Impact of state policies on renewable energy:A county-level spatial panel analysis

Pinky Thomas[*], Xiaoli Eitenne [†], Alan Collins [‡], Ritika Khurana [§]

Selected Paper prepared for presentation at the 2023 Agricultural Applied Economics Association
Annual Meeting, Washington, DC; July 22-25,2023

[*]West Virignia University, Email: pt0032@mix.wvu.edu
[†]University of Idaho, Email: xetienne@uidaho.edu
[‡]West Virignia University, Email: alan.collins@mail.wvu.edu
[§]University of Delaware, Email: Rkhurana@udel.edu

Impact of state policies on renewable energy:A county-level spatial panel analysis

Abstract

Renewable energy generation is growing as a result of concerns of environmental quality implications from fossil fuel-based electricity generation, declining costs of renewable energy, and policies incentivizing renewable energy adoption. Given the role of policy in renewable energy generation, we provide empirical analysis of the economic, political, demographic factors and policy instruments that drive county and state governments to generate energy using wind, solar, hydro, and geothermal energy. Using a panel dataset of 3017 counties from 2009 to 2019 in the contiguous US, we empirically examine the impact of policy instruments on aggregated renewable energy generation capacity and solar, wind, hydro and geothermal energy individually. We also explore the spatial spillover effects of neighboring counties' from state and federal policies [by incorporating county-level variations] that may affect renewable energy generation capacity of a particular county. Considering the spatial effects, the policy implication of this study suggests that the RPS target and Mandatory Green Power policy do have positive significant impact on the RE generation capacity. Except the sale tax incentive other financial incentive policies do not support the RE development.

Keywords: Renewable Energy Generation Expansion, Renewable Energy Policies, State Policies, Energy Intensity, RPS, Spatial Analysis
JEL Classification:

1 Introduction

A shift from fossil fuels to renewable energy (RE) in electricity generation is imperative to mitigate greenhouse gases emissions, a major contributor to climate change. According to Energy Information Administration[1], in 2000, fossil fuel combustion accounted for 73% of the total greenhouse gas (GHG) emissions in the United States. At the federal level, there is no regulations on GHG emissions from power plants. However, state leaders and local governments have come up with a variety of policy approaches that provide incentives for generation of electricity with RE (Engel and Orbach, 2008; Ohler, 2015; Shrimali and Kniefel, 2011; Shrimali et al., 2015; Yin and Powers, 2010), including as RPS, mandatory green laws, efficiency standards, tax breaks, credits, minimum standards and deregulated markets. These resulted in varying levels of renewable energy generated and consumed across the states and counties within the US.

RE deployment has been supported by a variety of state and local government subsidies and policies such as distributed generation policies for renewable energy implemented by both state and local governments. From a range of subsidies and policies available, the most widely adopted policies across states is the renewable portfolio standard (RPS) which requires a minimum amount of renewable energy in the portfolio of electricity-generating resources in the participating state. Meanwhile, the energy efficiency resource standards (EERS) implemented in some states require utilities to achieve a certain percentage of energy savings based on the amount of electricity or natural gas sold in the state. For example, the New York state aims at an annual reduction of 3% electricity sales by 2025. Further, the mandatory utility green power option (MUGPO) allows customers to voluntarily purchase "green power" from renewable energy. Market deregulation is another important policy that encourages alternative energy sources in the US. Multiple state-level sales tax credit and production incentives are available. Despite so many policies, the capacity to generate energy from renewable sources remains low.

Research in the related fields have discussed and analysed the impact of several policies on renewable energy generation (Charlier et al., 2018; Menz and Vachon, 2006; Ohler, 2015; Zhao and Chen, 2018; Delmas and Montes-Sancho, 2011; Yin and Powers, 2010). Despite

[1] U.S. Environmental Protection Agency(April 2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 . Includes U.S. Territories.

the abundance of literature on the impact of different renewable energy policies on renewable energy generation capacity, the existing literature is limited in two fronts. First, most of the papers have focused on individual RE sources, mainly wind or solar (Hitaj, 2013; Carley, 2009; Delmas and Montes-Sancho, 2011; Shrimali et al., 2015; Shrimali and Kniefel, 2011; Prasad and Munch, 2012). However, renewable sector also encompasses fuel sources such as geothermal and hydro. According to EIA 2022 [2], of the 20% electricity generated from renewable sources, about 18% of electricity is contributed by wind, solar,geothermal and hydro. Transition to RE requires power plants to evaluate available renewable resources and select the most economically efficient option. Thus, a comprehensive evaluation that accounts for all available RE generation capacity is needed when examining the impact of policy incentives on renewable electricity generation.

In the present study, we examine how state-level policies affect the total RE capacity, as well as the capacity for an individual RE resource, at the county level. Second, previous studies analyzing RE generation capacity overlook the potential spatial interactions across counties and states. The economic and social drivers leading to the effectiveness of the policy instruments could be driven by spatial interactions as well. This paper seeks to analyze the econometric implications of regional dependency by addressing the spatial relationships between neighboring regions in effectively implementing the state and federal policies to promote the renewable energy.

To address the spatial dependency between neighboring regions we use spatial panel analysis by incorporating spatial lag with random effect to assess the impact of policy instruments on the renewable energy generation capacity. Our results suggest that RPS requirements, MUGPO and sales tax incentives positively impact increased RE generation capacity. We also found that the indirect effect from neighboring counties is more pronounced than the direct effect of these policies on the RE generation capacity.

The rest of the paper proceeds as follows.Section 2 discusses the literature review. In Section 3 discusses the the empirical methods used to study the impact of policy instruments on renewable energy generation capacity. Section 4 presents data, descriptive statistics and data sources. Key results are discussed in Section 5. The last section concludes the paper.

[2] https://www.eia.gov/electricity/monthly/current_month/august2022.pdf

2 Literature Review

Many studies have examined factors affecting renewable energy generation capacity including solar, wind, hydro and geothermal energy. A part of the literature focuses on the relationship between renewable energy generation capacity and economic growth at the country-level, studying it from Environmental Kuznets Curve (EKC) standpoint (Menyah and Wolde-Rufael, 2010; Sadorsky, 2009; Ohler, 2015). Some of them argue that socioeconomic and political factors drive the adoption and deployment of renewable energy generation capacity. These factors that drive renewable energy generation include policy drivers, such as renewable portfolio standards or energy efficiency resource standards, federal and state financial incentives such as property tax or corporate tax; as well as market drivers, such as consumer demand for green power, natural gas price volatility, and wholesale market rules (Zhao and Chen, 2018; Huang et al., 2007; Lyon and Yin, 2010).

One of the major factors that emerge from these studies that influences renewable energy deployment is federal and state policies. A large portion of literature studies the effectiveness and efficiency of policy instruments affecting renewable electricity development. For example, Shrimali et al. (2015) finds that production tax credit alone has been effective in promoting 1.4 GW per year of wind energy deployment in the U.S. When production tax credit is combined with mandatory green power, then the wind deployment in a state increases by 200 MW per year on average. Further, Menz and Vachon (2006) find that requiring electricity suppliers to provide green power options to customers is positively related to development of wind energy, but if retail customers are allowed to choose their electricity, then that has a negative impact on wind energy development. In contrast, Carley (2009) reveals a shortcoming of RPS policies for total amount of energy generation and finds no strong evidence of RPS policies in achieving the objective of increasing the percentage of RE generation in a state.

The consequence of policies on renewable generation is varied and sometimes even unintended. The disproportionate effect of policies is ascribed to difference in context, policy design, implementation practices of states and institutional characteristics. For example, Delmas and Montes-Sancho (2011) find that overall RPS has a negative impact on investments in renewable capacity. However, when discussing the utility ownership types, investor-owned utilities seem to respond more positively to RPS mandates than publicly owned utilities. By contrast, MUGPO appears to have a significant effect on installed renewable capacity for all utilities regardless of the context in which it is implemented. Yin and Powers (2010) finds that stringent RPS (based on incremental percentage requirement) design have is positively related to in-state renewable electricity development, relative to overly simplistic RPS measure (nominal RPS requirement).

Overall, literature has mixed impacts of federal state and county level policies with respect to the renewable energy generation and suffers from several limitations. While majority of the studies use state level data, we use the county level data to identify how different counties, based on the presence of utilities, respond to the state level policies. We consider county level data to avoid any kind of selection bias based on the profitability or potential for each energy resources of regions. Counties that are infeasible for wind might be feasible for solar or hydro or geothermal. By accounting for renewable resources with county as unit of analysis, we analyse the spillover effects between regions using spatial analysis. This helps to better understand the distribution of renewable resources and identify areas in terms of policies to further focus for efficient development of RE capacity.

3 Methods

In this section, we discuss the methods used to study the causal relationship between renewable policy instruments and RE generation. Given that we have a panel dataset, we start with a basic pooled OLS, fixed- effects (FE) and random-effects(RE) model to account for potential endogeneity that may arise from cultural factors, difference in business practices across panels or through national international agreements over time in fixed effects. We employ random effects model to account for time-invariant policy variables including policy instruments and other static explanatory variables such as level of wind speed. Next, we utilize Tobit model to study the effects on individual energy generation including solar, wind, geothermal and hydro. To address the significant censoring (i.e. large numbers of zeroes) found in individual energy generation data, we use Tobit model, which in the face of OLS estimators would have rendered biased and inconsistent estimates. Last, we employ spatial econometric models to investigate spillover effects of policy effect on renewable energy from neighboring counties. Based on the robustness checks, we found the existence spatial dependency. Hence, we conclude that the estimates for the OLS,FE,RE and tobit models would be biased.Spatial analysis can address the spatial dependency in the attributes and obtain unbiased estimators.

3.1 Panel Models

We first estimate the impact of policy instruments on renewable energy generation capacity, as shown in Eq. 1 using pooled OLS, fixed- and random-effects panel models. The pooled OLS model assumes that unobservable characteristics are uncorrelated with X_{it}. The fixed-effects estimation allows for unobserved heterogeneity to be correlated with the time-varying covariates. In contrast, the random-effects model assumes that μi is uncorrelated with the explanatory variables and allows the estimation of time-invariant variables.

$$y_{it} = \beta_0 + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z1_{it}} + \boldsymbol{\pi Z2_{it}} + \mu_i + \alpha_t + \epsilon_{it} \tag{1}$$

In Eq.1, y_{it} is the renewable energy generation capacity for county i in year t. X_{it} are different policy instruments in county i at time t. $Z1_{it}$ is a vector of covariates which are time-varying, $Z2_{it}$ is a vector of covariates which are not time-varying, μ_i captures county-specific effects, α_t capture year-specific effects. The year dummies are used to control for time-specific events that may influence states, for example, recession, federal election, etc. Inclusion of the fixed-effects avoids any heterogeneity bias that may occur from imposing a common constant term. The time-varying errors (ϵ_{it}) are assumed to be uncorrelated with the independent variables.

3.2 Tobit Model

We estimate the individual impacts of policies on RE sources of solar, wind, geothermal and hydro through eq 2. Since only limited numbers of counties have RE generation capacity for each RE source, most counties for most time periods have zero generation capacity (Hitaj, 2013). The zeroes in the dependent variable indicate the reporting threshold of each plant which is less than one megawatt or zero megawatt. If the plant generates less than one megawatt of energy from particular renewable source from plants in a given county, it is indicated by zero. Thus, we use tobit model (also called a censored regression model). Therefore, y_{it} in eq 2 takes on the value of zero with positive probability and is continuous for y_{it} greater than zero, resulting into a left-censored distribution with residuals following a normal distribution (Amore and Murtinu, 2021). Hence, it leads to unbiased coefficient estimates. Traditional estimation of panel OLS would lead to biased and inconsistent estimators as there is selection bias within the sample data and also error term will be correlated with the explanatory variables (Wooldridge, 2002).Whereas, the tobit model captures the uncensored or observed portion of the dependent variable and provide more accurate estimates by using the maximum likelihood approach. The latent model is expressed as follows:

$$
\begin{aligned}
y^*_{it} &= \boldsymbol{\beta} X_{it} + \epsilon_{it} \\
&\qquad\qquad \epsilon|x \sim N(0;\sigma^2) \\
&\text{The observed variable is: } y_{it} = \begin{cases} y^*_{it} & \text{if } y^*_{it} > 0 \\ 0 & \text{if } y^*_{it} \leq 0 \end{cases}
\end{aligned} \tag{2}
$$

where the coefficients estimate the value of y^*_{it}, which is the latent variable.The above equation also conveys that the residuals follow a normal distribution and the dependent variable is left censored.

3.3 Spatial Panel Models

Eq.(1) and (2) may suffer from endogeniety bias because of the underlying assumption that the observations or regions are not independent of one another (LeSage and Pace, 2009). Anselin (1988) suggests that omitting the spatial correlations when variables are spatially correlated would lead to biased variance of the estimators. Spatial correlation violates the assumption of independence between observation leading to biased variance. Possible sources of correlation arise from between county-specific effects and their neighbors as observations that are geographically close to each other are likely to be similar. This could be explained in terms of the endogenous interaction which could imply that there may be interactive effect of RE capacity of a given county and the neighboring county. Also, spatial correlation may be affected by the socio-political factors of those counties or state. For example, the presidential voting pattern similarity across the neighboring counties could cause spatial correlation.Or the measures for RE policies in neighboring counties interacts with the RE generation capacity in the given county causing exogenous interaction. The economy and the similar demographic patterns also could result in exogenous interaction leading to spatial correlation.

