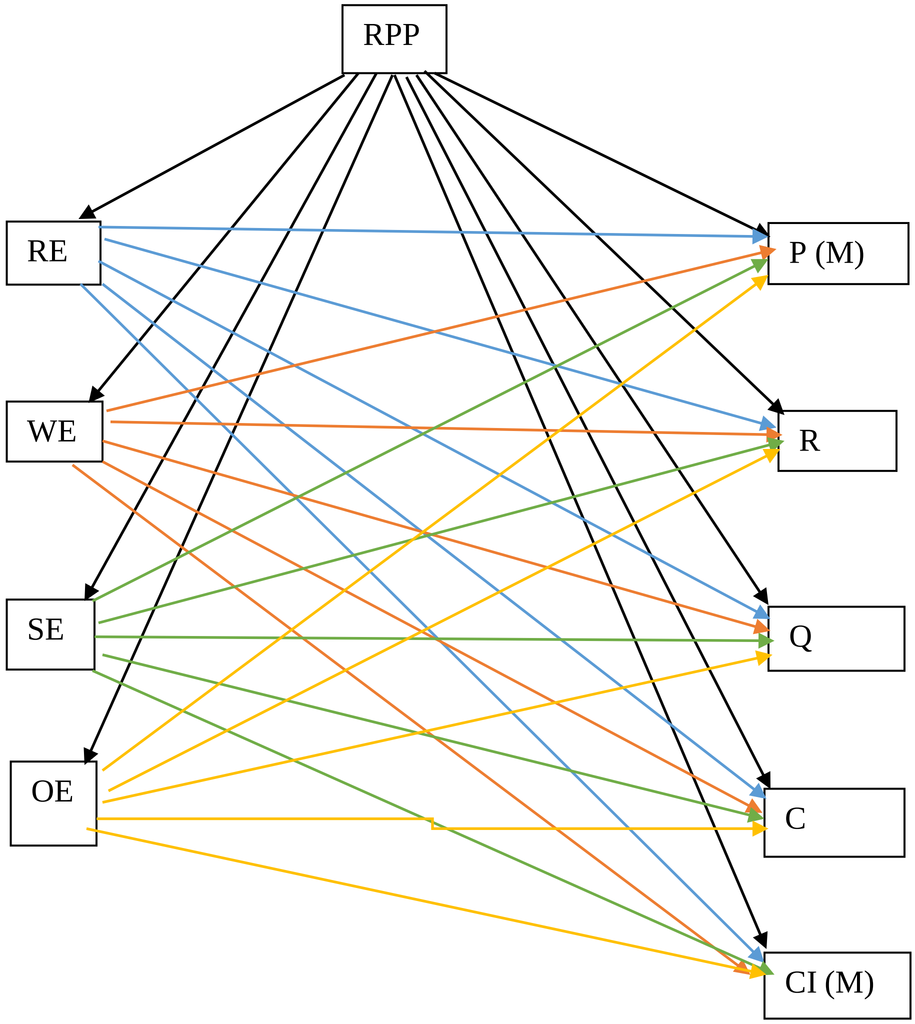


Figure C2: Simplified path analysis model of percentage

Notes: M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I found no significant pathways that began with the percentage independent variable.

