Do the Renewable Portfolio Standards (RPS) promote the renewable electricity generation in the USA? Evidence from panel data econometric study.

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Abstract: Renewable Portfolio Standard (RPS) is a widely implemented and discussed supply side state-level regulatory policy instrument aimed to promote generation of renewable energy. Existing literature on RPS developed from discussion of an appropriate policy design, its implementation on national versus state levels and factors driving states to adopt the policy to the analysis of its effectiveness and economic impact. The main objective of this paper is to analyze the impact of the RPS on the share of renewable energy in electricity production and to quantify it using the panel data econometrics methods. Existing literature gives contradictory evidence of RPS policy impact on various measures of renewable energy production. It seems that binary RPS indicators (taking value of one if a policy is implemented and zero otherwise) are not good predictors since they do not take into account difference between regional policies, while RPS stringency variable had good explanatory power. In this paper, I propose to use RPS fractional goal as a proxy for RPS stringency, which is easily available and does not require difficult calculations. A set of control variables and econometric model are chosen in line with previous research.

Keywords: Renewable Portfolio Standards (RPSs); electric power industry; renewable energy policy; policy compliance; penalty; econometric modeling; microeconometric; panel data estimation; fixed effects; random effects.

Subjects: C - Mathematical and Quantitative Methods; C01 – Econometrics; C23 - Panel Data Models & Spatio-temporal Models; C52 - Model Evaluation, Validation, and Selection; L - Industrial Organization > L52 - Industrial Policy ; Sectoral Planning Methods; O - Economic Development, Innovation, Technological Change, and Growth; O25 - Industrial Policy; Q - Agricultural and Natural Resource Economics ; Environmental and Ecological Economics > Q2 - Renewable Resources and Conservation > Q28 - Government Policy.

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1. Introduction

The electric power industry, being the largest consumer of energy (both from traditional fossil and alternative renewable sources), became the most frequent subject of regulatory policies and financial incentives aiming to stimulate renewable electricity generation. Among those, RPS requiring electric power producers to meet a minimum fractional goal measured as a percentage of electricity generated from the qualifying renewable energy sources became the most wide-spread policy instrument.

Although the first RPS-like policy mechanism was enacted in Iowa as early as in 1983 (in the form of the Alternative Energy Law), it was not until 1997 when the modern adoption of RPSs began. Massachusetts and Nevada pioneered the movement, following Connecticut in 1998, and four more states in 1999. Iowa adopted its modern RPS in 2001, California and New Mexico joined the policy in 2002. Active diffusion of this policy started in 2004, when six more states joined this policy. Other 13 states adopted the RPSs during the years 2005-2008, following by Kansas in 2009 and Oklahoma with West Virginia in 2010. Currently 29 states, Washington DC and two territories have the RPSs, while 8 states and two territories have renewable portfolio goals (RPG), which are not mandatory. Because

RPG specify only final fractional goal to meet by a certain year in future and do not have schedule suggesting gradual increase of the fractional goal states with RPG are not interest of this study. Some states, although implemented RPS, have not explicitly specified penalty sizes and enforcement mechanisms. Sometimes there is a gap observed between the year when RPS was enacted and a year when compliance is required as a minimum fractional goal (in most states) or as an absolute value (as in Texas and Iowa). This paper focuses on those states that had not only enacted RPS by at least year 2011 but also had certain specific fractional goals. Iowa and Texas have no fractional goals and therefore excluded from study. Washington did not have fractional goals to meet before 2012 although its RPS was enacted in 2006. Indiana has enacted its RPS in 2011 with the first fractional goal to meet in 2012. Therefore, Iowa, Texas, Washington and Indiana were excluded from this analysis.