To address this issue, we consider a spatial panel lag with random effects (SLM-RE). With a SLM-RE model, the value of the dependent variable observed in a county is partially determined by a spatially weighted average of neighboring dependent variables. That is, renewable energy capacity generation in one county is influenced by the generation capacity in the neighboring counties because of the spillover effects. It allows dependence among observations that are in close geographical proximity (LeSage and Pace, 2009) by identifying cohorts of nearest neighbors (Anselin, 1988; LeSage and Pace, 2009). We see spatial dependence in behaviour of counties that are nearest neighbors.

The Global Moran's I test statistic serves as an indicator to identify whether a model is spatially correlated. This statistic is commonly used as an indicator of spatial dependence in a data set[3] (Bivand et al., 2009; Jin and Lee, 2015).

We conduct a Lagrange Multiplier test (Table A.3) with a chi-squared distribution to examine the presence of potential spatial dependence. This test specifies the presence of a spatial error and spatially-lagged dependent variable in the model. The test is performed using the residuals of a non-spatial model. If the alternative hypotheses is not rejected, then it means that a spatial lagged or a spatial error in the model exists(Anselin, 1988). According to the LM test stastic, SLM model best fits our data set. The SLM model is specified as

$$y_{it} = \lambda \sum_{i=1}^{N} w_{ij} y_{jt} + x_{it}\beta + \mu_i + \epsilon_{it} \quad (3)$$

where y_{it} is the renewable energy generation capacity for county i at time t (i = 1, ...,N ; t = 1,..,T). $\sum_{i=1}^{N} w_{ij} y_{jt}$ represents the endogenous interaction effects of the dependent variable y_{it}.

A spatial econometric approach is based upon a weight matrix where the elements of the matrix represent the direction and strength of spillovers between each pair of units (counties in this research) because of cross-sectional dependence (Bhattacharjee and Holly, 2011). The weight matrix W is a square matrix, n x n, with diagonal elements 1. n is the number of observations, and each observation represents a region. Non-zero elements in the i, j row and column positions of the matrix W indicate that region/ observation j is a neighbor to i (LeSage, 2014).

[3] Based on the global moran's test result we reject the null hypothesis against spatial dependence

We use the K-nearest neighbor approach, a non-parametric method (Fix and Hodges, 1989; Hechenbichler and Schliep, 2004), for the weight matrix. KNN algorithm assumes that similar things exist in close proximity. As we have used the longitude and latitude decimal degrees, distances between counties measured in kilometers are used to find the nearest neighbors. Since, our data set is a spatial polygon data frame, the values are taken from the given coordinate points itself. The KNN function identifies the neighbors by Euclidean distance using the latitude and longitude points in the data.The weights act as covariates in the model as the weight matrix formed matches the dimensions of the covariates in the model.

We fix the k-value (number of neighbors) at 15[4] (Hechenbichler and Schliep, 2004). Also, we tried to let the KNN function to predict the number of neighbors and accordingly, the function returned K = 35. In order to avoid over fitting of the model, our results presented are with K = 15 and the results with predicted K value (=35) are given in the appendix (Table A.6 - A.8).

4 Data and Variable Description

A balanced panel data set consisting of 3017 counties of US (contiguous US excluding DC) from 2009 to 2019 is used in the research. Due to data unavailability of nameplate capacity renewable energy generation prior to 2009, we limit the analysis to a decade-long effect of policies i.e. from 2009 to 2019. In the following sub-sections, the dependent variables are first described, followed by a discussion on the seven policy variables, and finally the control variables included in the models. Detailed descriptions of variables and sources are provided in the appendix A.1 and descriptive statistics of all variables are shown in Tables 1 and 2.

4.1 Dependent Variable

RE generation capacity, the dependent variable, is the sum of nameplate capacity for electricity generation units of solar, wind, hydro and geothermal power. The nameplate capacity energy generation is the installed capacity of a generator [5]. We also consider individual renewable energy source including solar, wind, hydro and geothermal energy generation as dependent variables in different model specifications. By studying the impact of policies and incentives on

[4] if k is small then noise will have a higher dependency on the result and chances of under-fitting of the model is high. If k is big then the principle behind using KNN will be destroyed causing over-fitting of the model

[5] Nameplate capacity, expressed in megawatts, is the maximum rated output of a generator under specific conditions.

each renewable source separately at county level, we are able to focus on micro-level renewable energy deployment. Another advantage of independent analysis of each source is it permits us to examine the heterogeneous ("if", "when" and "how much") impact of policies on different renewable energy sources.

Data for renewable energy generation capacity are obtained from U.S. Energy Information Administration (EIA). Each year the EIA collects generator-level specific information on the existing and planned capacities for electric power plants with 1 megawatt or greater of combined nameplate capacity through Form EIA-860. From the Table 1, the maximum RE installed capacity in a county is 9101.2MW considering all the renewable energy sources. The minimum value of zero indicate the installed capacity of generators in a county which are less than 1MW.

Table 1: Descriptive Statistics

Variables	Unit	Mean	St. Dev.	Min	Max
Dependent Variables					
RE generation	MW	55.18	273.07	0.00	9,101.20
Wind energy	MW	20.11	103.59	0.00	3,635.90
Solar energy	MW	3.95	51.27	0.00	2,955.20
Geothermal energy	MW	1.08	30.69	0.00	1,518.00
Hydro energy	MW	30.05	233.67	0.00	9,101.20
Control Variables					
Primary energy	Billion BtU	2,615,446	4,519,858	2,702	23,472,040
NG price	$/million BtU	7.50	1.87	3.40	15.17
Solar potential	MWh/year	1,759.60	2,456.67	0.00	12,311.70
Wind speed L1	MW	4,977.92	12,680.60	0.00	45,733.20
Wind speed L4	MW	28,007.41	48,885.95	0.00	140,249.40
Wind speed L5	MW	53,792.91	87,028.97	0.00	267,336.70
Wind speed L9	MW	29,106.86	31,040.17	0.00	206,318.60
Wind speed L10	MW	16,420.13	31,437.95	0.00	200,946
Per capita income	$	42,736.89	11,835.28	16,562.12	235,690.00
EPU	Index	68.87	25.31	21.10	237.57
Unemployment rate	% of labor force	6.51	3.05	0.80	29.40
Population	Thousands	101.01	327.51	0.04	10,094.86
White	% of population	0.86	0.16	0.08	1.62
Democrat	% of total voters	35.76	15.04	3.14	90.21

Note: ‡ N=33187, [1]Energy Intensity = Ratio of total primary energy to GDP, RE= Renewable energy, BtU = British thermal unit, NG = Natural gas, EPU = Economic and political uncertainty, Wind speed L1 = Level 1, L4 = Level 4, L9 = Level 9, L10 = Level 10. Per capita income is inflation adjusted for 2019.

4.2 Policy Instruments

Policy variables or policy instruments capture the effects of different types of renewable energy regulation at state or county. The policy instruments form a compelling argument in explaining the variation in adoption of renewable technology which results in variation in generation capacity of renewable sources (Sarzynski et al., 2012). In this study, we consider several policy instruments and incentives including RPS, EERS, MUGPO, market deregulation, tax incentives including sales tax and property property tax incentive that drive renewable energy generation focusing more narrowly on county level experiences. Previous literature have used corporate tax and found the significant impact of corporate tax on RE generation. For the period under consideration in this study, we found that corporate tax was ineffective or dormant for few years and data related to the implementation or dropping of the policy for the dormant period wasn't available. Even though, we found significant impact of corporate tax on RE generation without incorporating the dormant period data, we choose to not use it for our primary analysis

Data for all the policy instruments is obtained from database for State Incentives for Renewables and Effeciency (DSIRE) database [6]. For dichotomous policy instruments, 1 is accorded to the years it was effective and 0 otherwise. For example, a policy that was implemented in 2010 is coded '0' for years prior to that, coded '1' from start year.

Figure 1 displays the year in which each state adopted a policy or an incentive to facilitate the growth of renewable energy in the state. For showing the start date of policy, the year is limited from 1997 on wards in the figure. Table 2 shows the summary statistics of different regulatory policy instruments and financial incentives used in this study.

4.2.1 Renewable Portfolio Standards (RPS)

The renewable portfolio standards (RPS) specify the amount of a state's electricity sales or capacity that must be renewable-based. RPS requires electric utilities and other electric providers to supply a specified minimum percentage (or absolute amount) of customer demand to be met with eligible sources of renewable electricity. RPS policies and rules vary significantly from state-to-state. Generally called electricity portfolio standards take one of the following

[6] DSIRE is operated by the North Carolina Clean Energy Technology Center at N.C. State University

Table 2: Policy instruments

Statistic	Mean	St. Dev.	Policy Type	Level	Variable Type
RPS	0.64	0.48	Regulatory	State	Dummy
RPS requirement (%)	0.04	0.07	Regulatory	State	%
RPS requirement LI (%)[1]	0.03	0.06	Regulatory	County	%
MUGPO	0.14	0.34	Regulatory	State	Dummy
EERS	0.52	0.50	Regulatory	State	Dummy
Deregulated	0.61	0.49	Regulatory	State	Dummy
Sales tax	0.69	0.46	Financial incentive	State	Dummy
Property tax	0.73	0.44	Financial incentive	State	Dummy
Corporate tax credit ∓	0.24	0.43	Financial incentive	Federal	Dummy

Note: ‡ N = 33,187. [1] LI = Low income counties. The maximum RPS requirement (%) achieved by a state is 100. Policy variables included as dummy variables have values as 1 for presence of policy and 0 otherwise. ∓ Corporate tax though a federal policy, implementation years vary for states.

forms: RPS, Clean energy standards (CES), or Alternative Portfolio Standard (APS) [7]. Either RPS, CES, or APS has been adopted by 34 states and District of Columbia [8].

In addition to different types of standards, they are also structured as voluntary goals or mandatory requirement percentage requirements. States have chosen to either implement mandatory RPS policies or adhere to voluntary goals or both. The difference between the two is of legality i.e. mandatory requirements are typically legal in nature, with underlying laws on penalties imposed in case of non-compliance; whereas goals are essentially voluntary, with no recourse to law in case of non-compliance (Wiser and Barbose, 2008). Hence, in our analysis, the RPS dummy includes all counties in corresponding states which has with either voluntary or mandatory RPS policy. Whereas, in case of RPS requirements and RPS requirements with low income variation incorporated, we can see that the data for states with voluntary requirements is zero.For example, Oklahoma has RPS policy in place and it has a voluntary goal of 15%. Consequently, the data from Berkeley lab for RPS requirements is showing 0% for Oklahoma. Therefore, the data for RPS requirements and RPS requirements with low income variation incorporated include only mandatory requirements.

In our study, we have used *RPS_dummy* which is defined on the basis of whether an RPS

[7] The difference between RPS and CES is that while RPS promotes renewable energy, clean energy standard promotes any energy source with low carbon which includes nuclear energy as well. In case of APS, this policy offers incentives for installing alternative energy sources which not necessarily just renewable energy sources but also sources which increase energy efficiency and reduce the fossil fuel usage.

[8] DC is not included in our study as most of the data points are missing for DC

