Renewable Portfolio Standards: True Commitments or Pure Symbols?

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April 20, 2009

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Abstract

Most existing empirical research on the impact of Renewable Portfolio Standards (RPS) policies has employed a cross-sectional approach or over-simplified measure for RPS which ignored the heterogeneity in RPS designs. In this paper, we have introduced a new way to measure the stringency of RPS that explicitly accounts for some RPS design features that may have a significant impact on the strength of an RPS. The difference between this new measure and other more commonly used measures is striking; some seemingly aggressive RPS policies in fact provide only weak incentives, while some seemingly moderate RPS policies are in fact fairly ambitious. We also investigate the impacts of renewable portfolio standards on the renewable electricity development using our new measure of RPS stringency, and compared the results with those when alternative measures are used. The difference in the estimates is again striking. Using our new measure, the results suggest that, on average, RPS policies have had a significant and positive effect on renewable energy development. These findings are masked when differences between RPS policies are ignored. We also find that another important design feature – allowing "free trade" of REC's – can significantly weaken the impact of an RPS. These results should prove instructive to policy makers that are interested in RPS policies, especially for countries who are developing an RPS such as China.

1 Introduction

In the U.S., power plants are responsible for approximately 40 percent of the nation's carbon dioxide emissions, leading environmental and other interest groups to target this sector as they seek to reduce emissions in response to concerns of global climate change. The lack of action by the federal government has led some state and local governments to fill this void with a variety of policy approaches (Engel and Orbach, 2008). One of the most common state-level policy instruments, and the object of significant attention, is known as a renewable portfolio standard (hereafter, RPS). An RPS is a policy that ensures that a minimum amount of renewable energy (such as wind, solar, biomass, or geothermal energy) is included in the portfolio of electric generating resources serving a state. The laws state that this requirement generally increases over time, and the stated intent of these policy measures is usually some combination of increasing the diversity, reliability, public health and environmental benefits of the energy mix[1]. As of April 2009, 30 states[2] and the District of Columbia have passed renewable portfolio standards.

While RPS policies all share several key features, they vary dramatically in design across states. These design differences have been carefully detailed by Berry and Jaccard (2001); Wiser et al., (2005); Wiser et al., (2007); and Wiser and Barbose (2008). However, econometric analyses of the effectiveness of RPS policies have largely ignored this heterogeneity in RPS design. For methodological convenience, previous empirical analyses have treated RPS policies as identical or have characterized the differences between them in an overly simplistic manner. A primary argument in the present study is that without properly accounting for the wide heterogeneity we see in RPS policies, empirical studies of their effectiveness may result in very misleading conclusions. Moreover, careful analysis of these differences and their influence on RPS effectiveness can afford policymakers an opportunity to improve the effectiveness of RPS policies through their redesign.

In this paper, we develop a measure for the strength of an RPS. This measure explicitly considers some key design features that could potentially affect the magnitude of the incentives for developing new renewable capacity. This new measure suggests that some seemingly aggressive RPS policies in fact provide only weak incentives, while some seemingly moderate RPS policies are in fact fairly ambitious. It follows that in any analysis addressing the question of whether RPS policies are "true commitments" or "pure symbols", imposing uniformity on the policy is inappropriate.

Based on the new measure, we present the most rigorous statistical analysis of RPS policies to date. We find that RPS policies do in fact lead to a statistically significant increase in renewable electricity development. This result

[1]Some proponents of RPS policies have also claimed that they can provide employment benefits (the often-discussed "green jobs"), or generate learning economies important for the development of renewable technologies, though these questions are not examined in the present paper.

[2]The 30 states are AZ, CA, CO, CT, DE, HI, IA, IL, MA, MD, ME, MI, MN, MO, MT, NC, NH, NJ, NM, NV, NY, OH, OR, PA, RI, TX, VA, VT, WA, and WI. Virginia and Vermont have passed unconventional policies that have been deemed by some to be "optional". However, unlike the voluntary policy, of say, North Dakota, the policies in both Virginia and Vermont contain credible commitments that provide real incentives for renewable development. Nonetheless, we have also performed the empirical analysis presented in this paper with alternative classifications of the Virginia and Vermont policies, and the results are qualitatively identical. These results are available upon request.

stands in sharp contrast to those when the difference between RPS stringency is ignored or measured in an overly simplistic manner, as has been done in previous studies.