2. Data

Data about the RPS policies across the U.S. are collected in the Database of State Incentives for Renewables and Efficiency (DSIRE), funded by the U.S. Department of Energy. The subject of this study constitutes 25 states, including Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Kansas, Massachusetts, Maryland, Maine, Minnesota, Missouri, Montana, North Carolina, New Hampshire, New Jersey, New Mexico, Nevada, New York, Ohio, Oregon, Pennsylvania, Rhode Island and Wisconsin. States are observed over a period of 9 years (2003-2011), which provides at most 9 observations per state. Panel is imbalanced because only 2 states had fractional goals in 2003, 3 in 2004, 5 in 2005, 10 in 2006, 13 in 2007, 17 in 2008 and 19 in 2009, 22 in 2010, 25 in 2011;

therefore full sample includes 116 total state-year observations. All nominal values were expressed in real terms using Consumer Price index (CPI) with 2005 as a base year (to make it consistent with data on real gross domestic product by state already reported with 2005 as a base year). CPI data are uploaded from the Bureau of Labor Statistics web-site.

Dependent variable in this study **"reshare"** is defined as the **share of electricity generation by the total electric power industry produced with the use of renewable sources**, measured as a percentage. It is calculated using the following formula:

$$reshare = \frac{electricity\ generated\ from\ renewable\ sources}{total\ electricity\ generated} * 100\%$$

[equation 1]

Data on distribution of electricity generated in megawatt hours (MWh) by energy sources derived from historical tables of the US Energy Information Agency (US EIA). Renewable sources include electricity generated from geothermal, hydro, solar, wind, wood and other biomass, while total energy sources also contain coal, natural gas, nuclear energy, and petroleum.

The main explanatory variable used in this study, **"rpsgoal"**, is defined as **mandatory fractional goal imposed in the states RPS policies** (measured as percentage). Fractional goals set by different states varied a lot - from 0.02% to 23.20%, with overall mean 7.74%. "What will be the marginal impact of setting a fractional goal of RPS higher by 1%?" is the main question of this study. To be able to estimate this marginal effect reliably, I take into account for other factors that could have impact on the dependent variable of this study, using additional control and explanatory variables.

First of all, we can think that some states have legislature more environmentally concerned than others. To capture this difference, I use variable named **"lcvs"** which stands for **league of conservation voters senate scores**, measured as a percentage of votes in favor of the environmentally friendly legislature states. I collected these data from the annual scorecards published by the League of Conservation Voters (2013). We can see that "lcvs" varied from 27.36% to 100%, with overall mean of 75.47%. This means that there were states where the senate members voted for less than a third to all environmental statutes. Overall mean was 75.47%. This is not surprising since the subjects of this study are chosen conditionally on RPS being already enacted.

Then, having **penalty or alternative compliance payment for non-compliance imposed in the states RPS policies ("penalty")** should make difference for the effectiveness of RPS policy. Very interesting, almost a half of states (12 out of 25 in this study) did not have any penalties implemented, while in those states that included penalty or alternative compliance payment, its size varied from 0 to 65.27 USD in nominal terms, from 0 to 69.28 USD in real terms.

One can argue that higher electricity prices allow industry to invest more in renewable production. This calls to include such control as **lagged average electricity price (for all sectors, in all electric power industry)**, **"rpel_1"**. It varied from as low as 3.00 cents per KWh to as high as 22.50 cents per KWh with overall mean of 10.74 cents per kWh.

Real gross domestic product by state per capita “rgspcap” has to be controlled for since it also can impact the share of electricity generated from the renewable energy. In our sample “rgspcap” varied from 31.86 to 63.16 thousand USD with overall mean 44.41 thousand USD.

Summary statistics of dependent, explanatory and control variables used in this study is presented in table 1.