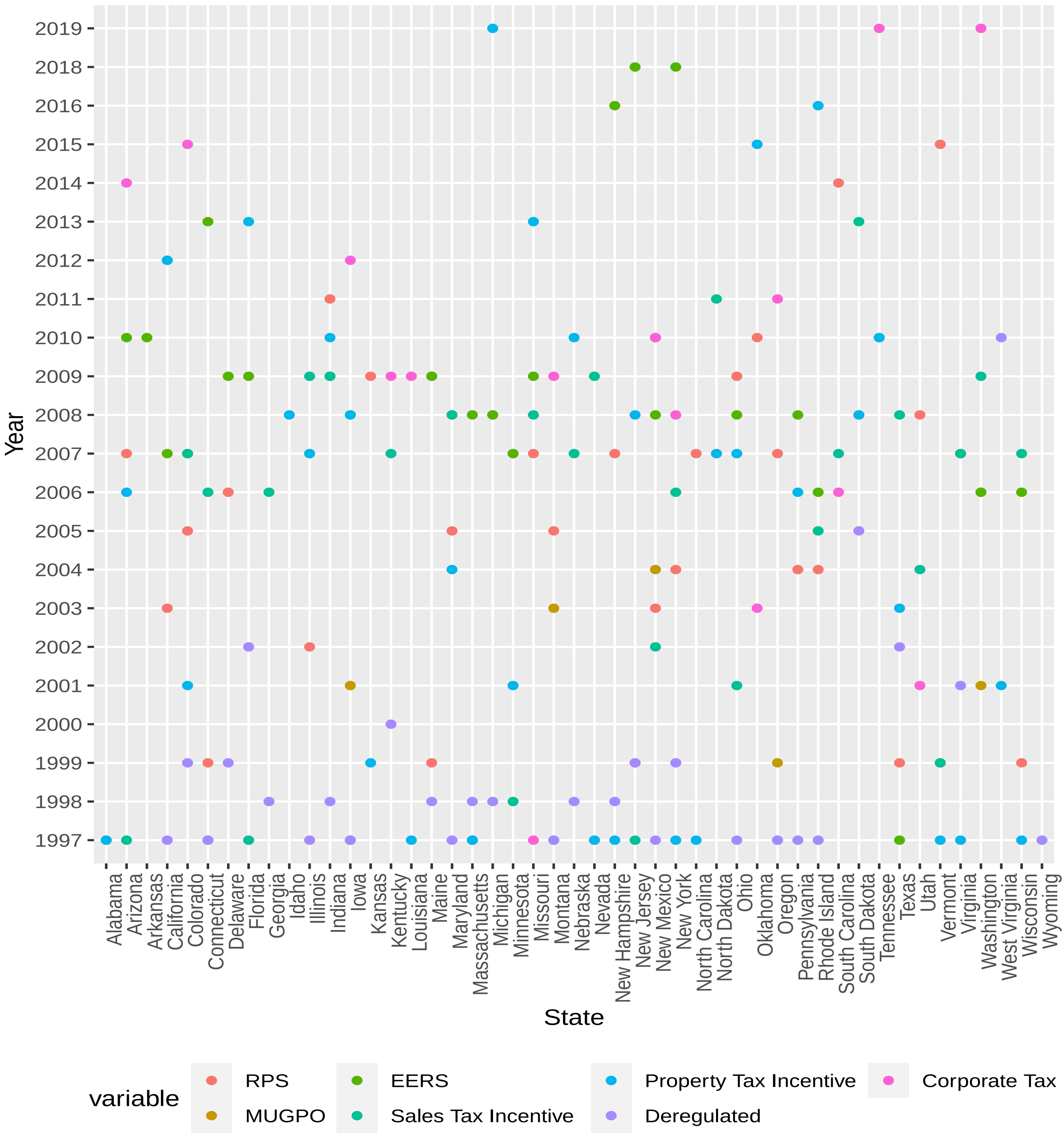

Figure 1: Timeline of adoption of policy instruments by state and year

or similar policy is adopted in a state or not. If RPS or any other forms of electricity portfolio standard is adopted(voluntary or mandatory) then it is coded as 1 from the start year and 0 for counties and years of non existence of the policy. *RPS_requirement* is the percentage of applicable retail electricity sales. These are regulations on load serving entities or utilities.

Data for RPS requirement is from Lawrence Berkeley National laboratory database (Barbose, 2021). There are 13 states [9] with RPS regulation where a waiver or subsidy based on the description given is allotted for low income counties. These low income counties need not achieve the requirements. To incorporate the county level variations, we collected the low income county data from the Federal Income Finance Agency and allotted 0% requirement for all the low income counties in those 13 states. The description of each of the RPS variables are given in appendix A.2.

4.2.2 Energy Efficiency Resource Standards (EERS)

EERS is a quantitative long term energy savings requirement.[10] This policy requires energy providers (electric and natural gas) to reduce energy sales, and spend a minimum percentage of their annual operating revenues on activities to advance energy efficiency, demand-side management and certain types of renewable energy. We adopt the National Database of State Incentives for Renewable Energy DSIRE (2022) definition of EERS, which categorizes a state's policy to be a "standard" when it meets a four-part criteria: (1) the policy was adopted by the state legislature or regulatory body, (2) the policy has a binding requirement, (3) the policy includes specific requirements for energy savings and (4) the policy set a schedule for meeting the requirements. Basing our variable on this criteria, a state is accorded 1 when all the four criteria are met, or else 0. If a state is otherwise categorized (e.g. as having a statewide goal as opposed to having a standard), it is because the state's policy did not meet at least one of the criterion. Of the 48 contiguous states and DC, about 51% states have mandated efficiency resource standards, out of which 10% states and DC have efficiency resource goals. Florida met its efficiency goals and has no EERS programs in place.

4.2.3 Mandatory Utility Green Power Option (MUGPO)

MUGPO requires electric utilities to provide customers the option to buy electricity produced either from the renewable energy sources or alternative green energy providers (Menz, 2005; Delmas and Montes-Sancho, 2011). Electric companies have the choice of either produc-

[9] CA, CO, CT, IL, MD, MA, MN, NH, NJ, NY, OR, RI, WA

[10] EERS policies are also known as Energy Efficiency Portfolio Standards (EEPS).

ing electricity themselves, sourcing electricity from alternative producers, or buying renewable energy credits from Public Utility Commission (PUC) to meet the demand. The underlying principal of MUGPO is consumers' willingness-to-pay for green products and availability of electricity generated from green options. This allows consumers to increase the demand for environment-friendly option as opposed to options that are perceived as environmentally detrimental. (Delmas and Montes-Sancho, 2011). Only 16% of the states have implemented the MUGPO as of 2019.

4.2.4 Deregulated Markets

In a deregulated energy market, generators sell electricity to a wholesale market, where it is purchased by retail suppliers to be sold to consumers. The electricity is distributed and operated through a grid, which is owned by transmission or utility company. Energy market deregulation or restructuring made electricity generation, operation and distribution competitive, which was earlier dominated by regulated integrated utilities (Woo et al., 2006). As a result, consumers benefit from competitive rates, choice between variety of suppliers and generation options.

As of 2022, 29 states or 60% states (Table 2) have deregulated electricity markets for residential, commercial and industrial consumers, while many states are still fully regulated, eliminating competition. States that have either partially or fully restructured energy markets are set equal to one, while states with fully regulated or deregulation terminated after a period are coded as zero. Regional Transmission Operators are developed in early 1990s in US to encourage competitiveness in the deregulated markets. Hence we also consider different RTOs as a control variable and described below.

4.2.5 Financial Incentives: State Tax Incentives, Property Tax Incentives and Corporate Tax Credit

State governments can use various types of financial incentives to encourage the use of renewable energy technologies. Financial incentives include sales tax incentives, property tax incentives and corporate tax credits. The presence of these incentives in any county are indicated by dummy variables, 1 if the incentive is available in any county and 0 otherwise. Information on the presence of these incentives are available in the DSIRE database.

Sales tax incentives provide partial or total sales tax relief to purchasers of renewable energy.

This is financial incentive provided by the state which makes the renewable energy systems investment less expensive. According to DSIRE (2022), the sales tax exemption could be allotted to systems that uses a particular quantity (in MW) of energy generated from renewable sources. Almost 64% of states have implemented sales tax incentive for purchasers of renewable energy.

While property tax incentive provides partial or total property tax relief to owners of the real properties where renewable energy is utilized, preventing an increase in property value assessment after installation of renewable energy (Sarzynski et al., 2012). Property taxes exempt the values added to property by the renewable energy generation installation and thus encouraging property owners to install more renewable energy sources. The exemption could be claimed for all residential, commercial, industrial or mixed use buildings if it develops any renewable energy systems to produce energy. By 2019, around 78% of states have property tax in place to support the installation of renewable energy.

Corporate Tax Credit or the renewable electricity production tax credit as it commonly known is a per kilowatt hour(kWh) federal tax credit included under section 45 of the U.S. tax code for electricity generated by qualified renewable energy resources (DSIRE, 2022; EPA, 2022) [11]. The generated electricity must be sold to earn the tax credit by the tax payer [12].Though this incentive is a federal policy, the date of enactment of this policy in each state is different. Hence,there is spatial and temporal variation in its implementation. We use a dummy variable to indicate the presence of this corporate tax credit from the start year in each state. Although, this is federal policy only 30% of the states have enacted this policy.

4.3 Control Variables

While empirically analysing the impact of multiple policy instruments we also intend to understand how the economic pressure variables relate to energy transition. According to Ohler (2015), the unemployment rate acts as a driving force for RE development. Meanwhile, there are several studies which have looked into the income per capita, natural gas price etc as predictors of RE generation (Ohler, 2015; Wei et al., 2010). Higher rates of unemployment and higher incomes

[11] The federal renewable electricity production tax credit (PTC) is an inflation-adjusted per-kilowatt-hour (kWh) tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year. The duration of the credit is 10 years after the date the facility is placed in service (DSIRE, 2022).

[12] Molly F. Sherlock, Joseph S. Hughes, 2020. CRS Report, *The Renewable Electricity Production Tax Credit: In Brief*

have been shown to be associated with more renewable energy consumption and adoption (Yin and Powers, 2010; Sadorsky, 2009; Prasad and Munch, 2012). The unemployment and per capita income (inflation adjusted to 2019) data are provided by US Bureau of Labor Statistics and American Community Survey, US Census Bureau, respectively. As the unemployment rate is the average of annual rate, the data doesn't include seasonal variation. For per capita income, we have manually adjusted for inflation based on 2019. Natural gas price is widely used in previous studies on renewable energy and policy instruments(Shrimali and Kniefel, 2011; Berry, 2005; Wiser and Bolinger, 2007).The state-level natural gas citygate price data is obtained from EIA.

Investment decisions in the renewable energy sector are also affected by economic policy uncertainty (EPU). We incorporate state-level EPU data which controls for any kind of socio-economic uncertainty that may occur. Data for EPU is from National Bureau of Economic Research [13] (Baker et al., 2022). We also take into account the regional transmission organizations (RTOs) which coordinate the electricity transmission at a regional level. Yu et al. (2022) accumulates evidence proving that the energy intensity which is a measure of the total primary energy per unit of GDP is a strong predictor of renewable energy development. To capture the effect of political influence on generation capacity of renewable source, we include political affiliation which is represented as county-level returns for presidential elections. The data for political affiliation is from Harvard dataverse[14] (Data and Lab, 2018).

The NREL Regional Energy Deployment System (ReEDS) has classified the wind potential in regions based on wind speeds. The wind speed categorization (1-10) is averaged based on wind speed for all years between 2001-2013 and ranges from 1.72 m/s to 12.89 m/s. Wind Speed class 1 being regions with high wind speed and hence high potential (MW). We have chosen the wind speed class 1(top 1% of all potential wind capacity), class 4(indicative of moderate speed and representative of majority of wind installation) and class 10 (least wind speed and hence lowest potential but highest percentile). Wind potential is measured in MW.

Solar potential (MWh/year) and energy intensity are the other control variables included in the study. Energy intensity is calculated as the ratio of total primary energy to GDP calculated annually.Yu et al. (2022) find that RE development has a negative impact on the energy intensity.

[13] https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/VOQCHQ

[14] https://www.policyuncertainty.com/

There exists differences in the impact in high development and low development regimes. To study the threshold effect of RE development on energy intensity, they use dynamic panel threshold regression model. As opposed to this study, we use energy intensity as a control variable while RE capacity remains our outcome variable.

Regional transmission organizations(RTO) ensure reliability and optimize the supply and demand in the wholesale electricity market. Hence, we also assess how different RTOs impact the RE generation capacity in the counties. RTOs were initiated in the early 1990s as Federal Energy Regulatory Commission's (FERC) policy to encourage competition in the market. There are seven RTOs [15] in the US. We use the RTOs to assess how these operators address the competitiveness in the county level RE generation. The base group that is being compared against is the counties which do not come under any RTO.

5 Results

We first present results from standard panel regression models with county and time-fixed effects to show the impact of policy instruments on renewable energy generation capacity. Next, we present results of Tobit model since the dependent variable of solar, wind, geothermal and hydro energy are left-censored. Lastly, we discuss results of spatial panel lag models with random effects due to spillover effects of policies of neighboring counties and states that may affect renewable energy generation capacity of a particular county.

5.1 Panel Models

The panel data estimation is for a balanced panel of 3017 observations for each year from 2009 to 2019. The dependent variable is renewable energy generation capacity measured in MW. The fixed effects model estimates the average effects of the explanatory variables on RE generation while controlling for any time-invariant differences across the panel units. In Table 3, the results of the fixed effects models are presented in columns (1), (2), and (3). However,the fixed effect model does not account for the time invariant factors due to we have included random-effects models, which the random effect models seem to explain the estimates better.

[15] CAISO = California Independent System Operator, ERCOT = Electric Reliability Council of Texas , ISONE = New England's Interconnection, MISO = Midwest Independent Transmission System Operator, NYISO = New York Independent System Operator, PJM = Pennsylvania-New Jersey-Maryland Interconnection SPP = Southwest Power Pool

The random effects model, presented in columns (5), (6), and (7), estimates the effects of the policy variables on the RE generation (the table with results including all the control variables are provided in the Appendix A.3). We perform Breush-Pagan (BP) test of homoscedasicity to check whether the variances across counties is zero. The chi-square value of 51.04 of Hausman-Wu test (Hausman, 1978) is significant, suggesting that fixed-effect model is better than random effects.

RPS requirement and RPS req in low-income counties have a positive significant impact on RE capacity, while mere presence of RPS policy in a state has no significant impact on RE generation capacity. This suggests that the positive effect of RPS sales requirement on RE is driven by the variation across panel units rather than the time-invariant differences across states.

The results show that the RPS req (columns 2 and 5) and RPS req in low income counties (column 3 and 6) has a positive effect on RE development in both fixed and random effects models. The RPS req variable also has a positive effect on RE development in all models, but the effect is much stronger in the random effects model. This suggests that the effect of RPS requirement on RE development is not constant over time.

MUGPO has a positive effect on RE development across both fixed and random-effects models. This suggests that the presence of municipal utilities that generate renewable energy is linked with higher levels of RE development. On the other hand, EERS has a mixed effect on RE development. It has a positive effect in the random effects model but a negative effect in the fixed effects model. This suggests that the effect of EERS on RE development is not constant over time and that it may be influenced by unobserved heterogeneity between states.