The remainder of the article is organized as follows. In the next section, we provide a brief overview of the research done on RPS policies to date. In section 3, we present background on RPS policies, key dimensions of heterogeneity between them, and propose a new measure for the strength of RPS policies. In section 4, we present an empirical framework for estimation of the effectiveness of an RPS in promoting renewable energy development. Section 5 describes the data and compares different measures for RPS stringency. In section 6, we present the results of our estimations. Finally, in section 7, we conclude.

2 Literature Review

Rigorous study of renewable portfolio standards has been rare. In this section, we outline the existing literature on these relatively new policies. In this paper, our primary concern is not the efficiency of RPS policies, but rather their effectiveness - which is a necessary (though not sufficient) condition for efficiency. Furthermore, the effectiveness criterion may be a more useful criterion than efficiency when other more efficient policies being considered are politically infeasible. Nonetheless, we review the literature on both questions in this section.

State-level RPS policies are often seen by economists as a suboptimal policy for two key reasons. First, since the most significant environmental benefits from RPS legislation come from the internalization of *global* externalities, a regional approach runs the risk of inducing welfare losses in the regulated region without incurring environmental benefits, as the damaging pollutants can continue to be produced elsewhere. For example, Bushnell, Peterman, and Wolfram (2007) argued that the effectiveness of such local initiatives is limited due to a leakage or reshuffling problem and claimed that RPS policies are “largely symbolic unless they facilitate change beyond their local regions”. Second, since many states require that the renewable electricity be generated in-state, the principle of allowing the cost of pollutant reduction to be minimized by allowing these reductions to occur where they are least costly is violated.

Two recent papers have developed theoretical models to examine the cost-effectiveness of RPS policies. Palmer and Burtraw (2005) perform numerical simulations to predict the impacts of a *national* RPS, and find that it raises electricity prices, but that it is not as cost-effective as a cap-and-trade policy for reducing carbon emissions. Fischer and Newell (2008) develop and calibrate a model that predicts that an RPS-like policy is a sub-optimal policy whether the goal is reducing carbon emissions or promoting technological progress. A third paper, (Michaels 2007), though lacking a formal model, is also extremely critical of the oft-proposed federal RPS, arguing that it is an inefficient way to achieve any of the policy objectives often attributed to an RPS. Further, the article’s author argues that the record of state implementation of RPS policies has, thus far, been largely symbolic.

Nonetheless, and perhaps in part because they are perceived to address several political goals at once, state-level RPS policies have proliferated. Lyon and Yin (2007) examine the political economy behind these policies, and find that renewable energy potentials (measures of the strength of the wind and solar resources in a state), Democratic majorities in the state legislature, and organization of the renewable industry are all significant antecedents of a state-level RPS. Interestingly, they do *not* find that high levels of renewable development make a state more likely to adopt an RPS.

Distinct from, though not orthogonal to, the question of efficiency is the question of effectiveness. Namely, do RPS policies achieve their primary stated goal of increasing renewable capacity and generation in the states in which they are passed? The most prominent studies have not included complete statistical analyses and have concluded that the policies are either ineffective (Bushnell et al 2007) or "largely symbolic" (Michaels, 2007).

As far as we know, only three (Menz and Vachon, 2006; Adelaja and Hailu, 2007; Kneifel, 2008) studies have employed statistical analysis to empirically identify the impacts of RPS on renewable energy development. These studies, however, have taken a rather blunt approach. Menz and Vachon (2006) and Adelaja and Hailu (2008) both find a positive relationship between an RPS and renewable development, but they use simple cross-sectional data, precluding any conclusions regarding causality. Kneifel (2008), on the other hand, uses a panel data approach and finds that RPS policies do not lead to an increase in renewable capacity in a state if the requirement is based on generation as most states did.