Variable		Mean	St. Dev.	Min	Max	Observations	
“reshare”, %	Overall	11.83	13.64	0.79	80.08	N	116
	Between		18.43	0.87	80.08	N	25
	Within		1.76	6.27	18.69	T-bar	4.64
“rpsgoal”, %	Overall	7.74	5.91	0.02	23.20	N	116
	Between		5.03	0.02	20.51	n	25
	Within		2.21	2.15	15.30	T-bar	4.64
“lcvs”, %	Overall	75.47	27.36	0	100	N	116
	Between		27.04	0	100	n	25
	Within		14.44	19.97	114.97	T-bar	4.64
“penalty”, dollars per MWh	Overall	25.19	25.42	0	69.28	N	116
	Between		24.96	0	62.28	N	25
	Within		1.60	19.58	32.19	T-bar	4.64
“rpel_1”, cents per KWh	Overall	10.74	3.00	6.72	22.50	N	116
	Between		3.41	6.77	20.91	N	25
	Within		0.81	7.79	12.79	T-bar	4.64
“rgspcap”, thousand dollars per person	Overall	44.41	7.30	31.86	63.16	N	116
	Between		7.25	32.31	62.27	N	25
	Within		1.32	40.73	47.78	T-bar	4.64

Table 1. Descriptive Statistics

One can ask why we have not taken into account variables capturing the difference in climate and affecting capacity of renewable energy production in a particular state. An answer lies in the econometric technique used for this study – panel data estimation, which is discussed next.

3. Econometric Model and Empirical Results

The advantage of panel data estimation methods is that looking at the variations in cross-section and time-series dimension simultaneously we can ignore the difference in individual time-invariant characteristics of these states.

I use a two-way error component panel data model which can be presented as the following equations:

$$reshare_{it} = X'_{it}\beta_x + W'_i\beta_w + e_{it}$$

[equation 2]

$$e_{it} = c_i + \tau_t + v_{it}$$

[equation 3]

In the equations above i=1…25 stands for individual states, and t refers to a year in such a way that t=Ti…2011, where Ti is a year in which a state had an RPS fractional goal for the first time. Ti can vary from 2003 (as, for example, in New York State) to 2010 (as, for example, Minnesota, for which I have only two observations – in 2010 and 2011), while Ti is empty for Kansas since it has only one observation (in 2011). Xit is a matrix of time-variant explanatory and control variables for each state (containing data on “rpsgoal”, “lcvs”, “penalty” “rpel_1” and “rgspcap” for each state-year observation. I chose the above set of control variables because I want to identify a full impact of “rpsgoal” on “reshare”. To avoid omitted variable bias I include as controls such state characteristics as environmental friendliness of state senators (“lcvs”), GSP per capita (“rgspcap”), lagged electricity price (“repel_1”) and difference between regional RPS in their enforcement mechanisms captured by “penalty”. A vector of coefficients βx is the one I am interested to estimate, with coefficient on “rpsgoal” in the focus of this study.

Because I do not have time-invariant variables other than intercept, Wi is a matrix of ones, while βw includes estimates of intercept coefficient. Thus the second term of equation (2) captures an intercept, which stands for some constant share of electricity produced from renewable common for all states in this study.

Error term eit is called two-way because, as shown in equation (3), it includes both individual state effects and time effects (the first two terms respectively) while the last term is the stochastic disturbance (independently and identically distributed random variable with zero mean). I assume that all explanatory/control variables and individual state effects are exogenous with respect to the stochastic disturbance term, as shown in equations (4) and (5):

$$E(v_i | X_i, W_i, c_i) = 0$$

[equation 4]

$$E(v_{it} c_i) = 0$$

[equation 5]

Intuitively, it is important to have individual state effects, since states differ by political ideology, natural potential to produce renewable energy and economic conditions and these variables are not time varying. I first assume there are fixed effects in the model present. Intuitively, I want to make conclusions on the fixed set of states and all of my explanatory variables are time-variant. Fixed methods estimation allows for correlation between individual state effects and a set of explanatory/control variables, which can be expressed as following:

$$E(c_i|X_i, W_i) \neq 0$$

[equation 6]

I refer to the Chow test (F-statistics) for overall significance to conclude whether fixed effects are present in a model. I also run random effects model. It is stricter in a sense that it forces assumption about zero correlation between individual state effects and a set of explanatory/control variables, as it is shown in equation (7):

$$E(c_i|X_i, W_i) = 0$$

[equation 7]

I refer to the Breusch-Pagan Lagrangian multiplier test for random effects (BP LM Chi^2 test) to conclude whether random effects are preferred over pooled Ordinary Least Squares estimation (OLS). I use the Durbin-Wu-Hausman test to choose between fixed and random effects model. If both fixed and random effect models give consistent results, random effect estimators are efficient and should be preferred. If random effects model is rejected, its estimates are inconsistent and fixed effects estimators must be used instead.