Financial incentives in the form of taxes play an important role in RE generation. Property taxes are negatively associated with RE development in all models, while the sales tax has a positive effect on RE. This suggests that different taxes may influence the adoption of renewable energy in different ways. Deregulation has a negative effect on RE development, implying that deregulation may be associated with lower levels of RE development.

Overall, the results suggest that RPS and MUGPO are important factors that affect RE across states in the US, even after controlling for other factors that may affect RE in each state. However, the effect of RPS may vary across panel units, while the effect of MUGPO is consistent across panel units.

Table 4 presents Tobit regression models for four types of renewable energy generation: wind, solar, geothermal, and hydro (the table with results including all the control variables are provided in the Appendix A.4). The models estimate the relationship between renewable energy generation and several factors, including Renewable Portfolio Standards (RPS), RPS requirement, the Market-Unit Gross Pool Operator (MUGPO), the Energy Efficiency Resource Standard (EERS), and Property Tax. The dependent variable is the amount of renewable energy generated, measured in gigawatt hours (MW). Columns (1) to (3) show the results for wind energy, with column (1) estimating the effect of RPS, column (2) estimating the effect of RPS requirement, and column (3) estimating the effect of RPS requirement in low income counties. The same suit is followed for solar, geothermal and hydro energy.

The coefficients for RPS in column (1) and RPS requirement in column (2) are both statistically significant at the 1% level, indicating that both policies have a positive effect on wind energy generation. The coefficient for RPS requirement in low-income counties in column (3) is also statistically significant at the 1% level, indicating that this policy has an even stronger positive effect on wind energy generation in low-income counties. Solar energy generation is inversely related to presence of stand-alone RPS policy, however, it is positively related to RPS requirement in any state or in low-income counties. This implies that setting of specific requirements will result in increased generation of solar energy. Similar is the case with geothermal energy, The coefficients for RPS requirement and RPS requirement in LI in columns (8) and(9) are statistically significant, indicating that irrespective of geographical administration - state or low-income counties such requirements/requirement are beneficial for geothermal energy generation. For hydro energy, the coefficients for RPS in column (10) to (12) RPS of any form (presence or requirement) is positively associated with hydro energy generation.

MUGPO is negative and statistically significant for hydro and geothermal, while positive and significant for wind energy generation. This implies that presence MUGPO policy in states is associated with lower levels of solar and geothermal generation, while higher levls of wing energy generation. On the contrast, taxes (both property and sales tax) have negative impact on hydro energy but positive for wind energy and solar. EERS has mixed results for energy generation.

Table 3: Panel models

Dependent variable: RE	Fixed			Random			Pooled		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RPS (1 = Yes)	3.992			5.530			38.719***		
	(4.714)			(4.383)			(4.034)		
RPS req		166.010***			174.478***			122.054***	
		(18.378)			(18.084)			(29.897)	
RPS req (LI)			163.747***			168.095***			−27.330
			(19.391)			(19.151)			(32.009)
MUGPO				51.644***	54.002***	51.235***	97.106***	93.781***	92.023***
				(14.983)	(14.996)	(14.987)	(5.415)	(5.411)	(5.402)
EERS	3.367	−15.670***	1.721	3.605	−14.036***	0.809	−0.223	6.743	13.572***
	(5.627)	(5.993)	(5.620)	(4.977)	(5.302)	(4.976)	(4.096)	(4.129)	(4.067)
Property tax	3.551	3.747	2.947	4.337	4.594	3.748	−45.276***	−37.420***	−36.176***
	(2.919)	(2.900)	(2.902)	(2.856)	(2.829)	(2.833)	(3.933)	(3.834)	(3.828)
Sales tax	18.684***	20.098***	19.241***	23.609***	25.251***	24.155***	28.820***	25.690***	23.508***
	(4.412)	(4.399)	(4.397)	(4.122)	(4.113)	(4.110)	(3.721)	(3.713)	(3.755)
Deregulated	−4.113	0.855	−0.027	−23.989***	−21.360***	−23.837***	−52.714***	−54.676***	−53.945***
	(12.808)	(12.801)	(12.801)	(8.060)	(8.062)	(8.056)	(3.635)	(3.638)	(3.648)
Constant				−17.489	20.529	7.295	254.581***	183.148**	166.664**
				(89.084)	(89.054)	(89.024)	(83.650)	(83.339)	(83.259)
Observations	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187

Note: #Variables are in log form. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors statistics in parentheses.

Table 4: Tobit models

Dependent variable	Wind			Solar			Geothermal			Hydro		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
RPS	7.886***			−2.459**			−0.199			7.891***		
	(2.198)			(1.248)			(0.379)			(2.284)		
RPS req		26.357***			62.565***			3.058**			29.735***	
		(9.803)			(6.950)			(1.543)			(9.229)	
RPS req (LI)			34.197***			77.937***			3.980**			22.514**
			(10.296)			(7.373)			(1.617)			(9.635)
MUGPO	11.786**	11.667**	11.367**	−11.758***	−10.594***	−10.939***	−5.811***	−5.775***	−5.838***	55.989***	56.371***	55.834***
	(5.289)	(5.299)	(5.298)	(1.962)	(1.960)	(1.959)	(1.712)	(1.712)	(1.713)	(12.793)	(12.802)	(12.749)
EERS	0.594	−0.574	0.939	−0.796	−5.468***	−4.089***	0.164	−0.164	0.103	−1.706	−4.742*	−1.859
	(2.411)	(2.545)	(2.402)	(1.281)	(1.312)	(1.258)	(0.440)	(0.468)	(0.440)	(2.678)	(2.846)	(2.680)
Property tax	6.175***	6.886***	6.730***	4.777***	4.023***	3.863***	0.162	0.139	0.120	−4.633***	−4.171***	−4.249***
	(1.517)	(1.502)	(1.503)	(1.020)	(1.000)	(1.000)	(0.242)	(0.241)	(0.241)	(1.443)	(1.435)	(1.437)
Sales tax	4.520**	4.399**	4.253**	9.022***	10.233***	10.455***	1.087***	1.135***	1.119***	−5.579***	−5.674***	−5.935***
	(2.074)	(2.075)	(2.071)	(1.158)	(1.157)	(1.157)	(0.357)	(0.357)	(0.356)	(2.156)	(2.155)	(2.153)
Deregulated	−1.678	−1.384	−1.735	−1.633	−1.681	−2.288*	0.830	0.874	0.845	−7.643	−7.161	−7.525
	(3.245)	(3.251)	(3.251)	(1.310)	(1.310)	(1.312)	(0.797)	(0.797)	(0.797)	(5.188)	(5.192)	(5.185)
Constant	−31.005	−30.625	−31.959	138.503***	161.222***	150.318***	−1.806	−1.083	−1.129	−45.677	−39.826	−42.379
	(44.593)	(44.647)	(44.607)	(25.356)	(25.325)	(25.271)	(7.876)	(7.879)	(7.876)	(48.116)	(48.152)	(48.150)
Observations	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187
F Statistic	536.176***	529.264***	533.733***	1,238.490***	1,316.474***	1,347.237***	240.744***	244.547***	246.657***	247.247***	245.545***	241.388***

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors statistics in parentheses.

Table 5: Result Interpretation

	Wind	Solar	Geothermal	Hydro
RPS	+	-		+
RPS req	+	+	+	+
RPS req (LI)	+	+	+	+
MUGPO		-	-	+
EERS		-		-
Sales Tax	+	+	+	-
Property Tax	+	+		-
Deregulated				
Corporate Tax	+	+		

Note: Blank spaces in the table indicate no statistically significant results

While Hitaj (2013) identified a positive impact of the presence of RTO regulation on the wind power development, we accounted for each of the RTOs in the US relative to the base group of no RTO counties and analyzed that the presence of any RTO in the corresponding regions is having a mixed impact on the energy sources. California ISO has generally positive significant impact on promoting energy development from all the individual renewable resources relative to the base group of no RTO counties. Whereas, ERCOT, NYISO, PJM, ISONE have negative impact on solar energy and positive impact on wind energy development. While, CAISO and NYISO have positive impact on hydro power, ISONE and ERCOT have negative impact relative to the base group.

Economic and political stability has a negative impact on the geothermal generation capacity while it does not have any impact on solar, wind and hydro. While Wind speed L1 which is the regions with the highest wind speed has positive impact on wind generation capacity, Wind speed L4, indicative of a moderate quality wind regime, is showing a negative impact. And Wind speed L10 with least speed has no impact on wind generation. And these results follow the standard and expected norms of electricity generation from wind power plants. Whereas, Wind speed L4 and Wind speed L10 have positive impacts on electricity generation capacity from solar and geothermal.

Table 5 below summarises the varying impacts of policies which are the main drivers of different sources of energy. Main results from Table 4 are that the RPS percent requirement has statistically significant impact on the total RE generation capacity and on the solar and geothermal generation capacity and no significant impact on wind and hydro electricity generation capacity. Considering the county level variation in the RPS policy, RPS requirement with low income consideration in counties also has positive significant impact on solar and geothermal and no impact on wind and hydro generation capacity.Whereas the presence of RPS policy has a positive significant impact on wind power generation capacity which goes with the finding by Menz and Vachon (2006) and Bird et al. (2005). As solar and wind energy deployed for more smaller units of buildings and electricity generation, the positive impact of property tax incentive seems to encourage the growth in the generation capacity (Shazmin et al., 2016). While, corporate tax is on the quantity of energy sold and solar energy being encouraged to be installed on more houses, corporate tax is showing a negative impact on solar energy. While it shows a positive significant impact on wind energy (Hitaj, 2013).

Over all significance of MUGPO on RE generation does show a positive impact. MUGPO, corporate tax and sales tax incentive are showing positive significant impact on the RE generation capacity.While property tax incentive , EERS and energy market deregulation show negative significant impact on RE.

Though, sale tax does not have a significant impact on wind energy and hydro, it shows a positive impact on solar and geothermal. Whereas, positive significant impact of the property tax specifically on wind energy confirms the findings of Shrimali et al. (2015). We add to the contribution in the literature by also finding positive significant impact of sales tax on the total RE generation capacity from the random effects model. Corporate tax has positive significant impact on wind in the tobit models and also show positive significant impact on total RE capacity ion the random effects and fixed effects models.

5.2 Spatial Panel Models

The results in Tables 6 to 8 present results of impact of various renewable policies on renewable energy generation capacity using spatial panel random effect models with the spatial lag of the dependent variable corresponding to different RPS variations. Using spatial panel model allows to account for space and time unobserved effects of RE in the regression specifications. We conduct global Moran's test to show the existence of a spatial effect in renewable energy generation between a county and it's neighbors. The Moran's I statistic of RE is 0.013 with a p-value < 0.001, suggesting detection of spatial dependency in the data set thus validating the spatial models. Further, a significant p-value of Lagrange Multiplier test verifies the appropriateness of spatial lag model (Breusch and Pagan, 1980).

Across the three tables (Table 6 to Table 8) columns (1)-(4) show the estimate, direct, indirect and total impacts of each explanatory variable of the model.Lambda value indicates the strength of spatial dependence. In other words, lambda represents the extent to which the dependent variable in neighboring areas are correlated[16]. The three tables differ from each other on the treatment of RPS. Table 6 show results RPS and other renewable policies as dummy variables. Table 7 accounts for the percentage of RPS requirement of retail electricity sales maintained by a state and Table 8 shows results of renewable policies in low-income counties.

5.2.1 RPS

In Table 6, columns (1)-(4) show that the RPS has no impact on renewable energy generation. The coefficient of RPS on estimate, direct, indirect and indirect is insignificant and therefore, on the total effect. These results are consistent with Carley (2009) who show that the presence of RPS does not necessarily translate into increase in the generation of state's renewable energy. However, the RPS requirement maintained by a state has a positive and significant effect on RE generation (Table 7). The coefficient of direct and indirect effects are similar, indicating that a 1 percentage point increase in RPS requirement within a state (direct effect) and its neighboring states (indirect or spillover effect) will increase the RE generation by 99 MW, on an average. In low-income counties (Table 8), the impact of indirect effect of RPS requirement on RE generation is greater than the impact of direct effect, indicating that RPS requirements of neighboring counties of low-income counties have a higher influence over RE generation than RPS requirement of a given county.

[16]In the impact assessment, a change in particular explanatory variable in a region has a direct impact on the same region and indirect impact of the neighbors on the RE generation. The estimate gives the average effect of an explanatory variable on the dependent variable when the spatial lag is controlled for (lambda). The direct impact captures the average change in the renewable energy generation capacity of a particular county caused by a unit change in the explanatory variable. Indirect impact can be interpreted as the aggregate impact on the RE generation capacity of a specific county of all neighboring counties for a unit change in the explanatory variable. Total effect is the sum of the direct and indirect impacts.