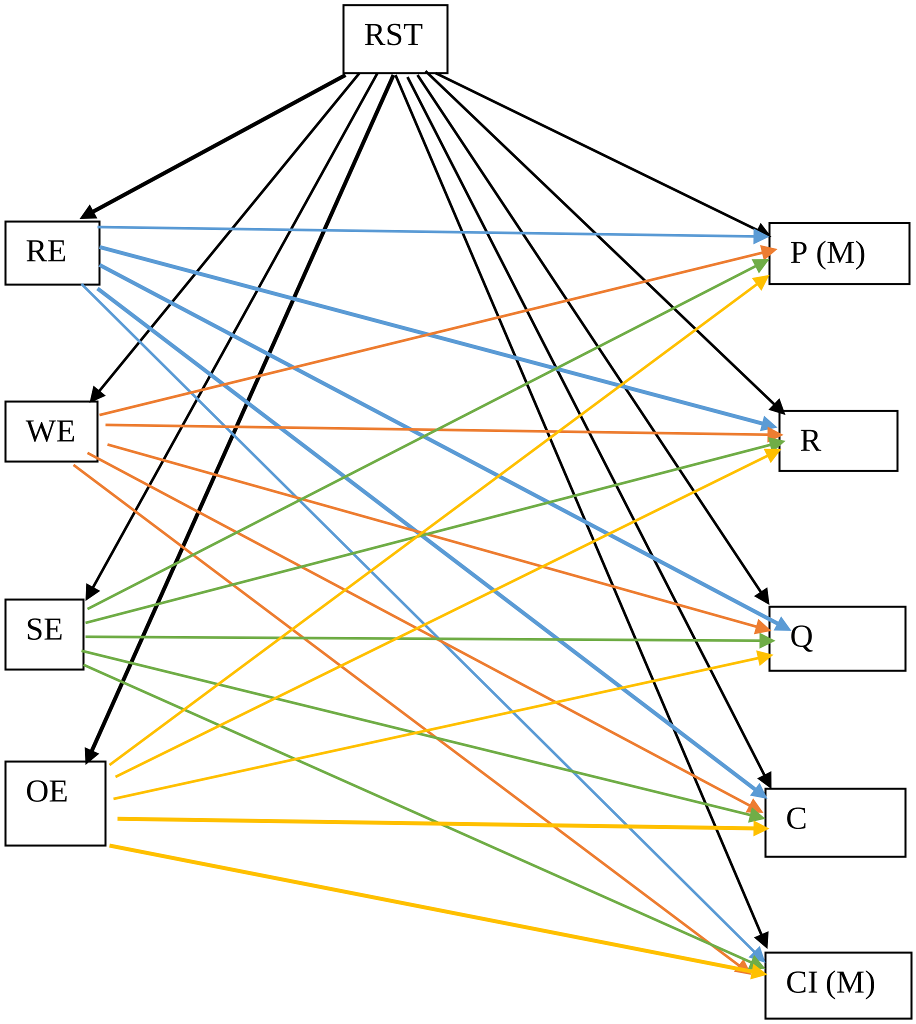


Figure C3: Simplified path analysis model of stringency

Notes: M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I discovered five significant pathways that began with stringency, which are in bold. I present the coefficients of the path analysis models in Table C1.

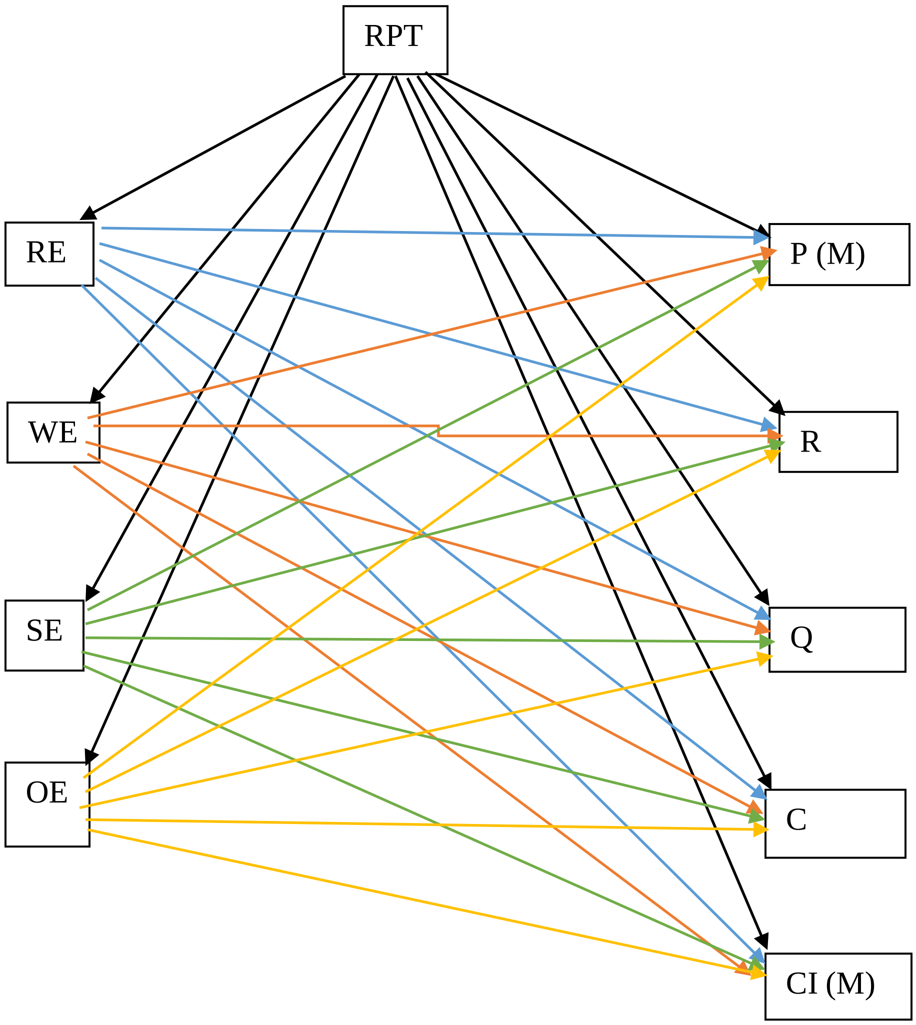


Figure C4: Simplified path analysis model of trading

Notes: M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I found no significant pathways that began with the trading independent variable.

C1**:** Significant Path Analysis Models

The five significant pathways of the path analysis models were the stringency-dispatchable-emissions path, the stringency-dispatchable-carbon intensity path, the stringency-renewable-revenue path, the stringency-renewable-quantity path, and the stringency-renewable-emissions path. I operationalized the variables to allow for a direct coefficient application rather than having to worry about standardized coefficients. I report the total impact of the results of path analysis models as follows:

Table C1: Path analysis models

| Independent Variable | Mediating Variable | Dependent Variable | Path Analysis Model Coefficient | Modified Impact Coefficient | N |
|---|---|---|---|---|---|
| stringency | dispatchable | emissions | 0.190** | 2.694** | 517 |
| stringency | dispatchable | carbon intensity (M) | -0.006** | 0.017** | 517 |
| stringency | renewable | revenue | -26.10** | 104.5** | 517 |
| stringency | renewable | quantity | -0.369** | 2.086** | 517 |
| stringency | renewable | emissions | -0.344** | 2.160** | 517 |

Notes: *p<0.05, **p<0.01, ***p<0.001. M represents the coefficients of a control variable or independent variable modified to magnify the apparent magnitude by a factor of one million. I operationalized NG control variable in MW-h per capita per year rather than W-h per capita per year and the PCA control variable in square kilometers per capita rather than square meters per capita.