Estimation results for both fixed effects and random effects methods (with robust heteroskedasticity-corrected errors) are presented in the table 2.

Variable	Fixed Effects	Random effects
"rpsgoal"	0.4757*** (0.1350)	0.4204*** (0.1199)
"lcvs"	0.0243** (0.0111)	0.0244** (0.0111)
"penalty"	0.4239** (0.1685)	0.2812** (0.1127)
"rpel_1"	0.0978 (0.2139)	-0.0284 (0.1970)
"rgspcap"	0.0162 (0.1153)	-0.0391 (0.1153)
R-square (within)	0.2270	0.2190
R-square (between)	0.0637	0.0782
R-square (overall)	0.0223	0.0359
Number of observations	116	116
F-test for FE	F(24,86) =204.09	-

LM BP test	-	Chi^2(1) = 61.60
Standard errors are presented in the parenthesis		
I use *, ** and *** for results significant at 10%, 5% and 1% significance levels respectively		

Table 2. Coefficient estimates. Dependent variable: "reshare"

Both models (with fixed and random individual state effects) give statistically significant and close coefficient estimates for "rpsgoal", "lcvs" and "penalty". All three variables have positive impact on "reshare".

Both F-test for fixed effects and LM BP test favor having individual state effects (fixed and random respectively) versus pooled OLS. Then I conduct the DWH (Durbin-Wu-Hausman test). The null hypothesis (Ho) in this test assumes zero correlation between individual state effects and a set of explanatory/control variables as presented in equation (7) and favors random effects. An alternative hypothesis (Ha) allows non-zero correlation between individual state effects and a set of explanatory/control variables as indicated in equation (6). I obtain DWH statistics, which follows Chi-square distribution with one degree of freedom, as chi^2(1)=3.81. Based on these results and using 5% significance level, one should favor fixed effects model, which I use to interpret results.

The main finding of this study is that, given other things equal, one more percent of RPS fractional goal increases the share of electricity generated from renewable energy by 0.48%. This shows that RPS policy indeed has an impact on decisions of electric power producers and results in switching from traditional fossil fuels to renewable and "clean" forms of energy.

The second finding is that having a penalty or an alternative compliance payment in the RPS design is an important feature which must be included in policy enforcement mechanism to motivate compliance: given other things equal, a "penalty" higher by one dollar per Kwh will increase the share of electricity generated from renewables by about 0.42%.

The third finding is that, given other things equal, one more percent of senators votes for environmentally friendly legislature increases the share of electricity generated from renewable energy by 0.02%. Although this effect is not very large in absolute value, it gives very interesting result: senators do help environment, their votes matter.

4. Conclusion

In this paper I analyzed what determines the share of electricity generated from renewable sources with the focus on the impact of the RPS fractional goal. This study is conducted on the aggregate state level. Panel is unbalanced, with at most 25 states in a given year and 9 observations per given state. To identify full impact of RPS on the share of electricity generated from renewable energy control I control for the socio-economic state characteristics and for the "environmental friendliness" of state senators. I found that the higher RPS fractional goal, the higher penalty embodied in the RPS and the more environmentally concerned state senators, the higher the share of the electricity generated from the renewable energy sources. Difficulties of this study come from the small sample size (116 state-year observations) and imbalanced panel. Although results are robust, adding more observations can help to prove the validity of the main results of this paper.

5. References and data

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