Table 6: Spatial panel lag with random effects for presence of renewable policies

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS	2.189	2.2417	2.3011	4.5428
	(4.193)	(4.8102)	(4.9175)	(9.7256)
MUGPO	35.868**	36.7296**	37.7018**	74.4314**
	(14.554)	(14.9306)	(15.4074)	(30.2998)
EERS	1.812	1.8559	1.9050	3.7609
	(4.771)	(4.9931)	(5.1350)	(10.1259)
Property tax	3.423	3.5052	3.5980	7.1032
	(2.723)	(2.5868)	(2.6592)	(5.2437)
Sales_tax_incentive	12.523***	12.8238***	13.1632***	25.9869***
	(3.947)	(4.0835)	(4.2192)	(8.2860)
Deregulated	-12.133	-12.4250	-12.7539	-25.1789
	(7.789)	(7.6076)	(7.8484)	(15.4474)
pop_est1000	0.123***	0.1259***	0.1292***	0.2551***
	(0.014)	(0.0136)	(0.0150)	(0.0282)
NG price	0.076	0.0777	0.0798	0.1575
	(0.659)	(0.6350)	(0.6563)	(1.2911)
EPU	0.035	0.0363*	0.0373*	0.0736 *
	(0.026)	(0.0226)	(0.0234)	(0.0460)
logIncome_Adj	-10.662	-10.9186	-11.2076	-22.1262
	(7.647)	(7.9278)	(8.2270)	(16.1463)
Unemp_rate	-2.351***	-2.4074***	-2.4711***	-4.8785***
	(0.309)	(0.3138)	(0.3405)	(0.6480)
Percent_DEMOCRAT	-0.063	-0.0648	-0.0665	-0.1313
	(0.121)	(0.115)	(0.1187)	(0.2337)
Energy_Intensity	-0.173**	-0.1769***	-0.1816***	-0.3586***
	(0.070)	(0.068)	(0.071)	(0.139)
log_solar_potential	0.659	0.6747	0.6926	1.3673
	(0.621)	(0.619)	(0.6366)	(1.255)
log_level_1	2.925*	2.9951	3.0744	6.0695
	(1.758)	(1.804)	(1.855)	(3.657)
log_level_4	-1.713	-1.7546	-1.8010	-3.5556
	(1.657)	(1.792)	(1.846)	(3.637)
log_level_10	0.001***	0.0005***	0.0005***	0.0011***
	(0.000)	(0.0002)	(0.0002)	(0.0003)
White_Percent	-3.758	-3.8486	-3.9504	-7.7990
	(23.628)	(25.7975)	(26.6404)	(52.4286)
Constant	132.420			
	(85.176)			
lambda	0.518***			
	(0.010)			

Note: K = 15. Simulated standard errors in parentheses for direct, indirect and total effects. Robust standard errors in parentheses for estimates. NG = Natural Gas, EPU = Economic and Political Unstability. $^{***}p<0.01$,$^{**}p<0.05$,$^{*}p<0.1$

Table 7: Spatial Panel lag with Random Effects with RPS requirement and other policies

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS req	97.5200***	99.811***	100.682***	200.493***
	(17.293)	(18.874)	(19.83)	(38.507)
MUGPO	37.4500	38.330***	38.665***	76.995***
	(14.558)	(13.868)	(14.157)	(27.976)
EERS	-8.0452	-8.234*	-8.306	-16.540*
	(5.082)	(5.159)	(5.246)	(10.399)
Property tax	3.5066	3.589	3.620	7.209
	(2.7011)	(2.638)	(2.696)	(5.331)
Sales_tax	13.5860***	13.905***	14.026***	27.932 ***
	(3.942)	(3.972)	(4.026)	(7.977)
Deregulated	-10.8050	-11.059	-11.155	-22.214
	(7.792)	(7.431)	(7.520)	(14.939)
pop_est1000	0.1227***	0.126***	0.127***	0.252***
	(0.0139)	(0.015)	(0.016)	(0.030)
NG price	0.2476	0.253	0.256	0.509
	(0.6595)	(0.678)	(0.691)	(1.369)
EPU	0.0379	0.039	0.039	0.078
	(0.0255)	(0.025)	(0.025)	(0.050)
log_Income	-13.8250*	-14.149**	-14.273**	-28.423**
	(7.6646)	(7.453)	(7.574)	(15.014)
Unemployment_rate	-2.0147***	-2.062***	-2.080***	-4.142 ***
	(0.3142)	(0.323)	(0.337)	(0.654)
Democrat (%)	0.0068	0.007	0.007	0.014
	(0.1211)	(0.120)	(0.122)	(0.242)
Energy_Intensity	-0.1738***	-0.178***	-0.179***	-0.357***
	(0.0696)	(0.066)	(0.066)	(0.132)
log_solar_potential	0.6682	0.684	0.690	1.374
	(0.6205)	(0.637)	(0.638)	(1.274)
log_Wind speed L1	2.8182	2.884	2.910	5.794
	(1.7554)	(1.912)	(1.954)	(3.864)
log_Wind speed L4	-1.5459	-1.582	-1.596	-3.178
	(1.6487)	(1.778)	(1.808)	(3.584)
log_Wind speed L10	0.0004***	0.000***	0.000***	0.001***
	(0.0002)	(0.000)	(0.000)	(0.000)
White (%)	5.7099	5.844	5.895	11.739
	(23.6270)	(24.945)	(25.109)	(50.045)
Constant	153.7300 *			
	(85.233)			
lambda	0.5136 ***			
	(0.0100)			

Note: K = 15. Simulated standard errors in parentheses for direct, indirect and total effects. Robust standard errors in parentheses for estimates. NG = Natural Gas, EPU = Economic and Political Unstability. ***p<0.01,**p<0.05,*p<0.1

5.2.2 Other policies

Effect estimates of other policies and incentives are as follows. The coefficient of MUGPO is positive and significant across the three tables (Table 6 to Table 8). These results are consistent with Bowen and Lacombe (2017) who also find that the RE generation goes up with mandatory green power laws in place. Sales tax is an important financial incentive that contributes in increasing the RE generation, however, the indirect effect is slightly more than the direct effect on renewable energy. Rest of the policies and incentives including EERS, Corporate tax and Deregulated markets have no impact on the generation of renewable energy.

6 Conclusion

In this paper, we conduct non-spatial and spatial analysis of the impact of policy instruments on the renewable energy generation capacity and also on each of the renewable resources such as solar, wind, geothermal and hydro. We use a panel data of 3017 counties for a period 11 years (2009 to 2019). We first panel random effect models take into account the possible spatial correlation that occurs between neighbouring counties on the overall RE generation capacity.

Results of this study show presence of policies - RPS, MUGPO and financial incentives like sales tax are effective for increasing RE generation in states. When we account for county level variation by considering presence of subsidies RPS regulation with a waiver or subsidy allotted for low income counties, we find that RPS requirements positively affect the generation of RE. When comparing the role of policy or an incentive to support renewable energy, our results show that policies including RPS and MUGPO have a higher total effect on the RE generation than a financial incentive (sales tax). This could be because RPS and MUGPO may have a more structured approach as compared to Sales tax incentive. Sales tax incentives are structured to reduce only a portion or full sales tax exemption for goods that are related to renewable energy projects (Couture and Cory, 2009). This is an important finding for policymakers, signalling the appropriate tool that can be used to increase the share of RE in a given region.

Our results account for the spatial dependence which is missing in previous studies, thus help in making very informed decisions about the policies that we addressed. Thus, our findings propose policy implications on renewable energy generation capacity based on different state and federal level policies which could be informative for both the policy makers and academia. Our study also helps in assessing how each of the different policies impact specific renewable energy resources. This helps by making policy more specific to regions that support individual renewable resources. Also,we show that the RPS policies with state level requirements and county level variations have direct effect in the same county as well as indirect or spill over effects from neighboring counties on the total renewable generation capacity irrespective of which renewable resource is used. Sales tax incentive and MUGPO existing in a county and its neighboring counties promotes RE generation capacity. RPS requirement with county level variation in the neighboring counties promotes RE capacity in the same county as well. Hence, we can conclude that there is spillover effects of policies implemented in neighboring counties promoting more RE generation capacity.

The body of literature that employs spatial econometric analysis to determine the renewable energy policy impacts between and across counties is still limited. In this paper, we address county-level variations and direct and indirect impact of policies on RE capacity which gives a better glimpse of the effectiveness of policies considering the spatial dependency. Moreover, more careful interpretation of the results of each policy on specific renewable resources is needed as each policy has different level of impacts on each of the resources based on the differences in implementation. As the importance of the renewable energy increases, our study will be critical for the policy makers and academia in helping to understand the link between policy and implementation on a county level basis.

Although we have addressed many crucial concerns that were missing in previous studies, it is important to acknowledge the limitations of this paper. First, we have used the state level policy data for county level analysis for all the policies except for RPS requirements with county level variation. Also, for RPS requirements with county level variation, we assumed zero for the counties with any kind of subsidy as we couldn't get the subsidised sales requirements for those counties. Second, Solar potential data are interpolated for a period of two years between every 4 years as the data was available for 4 year intervals. Utility level RTO data from EPA is also available for every alternative year. Hence, we used the previous year data for every other year. Third, state and local zoning laws can play a significant role in facilitating or prohibiting the renewable energy generation. We considered few of the state level policies in the study. Although local governments recognize the importance of promoting renewable energy as a means of addressing climate change, our study was unable to address the impact of local zoning laws on renewable energy deployment due to lack of available data.Further, we can extend the scope of the paper by addressing the zoning laws and its impact on RE generation. Also, we can consider local economic impacts on RE generation. These would provide the policy makers with a more comprehensive understanding of the benefits of RE generation.

Table 8: Spatial panel lag with random effects for low-income RPS counties and other policies

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS req LI	93.287***	95.486***	96.585***	192.071***
	(18.330)	(18.749)	(19.364)	(37.891)
MUGPO	35.848**	36.69357***	37.11587***	73.80943***
	(14.555)	(13.760)	(13.779)	(27.493)
EERS	0.264	0.27030	0.27342	0.54372
	(4.774)	(4.726)	(4.784)	(9.508)
Property tax	3.047	3.11840	3.15429	6.27269
	(2.704)	(2.647)	(2.656)	(5.300)
Sales tax	12.952***	13.2568***	13.4094***	26.6662***
	(3.939)	(4.127)	(4.268)	(8.375)
Deregulated	-12.151	-12.43757	-12.5807	-25.01828
	(7.788)	(8.020)	(8.170)	(16.179)
Population	0.122***	0.12522***	0.12666***	0.25189***
	(0.014)	(0.016)	(0.017)	(0.033)
NG price	0.301	0.30780	0.31135	0.61915
	(0.660)	(0.707)	(0.715)	(1.422)
EPU	0.034	0.035	0.036	0.071
	(0.026)	(0.030)	(0.030)	(0.060)
log_Income	-12.546	-12.8414*	-12.9892*	-25.8305
	(7.652)	(7.318)	(7.546)	(14.851)
Unemployment	-2.122***	-2.1716***	-2.1966***	-4.3682***
	(0.312)	(0.282)	(0.3073)	(0.583)
Democrat(%)	-0.022	-0.02229	-0.02254	-0.04483
	(0.121)	(0.1203)	(0.1216)	(0.2418)
Energy_Intensity	-0.178**	-0.1826***	-0.1847***	-0.367***
	(0.070)	(0.067)	(0.068)	(0.1348)
log_Solar potential	0.676	0.6918	0.6998	1.3916
	(0.620)	(0.610)	(0.6279)	(1.2378)
log_Wind speed L1	3.180*	3.2552*	3.2927*	6.5479 *
	(1.756)	(1.684)	(1.729)	(3.4098)
log_Wind speed L4	-1.898	-1.9432	-1.9655	-3.9087
	(1.649)	(1.5627)	(1.597)	(3.158)
log_Wind speed L10	0.00044***	0.00045***	0.00045***	0.00090***
	(0.000)	(0.0001)	(0.0002)	(0.0003)
White(%)	-0.478	-0.4894	-0.495	-0.9844
	(23.581)	(26.4381)	(26.823)	(53.2512)
Constant	146.280 *			
	(85.193)			
lambda	0.514 ***			
	(0.010)			

Note: K = 15. Simulated standard errors in parentheses for direct, indirect and total effects. Robust standard errors in parentheses for estimates. NG = Natural Gas, EPU = Economic and Political Unstability. LI = Low-income. ***p<0.01,**p<0.05,*p<0.1

References

Amore, M. D. and Murtinu, S. (2021). Tobit models in strategy research: Critical issues and applications. *Global Strategy Journal*, 11(3):331–355.

Anselin, L. (1988). *Spatial econometrics: methods and models*, volume 4. Springer Science & Business Media.

Baker, S. R., Davis, S. J., and Levy, J. A. (2022). State-level economic policy uncertainty. Working Paper 29714, National Bureau of Economic Research.

Barbose, G. (2021). Us renewables portfolio standards 2021 status update: Early release. lawrence berkeley national laboratory.

Berry, D. (2005). Renewable energy as a natural gas price hedge: the case of wind. *Energy Policy*, 33(6):799–807.

Bhattacharjee, A. and Holly, S. (2011). Structural interactions in spatial panels. *Empirical Economics*, 40(1):69–94.

Bird, L., Bolinger, M., Gagliano, T., Wiser, R., Brown, M., and Parsons, B. (2005). Policies and market factors driving wind power development in the united states. *Energy Policy*, 33(11):1397–1407.

Bivand, R., Müller, W. G., and Reder, M. (2009). Power calculations for global and local moran's i. *Computational Statistics & Data Analysis*, 53(8):2859–2872.

Bowen, E. and Lacombe, D. J. (2017). Spatial dependence in state renewable policy: Effects of renewable portfolio standards on renewable generation within nerc regions. *The Energy Journal*, Volume 38(Number 3).

Breusch, T. S. and Pagan, A. R. (1980). The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. *Review of Economic Studies*, 47(1):239–253.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy policy*, 37(8):3071–3081.

Charlier, D., Risch, A., and Salmon, C. (2018). Energy burden alleviation and greenhouse gas emissions reduction: Can we reach two objectives with one policy? *Ecological Economics*, 143:294–313.

Couture, T. and Cory, K. (2009). State clean energy policies analysis (scepa) project: An analysis of renewable energy feed-in tariffs in the united states (revised). Technical report, National Renewable Energy Lab.(NREL), Golden, CO (United States).

Data, M. E. and Lab, S. (2018). County Presidential Election Returns 2000-2020.

Delmas, M. A. and Montes-Sancho, M. J. (2011). Us state policies for renewable energy: Context and effectiveness. *Energy Policy*, 39(5):2273–2288.

DSIRE (2022). Database of state incentives for renewables and efficiency.

Engel, K. H. and Orbach, B. Y. (2008). Micro-motives and state and local climate change initiatives. *Harv. L. & Pol'y Rev.*, 2:119.

EPA, L. M. O. P. (2022). Renewable electricity production tax credit information.

Fix, E. and Hodges, J. L. (1989). Discriminatory analysis. nonparametric discrimination: Consistency properties. *International Statistical Review/Revue Internationale de Statistique*, 57(3):238–247.

Hausman, J. A. (1978). Specification tests in econometrics. *Econometrica: Journal of the econometric society*, pages 1251–1271.

Hechenbichler, K. and Schliep, K. (2004). Weighted k-nearest-neighbor techniques and ordinal classification.

Hitaj, C. (2013). Wind power development in the united states. *Journal of Environmental Economics and Management*, 65(3):394–410.

Huang, M.-Y., Alavalapati, J. R., Carter, D. R., and Langholtz, M. H. (2007). Is the choice of renewable portfolio standards random? *Energy Policy*, 35(11):5571–5575.

Jin, F. and Lee, L.-f. (2015). On the bootstrap for moran's i test for spatial dependence. *Journal of Econometrics*, 184(2):295–314.

LeSage, J. and Pace, R. K. (2009). *Introduction to spatial econometrics*. Chapman and Hall/CRC.

LeSage, J. P. (2014). What regional scientists need to know about spatial econometrics. *Available at SSRN 2420725*.

Lyon, T. P. and Yin, H. (2010). Why do states adopt renewable portfolio standards?: An empirical investigation. *The Energy Journal*, 31(3).

Menyah, K. and Wolde-Rufael, Y. (2010). Co2 emissions, nuclear energy, renewable energy and economic growth in the us. *Energy Policy*, 38(6):2911–2915.

Menz, F. C. (2005). Green electricity policies in the united states: case study. *Energy Policy*, 33(18):2398–2410.

Menz, F. C. and Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: Experiences from the states. *Energy policy*, 34(14):1786–1796.

Ohler, A. M. (2015). Factors affecting the rise of renewable energy in the us: Concern over environmental quality or rising unemployment? *The Energy Journal*, 36(2).

Prasad, M. and Munch, S. (2012). State-level renewable electricity policies and reductions in carbon emissions. *Energy Policy*, 45:237–242.

Sadorsky, P. (2009). Renewable energy consumption, co2 emissions and oil prices in the g7 countries. *Energy Economics*, 31(3):456–462.

Sarzynski, A., Larrieu, J., and Shrimali, G. (2012). The impact of state financial incentives on market deployment of solar technology. *Energy Policy*, 46:550–557.

Shazmin, S., Sipan, I., and Sapri, M. (2016). Property tax assessment incentives for green building: A review. *Renewable and Sustainable Energy Reviews*, 60:536–548.

Shrimali, G. and Kniefel, J. (2011). Are government policies effective in promoting deployment of renewable electricity resources? *Energy Policy*, 39(9):4726–4741.

Shrimali, G., Lynes, M., and Indvik, J. (2015). Wind energy deployment in the us: An empirical analysis of the role of federal and state policies. *Renewable and Sustainable Energy Reviews*, 43:796–806.

Wei, M., Patadia, S., and Kammen, D. M. (2010). Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the us? *Energy policy*, 38(2):919–931.

Wiser, R. and Bolinger, M. (2007). Can deployment of renewable energy put downward pressure on natural gas prices? *Energy Policy*, 35(1):295–306.

Wiser, R. H. and Barbose, G. L. (2008). Renewable portfolio standards in the united states: A status report with data through 2007. Technical report, LBNL, Berkeley.

Woo, C.-K., King, M., Tishler, A., and Chow, L. (2006). Costs of electricity deregulation. *Energy*, 31(6-7):747–768.

Wooldridge, J. M. (2002). Econometric analysis of cross section and panel data mit press. *Cambridge, MA*, 108(2):245–254.

Yin, H. and Powers, N. (2010). Do state renewable portfolio standards promote in-state renewable generation . *Energy Policy*, 38(2):1140–1149.

Yu, S., Liu, J., Hu, X., and Tian, P. (2022). Does development of renewable energy reduce energy intensity? evidence from 82 countries. *Technological Forecasting and Social Change*, 174:121254.

Zhao, Z.-Y. and Chen, Y.-L. (2018). Critical factors affecting the development of renewable energy power generation: Evidence from china. *Journal of Cleaner Production*, 184:466–480.

A Appendix

A.1 Variable Description

Table 9: Data, description and sources

Variable	Description	Units	Source
Dependent Variables			
RE production capacity	Total annual renewable (solar, wind, geothermal and hydro) energy production	MW	EIA
Economic Pressure Variables			
Energy consumption	Total annual energy consumption	Billion Btu	SEDS,EIA
NG price	Natural Gas Citygate Price(Annual)	Dollars per Thousand Cubic Feet	EIA
Unemployment rate	Ratio of unemployed persons to labor force(Annual Average)	%	BLS
Per capita Personal Income	inflation adjusted for 2019	Dollar	BEA
GDP	Real GDP in chained Dollars by county	Dollar	BEA
Environmental Pressure Variables			
RPS target	Renewable portfolio standard target	% target	Dsire
MUGPO	Mandatory Utility Green Power Option	Yes = 1	Dsire
Deregulated	Energy markets have the power to switch to another energy provider	Deregulation = 1	https://www.electricchoice.com/map-deregulated\-energy-markets/
Sale tax incentive	Financial Incentive	Yes = 1	Dsire
Property tax incentive	Financial Incentive	Yes = 1	Dsire
EERS	Energy efficient resource standards	Yes = 1	Dsire
Wind potential	Wind Capacity Potential at 80 meters for Wind Classes based on Wind Speed (miles/sec)- Classes 1,4 & 10 are used	MW	https://atb.nrel.gov/electricity/2021/land-based_wind
Solar potential	Solar Energy generation potential	MWh/year	Webber Energy Group
Democrat	Percentage of democrats to total presidential votes	%	Harvard dataverse
RTO	Regional Transmission Organization - all 7 RTOs as dummy variable	Yes = 1	EPA
Demographic Variables			
Population	Population estimate	Total number	Census

A.2 RPS variations and description

Table 10: RPS description

Policy	Description
RPS_*dummy*	coded 1 for every county in states with either voluntary or mandatory RPS policy in place
RPS_req	Sales target percentage for every county in states with mandatory targets. States with voluntary targets are allocated 0% in the dataset
RPS_req_LI	13 of the states in the study provide low income subsidy or waiver to low income counties. We incorporated low income data from Federal Income Finance Agency and allocated zero for low income counties in those 13 states and for the rest of the counties the mandatory target percentages are allocated based on the dataset

A.3 LM Test

	statistic.LMerr	parameter.df	p.value
LMerr	2176.03	1.00	$<2.2e^{-16}$
LMlag	2267.50	1.00	$<2.2e^{-16}$
RLMerr	31.71	1.00	$<1.902e^{-096}$
RLMlag	123.17	1.00	$<2.2e^{-16}$
SARMA	2299.21	2.00	$<2.2e^{-16}$

A.4 OLS Results

	Dependent variable: RE								
	Fixed			Random			Pooled		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RPS (1 = Yes)	3.992			5.530			38.719***		
	(4.714)			(4.383)			(4.034)		
RPS req		166.010***			174.478***			122.054***	
		(18.378)			(18.084)			(29.897)	
RPS req (LI)			163.747***			168.095***			−27.330
			(19.391)			(19.151)			(32.009)
MUGPO				51.644***	54.002***	51.235***	97.106***	93.781***	92.023***
				(14.983)	(14.996)	(14.987)	(5.415)	(5.411)	(5.402)
EERS	3.367	−15.670***	1.721	3.605	−14.036***	0.809	−0.223	6.743	13.572***
	(5.627)	(5.993)	(5.620)	(4.977)	(5.302)	(4.976)	(4.096)	(4.129)	(4.067)
Property tax	3.551	3.747	2.947	4.337	4.594	3.748	−45.276***	−37.420***	−36.176***
	(2.919)	(2.900)	(2.902)	(2.856)	(2.829)	(2.833)	(3.933)	(3.834)	(3.828)
Sales tax	18.684***	20.098***	19.241***	23.609***	25.251***	24.155***	28.820***	25.690***	23.508***
	(4.412)	(4.399)	(4.397)	(4.122)	(4.113)	(4.110)	(3.721)	(3.713)	(3.755)
Deregulated	−4.113	0.855	−0.027	−23.989***	−21.360***	−23.837***	−52.714***	−54.676***	−53.945***
	(12.808)	(12.801)	(12.801)	(8.060)	(8.062)	(8.056)	(3.635)	(3.638)	(3.648)
Population (1000s)	1.094***	1.079***	1.085***	0.159***	0.158***	0.157***	0.072***	0.072***	0.072***
	(0.047)	(0.047)	(0.047)	(0.014)	(0.014)	(0.014)	(0.005)	(0.005)	(0.005)
NG Price	0.445	0.776	0.881	−0.084	0.236	0.324	5.369***	6.304***	6.144***
	(0.711)	(0.710)	(0.711)	(0.693)	(0.693)	(0.694)	(1.180)	(1.178)	(1.184)
EPU	0.115***	0.118***	0.112***	0.082***	0.085***	0.079***	−0.188***	−0.253***	−0.236***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.062)	(0.062)	(0.062)
log$_{I}ncome$	1.780	−3.377	−1.658	5.119	−0.549	1.743	−20.725***	−15.015*	−13.306*
	(8.516)	(8.524)	(8.515)	(8.006)	(8.015)	(8.003)	(7.943)	(7.925)	(7.917)
(RTO)CAISO	−50.155***	−48.541***	−48.231***	−42.914***	−41.960***	−42.729***	226.771***	216.432***	227.614***
	(13.758)	(13.740)	(13.743)	(13.387)	(13.368)	(13.371)	(15.992)	(16.153)	(16.259)
(RTO)ERCOT	35.089***	34.973***	34.739***	37.560***	37.774***	37.066***	112.737***	116.294***	116.542***
	(6.436)	(6.427)	(6.428)	(6.356)	(6.346)	(6.348)	(9.381)	(9.385)	(9.392)
(RTO)ISONE	−5.162	0.967	−0.050	−3.322	−1.554	−1.825	28.123**	14.299	33.176***
	(14.415)	(14.412)	(14.411)	(13.448)	(13.431)	(13.434)	(12.079)	(12.709)	(12.561)
(RTO)MISO	1.482	3.372	2.518	2.413	4.374	3.430	21.771***	25.181***	26.485***
	(3.589)	(3.587)	(3.584)	(3.532)	(3.526)	(3.524)	(5.054)	(5.046)	(5.037)
(RTO)NYISO	7.976	6.395	7.749	10.366	7.600	10.391	67.042***	76.373***	80.915***
	(13.572)	(13.555)	(13.556)	(12.913)	(12.897)	(12.897)	(12.742)	(12.721)	(12.686)
(RTO)PJM	5.460	5.316	5.174	3.447	3.480	3.213	5.618	7.344	7.303
	(4.315)	(4.305)	(4.306)	(4.244)	(4.236)	(4.238)	(6.094)	(6.098)	(6.102)
(RTO)SPP	−24.305***	−24.793***	−24.761***	−24.274***	−24.699***	−24.605***	3.227	3.667	1.930
	(3.660)	(3.656)	(3.656)	(3.661)	(3.656)	(3.657)	(7.586)	(7.603)	(7.600)
Unemployment Rate	−3.342***	−2.773***	−2.934***	−4.116***	−3.486***	−3.683***	−0.943	−0.527	−0.944
	(0.328)	(0.332)	(0.330)	(0.323)	(0.329)	(0.326)	(0.653)	(0.660)	(0.656)
Democrat (%)	−0.153	−0.016	−0.065	0.072	0.197	0.146	−1.091***	−0.970***	−0.939***
	(0.134)	(0.135)	(0.134)	(0.126)	(0.126)	(0.126)	(0.146)	(0.146)	(0.146)
Energy_Intensity	0.093	0.084	0.081	0.076	0.070	0.063	−0.077	−0.048	−0.041
	(0.077)	(0.077)	(0.077)	(0.073)	(0.073)	(0.073)	(0.067)	(0.067)	(0.067)
log_Solar potential				0.348	0.370	0.384	1.592***	1.645***	1.629***
				(0.636)	(0.636)	(0.636)	(0.207)	(0.207)	(0.207)
log_Wind speed L1				4.422**	4.231**	4.860***	8.524***	8.286***	8.118***
				(1.806)	(1.804)	(1.804)	(0.715)	(0.715)	(0.722)
log_Wind speed L4				−2.561	−2.230	−2.845*	−7.067***	−6.113***	−5.930***
				(1.702)	(1.694)	(1.694)	(0.630)	(0.622)	(0.629)
log_Wind speed L10				0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
				(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
White (%)	−83.441**	−64.429*	−74.063*	−15.141	2.431	−8.556	35.793***	51.126***	50.763***
	(39.127)	(39.129)	(39.095)	(24.433)	(24.426)	(24.374)	(13.085)	(13.009)	(13.012)
Constant				−17.489	20.529	7.295	254.581***	183.148**	166.664**
				(89.084)	(89.054)	(89.024)	(83.650)	(83.339)	(83.259)
Observations	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187

Note: * (p<0.1), ** (p<0.05), *** (p<0.01). Robust standard errors statistics in parentheses.

A.5 Tobit Model Results

Table 11: Tobit models

	Dependent variable											
	Wind			Solar			Geothermal			Hydro		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
RPS	7.886***			−2.459**			−0.199			7.891***		
	(2.198)			(1.248)			(0.379)			(2.284)		
RPS req		26.357***			62.565***			3.058**			29.735***	
		(9.803)			(6.950)			(1.543)			(9.229)	
RPS req (LI)			34.197***			77.937***			3.980**			22.514**
			(10.296)			(7.373)			(1.617)			(9.635)
MUGPO	11.786**	11.667**	11.367**	−11.758***	−10.594***	−10.939***	−5.811***	−5.775***	−5.838***	55.989***	56.371***	55.834***
	(5.289)	(5.299)	(5.298)	(1.962)	(1.960)	(1.959)	(1.712)	(1.712)	(1.713)	(12.793)	(12.802)	(12.749)
EERS	0.594	−0.574	0.939	−0.796	−5.468***	−4.089***	0.164	−0.164	0.103	−1.706	−4.742*	−1.859
	(2.411)	(2.545)	(2.402)	(1.281)	(1.312)	(1.258)	(0.440)	(0.468)	(0.440)	(2.678)	(2.846)	(2.680)
Property tax	6.175***	6.886***	6.730***	4.777***	4.023***	3.863***	0.162	0.139	0.120	−4.633***	−4.171***	−4.249***
	(1.517)	(1.502)	(1.503)	(1.020)	(1.000)	(1.000)	(0.242)	(0.241)	(0.241)	(1.443)	(1.435)	(1.437)
Sales tax	4.520**	4.399**	4.253**	9.022***	10.233***	10.455***	1.087***	1.135***	1.119***	−5.579***	−5.674***	−5.935***
	(2.074)	(2.075)	(2.071)	(1.158)	(1.157)	(1.157)	(0.357)	(0.357)	(0.356)	(2.156)	(2.155)	(2.153)
Deregulated	−1.678	−1.384	−1.735	−1.633	−1.681	−2.288*	0.830	0.874	0.845	−7.643	−7.161	−7.525
	(3.245)	(3.251)	(3.251)	(1.310)	(1.310)	(1.312)	(0.797)	(0.797)	(0.797)	(5.188)	(5.192)	(5.185)
Population (1000s)	−0.003	−0.003	−0.003	0.037***	0.037***	0.037***	−0.002	−0.002	−0.002	0.071***	0.071***	0.071***
	(0.005)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.011)	(0.011)	(0.011)
NG Price	−1.101**	−1.171**	−1.061**	3.391***	3.211***	3.450***	0.001	0.005	0.012	0.694	0.604	0.668
	(0.480)	(0.480)	(0.481)	(0.321)	(0.317)	(0.319)	(0.073)	(0.072)	(0.072)	(0.481)	(0.481)	(0.482)
EPU	0.025	0.026	0.024	−0.052***	−0.048***	−0.051***	−0.001	−0.001	−0.001	0.004	0.005	0.003
	(0.016)	(0.016)	(0.016)	(0.012)	(0.012)	(0.012)	(0.002)	(0.002)	(0.002)	(0.015)	(0.015)	(0.015)
log_Income	4.166	4.065	4.165	−16.436***	−18.488***	−17.519***	−0.117	−0.229	−0.217	4.956	4.453	4.793
	(4.151)	(4.159)	(4.153)	(2.391)	(2.391)	(2.385)	(0.701)	(0.702)	(0.701)	(4.258)	(4.264)	(4.263)
(RTO)CAISO	14.274**	14.163**	13.866**	13.300***	11.032**	9.249**	11.746***	11.763***	11.763***	−50.447***	−50.230***	−50.245***
	(6.997)	(6.998)	(6.999)	(4.471)	(4.476)	(4.485)	(1.133)	(1.133)	(1.133)	(6.751)	(6.751)	(6.754)
(RTO)ERCOT	42.717***	42.862***	42.637***	−1.101	−0.900	−1.651	−0.046	−0.045	−0.057	−0.844	−0.842	−0.917
	(3.392)	(3.392)	(3.392)	(2.344)	(2.342)	(2.341)	(0.536)	(0.536)	(0.536)	(3.188)	(3.188)	(3.190)
(RTO)ISONE	−1.890	−2.010	−2.088	−6.929*	−12.209***	−12.379***	0.193	0.251	0.258	0.892	1.611	1.349
	(6.707)	(6.712)	(6.711)	(3.741)	(3.785)	(3.774)	(1.161)	(1.161)	(1.161)	(6.976)	(6.980)	(6.981)
(RTO)MISO	5.673***	6.326***	6.209***	0.560	0.436	0.523	−0.034	−0.013	−0.024	−1.726	−1.122	−1.326
	(1.886)	(1.885)	(1.883)	(1.284)	(1.279)	(1.279)	(0.299)	(0.299)	(0.299)	(1.785)	(1.786)	(1.785)
(RTO)NYISO	8.131	8.436	8.924	−18.865***	−20.976***	−19.370***	−0.052	−0.096	−0.062	0.792	0.660	0.971
	(6.570)	(6.572)	(6.569)	(3.852)	(3.841)	(3.837)	(1.105)	(1.105)	(1.105)	(6.614)	(6.615)	(6.617)
(RTO)PJM	4.963**	4.962**	4.903**	−2.784*	−2.599*	−2.540*	−0.094	−0.086	−0.092	−1.244	−1.490	−1.532
	(2.257)	(2.257)	(2.257)	(1.542)	(1.541)	(1.541)	(0.358)	(0.358)	(0.358)	(2.133)	(2.132)	(2.133)
(RTO)SPP	−17.079***	−17.421***	−17.304***	3.526**	3.049**	3.227**	0.112	0.088	0.091	1.738	1.417	1.584
	(2.031)	(2.032)	(2.031)	(1.542)	(1.540)	(1.540)	(0.311)	(0.311)	(0.311)	(1.863)	(1.865)	(1.865)
Unemployment	1.997***	1.944***	1.985***	−1.645***	−1.624***	−1.586***	−0.091***	−0.082**	−0.081**	−0.383*	−0.431*	−0.433*
	(0.236)	(0.235)	(0.235)	(0.172)	(0.170)	(0.171)	(0.034)	(0.033)	(0.033)	(0.226)	(0.225)	(0.226)
Democrat (%)	−0.344***	−0.314***	−0.315***	0.268***	0.257***	0.257***	0.022*	0.025**	0.024**	0.014	0.043	0.031
	(0.071)	(0.071)	(0.071)	(0.043)	(0.043)	(0.043)	(0.012)	(0.012)	(0.012)	(0.073)	(0.073)	(0.073)
Energy_Intensity	0.011	0.015	0.012	0.001	0.001	−0.005	−0.002	−0.002	−0.002	−0.009	−0.008	−0.010
	(0.037)	(0.037)	(0.037)	(0.021)	(0.021)	(0.021)	(0.006)	(0.006)	(0.006)	(0.038)	(0.038)	(0.038)
log Solar potential	0.846***	0.869***	0.872***	−0.089	−0.090	−0.086	−0.058	−0.059	−0.059	0.382	0.415	0.419
	(0.220)	(0.221)	(0.221)	(0.078)	(0.078)	(0.078)	(0.073)	(0.073)	(0.073)	(0.551)	(0.551)	(0.549)
log Wind speed L1	1.926***	1.750***	1.879***	1.001***	1.002***	1.218***	−0.057	−0.054	−0.039	1.853	1.615	1.729
	(0.647)	(0.647)	(0.648)	(0.251)	(0.250)	(0.251)	(0.206)	(0.206)	(0.206)	(1.542)	(1.542)	(1.536)
log Wind speed L4	−0.129	0.166	0.054	−0.383*	−0.471**	−0.666***	0.136	0.130	0.115	−2.148	−1.793	−1.894
	(0.604)	(0.600)	(0.601)	(0.226)	(0.223)	(0.224)	(0.194)	(0.193)	(0.193)	(1.448)	(1.446)	(1.440)
log Wind speed L10	0.00001	0.00000	−0.00001	0.0002***	0.0002***	0.0001***	0.0002***	0.0002***	0.0002***	0.001***	0.001***	0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.0001)	(0.0001)	(0.0001)
White (%)	−2.892	1.568	0.953	9.273**	8.704*	7.874*	0.621	0.849	0.679	5.215	9.318	7.926
	(10.349)	(10.327)	(10.320)	(4.502)	(4.458)	(4.464)	(2.477)	(2.471)	(2.468)	(16.444)	(16.444)	(16.422)
Constant	−31.005	−30.625	−31.959	138.503***	161.222***	150.318***	−1.806	−1.083	−1.129	−45.677	−39.826	−42.379
	(44.593)	(44.647)	(44.607)	(25.356)	(25.325)	(25.271)	(7.876)	(7.879)	(7.876)	(48.116)	(48.152)	(48.150)
Observations	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187	33,187

Note: * (p<0.1), ** (p<0.05), *** (p<0.01). Robust standard errors statistics in parentheses.

A.6 Spatial Lag-model4

Table 12: Spatial Panel lag with Random Effect - 1

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS	0.4953	0.5080	1.1455	1.6534
	4.1866	4.2774	9.6473	13.9195
MUGPO	22.1410	22.7093	51.2086	73.9179
	14.4500	14.7975	33.3467	48.0772
EERS	0.9761	1.0012	2.2576	3.2588
	4.7605	4.6518	10.5203	15.1659
Property_tax	4.4414	4.5555*	10.2724*	14.8279*
	2.7200	2.7062	6.0300	8.7240
Sales_tax	13.3960***	13.7396***	30.9821***	44.7217***
	3.9405	4.1498	9.7844	13.8740
Deregulated	-5.9800	-6.1336	-13.8309	-19.9645
	7.7535	7.6552	17.2701	24.9087
Population (1000s)	0.1269***	0.1301***	0.2934***	0.4235***
	0.0138	0.0160	0.0390	0.0538
NG Price	1.0489	1.0758	2.4259	3.5018
	0.6588	0.6780	1.5574	2.2328
EPU	0.0152	0.0155	0.0350	0.0506
	0.0256	0.0287	0.0646	0.0932
log_Income	-15.4760**	-15.8736**	-35.7944**	-51.668**
	7.6361	8.0094	18.4941	26.4582
Unemployment	-2.0052***	-2.0567***	-4.6377***	-6.6944***
	0.3085	0.2960	0.7383	1.0196
Democrat (%)	-0.0529	-0.0543	-0.1224	-0.1766
	0.1205	0.1231	0.2785	0.4014
Energy_Intensity	-0.2671***	-0.2740***	-0.6178***	-0.8917***
	0.0695	0.0669	0.1580	0.2236
log_Solar potential	0.6910	0.7087	1.5982	2.3069
	0.6161	0.6023	1.3925	1.9930
log_Wind speed L1	2.3471	2.4074	5.4285	7.8359
	1.7457	1.6417	3.7496	5.3853
log_Wind speed L4	-1.1407	-1.1700	-2.6383	-3.8083
	1.6457	1.5694	3.5554	5.1222
log_Wind speed L10	0.0002	0.0002	0.0005	0.0007
	0.0002	0.0002	0.0003	0.0005
White (%)	5.9504	6.1032	13.7624	19.8656
	23.5220			
Constant	157.9400*			
	85.0160			
lambda	0.7005***			
	0.0120			

Notes: ‡ Simulated standard errors from the impacts are given in brackets for the spatially lagged direct, indirect and total effects. K = 35

A.7 Spatial Lag-model5

Table 13: Spatial Panel lag with Random Effect - 2

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS_req	84.397***	86.512***	190.584***	277.096***
	17.278	16.703	38.861	55.047
MUGPO	23.643	24.235	53.389	77.625
	14.453	15.346	33.778	49.063
EERS	-7.629	-7.821	-17.229	-25.049
	5.072	5.166	11.531	16.679
Property_tax	4.393	4.503*	9.920*	14.423*
	2.699	2.605	5.781	8.375
Sales_tax	14.394***	14.754***	32.503***	47.258***
	3.936	3.766	8.735	12.428
Deregulated	-4.922	-5.045	-11.114	-16.158
	7.756	8.518	19.070	27.573
Population (1000s)	0.126***	0.130***	0.286***	0.415***
	0.014	0.013	0.033	0.045
NG Price	1.200*	1.230*	2.711*	3.941*
	0.659	0.670	1.492	2.158
EPU	0.018	0.018	0.040	0.059
	0.026	0.028	0.061	0.089
log_Income	-18.275**	-18.733**	-41.267**	-60.000**
	7.654	7.640	17.171	24.744
Unemployment	-1.707***	-1.749***	-3.854***	-5.603***
	0.314	0.312	0.755	1.056
Democrat (%)	0.006	0.006	0.013	0.019
	0.121	0.117	0.259	0.376
Energy_Intensity	-0.268***	-0.274***	-0.604***	-0.878***
	0.069	0.068	0.154	0.221
log_Solar potential	0.694	0.711	1.567	2.278
	0.616	0.623	1.377	1.998
log_Wind speed L1	2.294	2.351	5.180	7.531
	1.743	1.783	4.002	5.779
log_Wind speed L4	-1.058	-1.084	-2.389	-3.473
	1.637	1.705	3.824	5.526
log_Wind speed L10	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.001
White (%)	13.564	13.904	30.629	44.533
	23.521	26.628	58.886	85.479
Constant	176.920**			
	85.080			
lambda	0.695***			
	0.012			

Notes: ‡ Simulated standard errors from the impacts are given in brackets for the spatially lagged direct, indirect and total effects. K = 35

A.8 Spatial Lag-model6

Table 14: Spatial Panel lag with Random Effect - 3

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS req (LI)	87.9200***	90.133***	199.327***	289.460***
	(18.314)	(19.712)	(45.436)	(64.656)
MUGPO	22.2370	22.797*	50.414 *	73.211*
	(14.448)	(13.798)	(31.001)	(44.738)
EERS	-0.5883	-0.603	-1.334	-1.937
	(4.763)	(4.941)	(11.026)	(15.962)
Property_tax	3.9515	4.051	8.959	13.010
	(2.7007)	(2.804)	(6.332)	(9.126)
Sales_tax	13.8830***	14.233***	31.476***	45.708***
	(3.9325)	(3.828)	(8.591)	(12.357)
Deregulated	-6.0811	-6.234	-13.787	-20.021
	(7.752)	(7.483)	(16.630)	(24.095)
Pop_estimate(1000s)	0.1261***	0.129***	0.286***	0.415***
	(0.0138)	(0.014)	(0.037)	(0.051)
NG Price	1.2663*	1.298*	2.871*	4.169*
	(0.659)	(0.699)	(1.590)	(2.286)
EPU	0.0148	0.015	0.034	0.049
	(0.0255)	(0.025)	(0.055)	(0.079)
log_Income	-17.3350**	-17.772**	-39.302**	-57.073**
	(7.641)	(7.487)	(16.874)	(24.309)
Unemployment	-1.7789***	-1.824***	-4.033***	-5.857***
	(0.311)	(0.318)	(0.747)	(1.054)
Democrat (%)	-0.0159	-0.016	-0.036	-0.052
	(0.1206)	(0.120)	(0.266)	(0.386)
Energy_Intensity	-0.2722***	-0.279***	-0.617***	-0.896***
	(0.0695)	(0.066)	(0.150)	(0.215)
log_solar_potential	0.7014	0.719	1.590	2.309
	(0.6158)	(0.640)	(1.403)	(2.041)
log_Wind speed L1	2.6289	2.695	5.960	8.655
	(1.7435)	(1.930)	(4.334)	(6.257)
log_Wind speed L4	-1.3827	-1.418	-3.135	-4.552
	(1.637)	(1.800)	(4.026)	(5.822)
log_Wind speed L10	0.0001	0.000	0.000	0.000
	(0.0002)	(0.000)	(0.000)	(0.000)
White (%)	8.4263	8.638	19.104	27.742
	(23.472)	(24.796)	(54.809)	(79.578)
Constant	171.7000**			
	(85.0320)			
lambda	0.6962***			
	(0.0121)			

Notes: ‡ Simulated standard errors from the impacts are given in brackets for the spatially lagged direct, indirect and total effects. K = 35

A.9 Cross-sectional Spatial Random model-1

Table 15: Spatial lag - 2019 cross-section with zoning

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS	29.517**	30.0182*	23.7551*	53.7734*
	(14.985)	(15.901)	(12.090)	(27.795)
MUGPO	25.622	26.0577	20.6210	46.6787
	(18.815)	(20.2948)	(16.3306)	(36.4557)
EERS	20.567	20.9164	16.5524	37.4688
	(15.386)	(14.9553)	(12.2406)	(27.0068)
Property_tax	-36.027**	-36.6389*	-28.9945*	-65.6334*
	(16.544)	(18.8295)	(14.6555)	(33.2069)
Sales_tax	34.589**	35.1768**	27.8374**	63.0142**
	(14.363)	(13.346)	(11.688)	(24.668)
Deregulated	-27.893**	-28.3665**	-22.4480**	-50.8145**
	(13.465)	(12.598)	(10.542)	(22.853)
Pop_estimate(1000s)	0.022	0.0226	0.0179	0.0405
	(0.018)	(0.0176)	(0.0142)	(0.0316)
NG price	7.819*	7.9518*	6.2927*	14.2444*
	(4.587)	(4.754)	(4.048)	(8.736)
EPU	0.021	0.0211	0.0167	0.0378
	(0.200)	(0.1797)	(0.1461)	(0.3250)
log Income	-12.217	-12.4245	-9.8322	-22.2568
	(29.328)	(27.096)	(22.182)	(49.168)
Unemployment_rate	20.137***	20.4796***	16.2066***	36.6862***
	(4.777)	(4.722)	(4.385)	(8.8195)
Democrat(%)	-0.881*	-0.8963	-0.7093	-1.6056
	(0.531)	(0.537)	(0.451)	(0.982)
Energy_Intensity	−0.184	-0.1873	-0.1482	-0.3356
	(0.192)	(0.191)	(0.162)	(0.351)
log_solar_potential	3.226***	3.2805	2.5960	5.8765
	(0.767)	(0.750)	(0.702)	(1.403)
log_Wind_Speed_L1	7.611***	7.7401***	6.1252***	13.8653***
	(2.503)	(2.6059)	(2.2063)	(4.7214)
log_Wind_Speed_L4	−3.024	-3.0757	-2.4340	-5.5097
	(2.173)	(2.2208)	(1.7899)	(3.9873)
log_Wind_Speed_L10	0.001***	0.0009***	0.0007***	0.0016***
	(0.0002)	(0.0002)	(0.0002)	(0.0004)
White(%)	14.478	14.7241	11.6520	26.3761
	(53.684)	(50.2269)	(40.9203)	(91.0103)
Solar_zoning	11.028	11.2159	8.8757	20.0916
	(19.293)	(18.7357)	(15.0412)	(33.7026)
Wind_zoning	48.409***	49.2315***	38.9597***	88.1912***
	(16.140)	(15.3839)	(14.2883)	(29.034)
Constant	32.925			
	(308.832)			
Rho	0.45109***			
Observations	3,017	3,017	3,017	3,017

Notes: ‡ Simulated standard errors from the impacts are given in brackets for the spatially lagged direct, indirect and total effects.

A.10 Cross-sectional Spatial Random model-2

Table 16: Spatial lag - 2019 cross-section with zoning

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS_req	22.9270	23.3326	19.0050	42.3376
	(87.697)	(98.574)	(83.978)	(181.848)
MUGPO	23.3260	23.7389	19.3360	43.0749
	(18.893)	(19.322)	(16.422)	(35.525)
EERS	29.0590*	29.5729*	24.0879	53.6608 *
	(15.377)	(15.4837)	(13.4867)	(28.7175)
Property_tax	-28.4250*	-28.9275*	-23.5623*	-52.4898*
	(16.3120)	(17.0797)	(14.8094)	(31.5722)
Sales_tax	33.4680**	34.0601*	27.7428**	61.8029**
	(14.375)	(14.974)	(11.7765)	(26.286)
Deregulated	-30.1250**	-30.6573**	-24.9712*	-55.6286*
	(13.460)	(14.855)	(12.7007)	(27.2413)
Pop_estimate(1000s)	0.0208	0.0212*	0.0173	0.0385
	(0.0179)	(0.0203)	(0.0161)	(0.0362)
NG price	7.5673	7.7012	6.2728	13.9740
	(5.0136)	(5.5297)	(4.7237)	(10.1745)
EPU	0.0466	0.0474	0.0386	0.0861
	(0.2015)	(0.1767)	(0.1442)	(0.3202)
log Income	-9.6147	-9.7847	-7.9699	-17.7546
	(29.527)	(27.709)	(22.462)	(50.024)
Unemployment_rate	19.9370***	20.2897***	16.5265***	36.8162***
	(4.8644)	(5.2794)	(4.7047)	(9.5919)
Democrat (%)	-0.7638	-0.7773	-0.6331	-1.4104
	(0.5327)	(0.4982)	(0.4149)	(0.9073)
Energy_Intensity	-0.1621	-0.1650	-0.1344	-0.2994
	(0.1919)	(0.2225)	(0.1825)	(0.4036)
log_solar_potential	3.2661***	3.3239***	2.7074***	6.0313 ***
	(0.7674)	(0.8343)	(0.8371)	(1.6112)
log_Wind_Speed_level1	7.4142***	7.5454**	6.1459**	13.6913***
	(2.5167)	(2.8331)	(2.301)	(5.0419)
log_Wind_Speed_level4	-2.4834	-2.5273	-2.0586	-4.5859
	(2.1563)	(2.320)	(1.8789)	(4.1814)
log_Wind_Speed_level10	0.0009***	0.0009***	0.0007***	0.0016***
	(0.0002)	(0.0003)	(0.0002)	(0.0005)
White (%)	25.5240	25.9755	21.1577	47.1332
	(53.8810)	(52.6320)	(43.6167)	(95.9635)
Solar_zoning	12.0540	12.2676	9.9922	22.2598
	(19.2940)	(18.7319)	(15.6648)	(34.2575)
Wind_zoning	50.2430***	51.1318***	41.6482***	92.7801***
	(16.1270)	(16.9979)	(16.1533)	(32.2375)
Constant	-0.2732			
	(315.3800)			
rho	0.45847***			
Observations	3,017			
Note:	*p<0.1; **p<0.05; ***p<0.01			

A.11 Cross-sectional Spatial Random model-3

Table 17: Spatial lag - 2019 cross-section with zoning

	Dependent variable:RE			
	Estimate	Direct	Indirect	Total
RPS_req (LI)	6.9765	7.1000	5.7878	12.8878
	(84.277)	(85.241)	(73.024)	(157.891)
MUGPO	22.9610	23.3678	19.0490	42.4168
	(18.92)	)19.036)	(16.1115)	(34.908)
EERS	29.9820 **	30.5131 **	24.8737**	55.3868 **
	(15.215)	(15.2149)	(13.1801)	(28.111)
Property_tax	-27.6980*	-28.1881 **	-22.9784 **	-51.1664 **
	(16.049)	(14.935)	(12.62)	(27.281)
Sales_tax	33.7590 **	34.3571 **	28.0073 **	62.3643 **
	(14.449)	(15.088)	(12.8063)	(27.4557)
Deregulated	-30.4450 **	-30.9840 **	-25.2575**	-56.2415 **
	(13.407)	(14.762)	(12.993)	(27.436)
Pop_estimate(1000s)	0.0208	0.0211	0.0172	0.0384
	(0.0179)	(0.0194)	(0.0153)	(0.0344)
NG Price	8.0576 *	8.2003 *	6.6848*	14.8851 *
	(4.6119)	(4.5507)	(3.8752)	(8.3256)
EPU	0.0522	0.0531	0.0433	0.0964
	(0.2003)	(0.2045)	(0.1708)	(0.3743)
log_Income	-8.6873	-8.8411	-7.2071	-16.0482
	(29.291)	(26.0118)	(21.8348)	(47.7119)
Unemployment_rate	20.1510 ***	20.5081 ***	16.7178 ***	37.2258 ***
	(4.7874)	(4.7538)	(4.2805)	(8.6443)
Democrat (%)	-0.7479	-0.7611	-0.6205	-1.3816
	(0.5296)	(0.5700)	(0.4682)	(1.0318)
Energy_Intensity	-0.1612	-0.1640	-0.1337	-0.2978
	(0.1919)	(0.2090)	(0.1689)	(0.3770)
log_solar_potential	3.2727 ***	3.3306***	2.7151***	6.0457***
	(0.7672)	(0.8157)	(0.8109)	(1.5809)
log_Wind_Speed_level1	7.5046***	7.6375***	6.2259***	13.8634***
	(2.5192)	(2.7647)	(2.3446)	(5.0123)
log_Wind_Speed_level4	-2.5159	-2.5604	-2.0872	-4.6477
	(2.1880)	(2.4195)	(2.0165)	(4.4170)
log_Wind_Speed_level10	0.0009***	0.0009***	0.0007***	0.0016 ***
	(0.0002)	(0.0002)	(0.0002)	(0.0004)
White (%)	27.1710	27.6518	22.5412	50.1930
	(53.577)	(59.0047)	(49.9656)	(108.6784)
Solar_zoning	12.0070	12.2195	9.9611	22.1806
	(19.293)	(17.670)	(14.21)	(31.7466)
Wind_zoning	50.1980 ***	51.0873 ***	41.6454***	92.7328 ***
	(16.142)	(16.0316)	(14.228)	(29.5505)
Constant	−16.494			
	(308.519)			
Rho:	0.4587***			
Observations	3,017			
Note:	*p<0.1; **p<0.05; ***p<0.01			