However, even when the question of causality is addressed, these studies treat RPS's as more or less uniform across states. Menz and Vachon (2006) and Adelaja and Hailu (2008) both use a binary RPS variable, which totally ignores the heterogeneity across RPSs. Kneifel (2008) does differentiate between RPSs by using their nominal requirements, which are the RPS goals that are written into the laws, as his measure of the strength of the policies[3]. However, as evidenced in this paper, nominal requirement fails to capture some important design features that are decisive for RPS effectiveness and therefore may also lead to misleading conclusions.

The current study attempts to further the literature in two ways. First, we construct a measure that incorporates the most important design features of an RPS and therefore more accuratley assesses the strength of an RPS; secondly, we perform a panel data analysis and demonstrate how misleading conclusions might result when the heterogeneity of design is ignored as Menz and Vachon (2006) and Adelaja and Hailu (2008) or over-simplified as Kneifel (2008).

[3]Kniefel also differentiates between capacity-based and generation-based policies. However, given that most of the relatively few capacity-based policies are enforced on the basis of generation, using capacity conversion factors that are usually publicly-known, we argue that this difference is a false dichotomy.

3 Background

RPS policies, which are the central focus of this paper, differ from other policies designed to incentivize renewable energy installation and generation, in that they are essentially minimum quantity mandates, though with varying degrees of flexibility. All strive to ensure that a minimum amount of renewable energy is included in the portfolio of electric generating resources serving the state. Furthermore, all the RPS policies we examine here clearly specify the path of the requirement over time, and generally build to a final standard at some distant point in the future (for example, Michigan's RPS, passed in October 2008, has an ultimate target of 10 percent by 2015, with intermediate requirements of 2 percent by 2012, 3.3 percent by 2013, and 5 percent by 2014).

The fact that these requirements are written into the laws themselves provides researchers with an obvious measure for the strength of an RPS; we refer to this as the *nominal requirement*. [4] Although straightforward, using nominal requirement as a measure neglects a sizeable amount of policy heterogeneity that could potentially have significant impact on the strength of RPS. Previous research on RPS design (Berry and Jaccard, 2001; Wiser et al., 2005; Wiser et al., 2007; Wiser and Barbose, 2008) suggests that the heterogeneity in three distinct dimensions have the greatest importance. We examine each in turn, and discuss how we account for them in our analysis.

3.1 Coverage

Wiser et al (2005) have argued that a well-designed RPS should ideally apply equally and fairly to all load-serving entities in a state. However, in practice, there are vast differences in coverage, as different types of utilities are treated differently by some of the policies. For example, in Maryland and five other states (Iowa, Texas, Hawaii, Minnesota and Wisconsin), all utilities, including investor-owned utilities, power marketers, rural cooperatives, and municipal cooperatives, are required to comply. However, other states have provided partial exemptions in meeting RPS requirements, either to entire classes of utilities, or in some cases, to individual utilities. In Montana, the RPS applies only to investor-owned utilities, which generate only 45 percent of the electricity that is sold in the state. Five other states (Connecticut, Pennsylvania, Arizona, Illinois and Colorado) have exemptions of a similar magnitude, such that less than 60 percent of the electricity market in those states is covered by RPSs.

[4] This, to a certain extent, is the approach taken by Kneifel (2008). Kneifel (2008) takes the target requirement in a number of years after enactment, and linearly interpolates backwards to the enactment date of the policy to obtain the requirement for each year after enactment. For example, a policy enacted in 1996 with a sales requirement of 1.0% beginning in 2000 would be linearly interpolated to be 0.2% in 1996 and increase by 0.2% each year until it reaches 1.0% in 2000. We argue that this is a strong and ultimately unnecessary assumption. First, all states stipulate the requirement to be enforced in every year until the ultimate goal is reached, and these do not generally follow linear patterns. Second, given the large fixed costs associated with renewable energy generation and the learning curves often thought to accompany renewable energy development, it's not clear why we should expect producers to develop renewable capacity in a linear manner, even in years when the time path of the requirement is not explicitly laid out. In this paper, we start from the actual scheduled requirements in each state.

3.2 Existing Capacity

Another design feature that could affect the effectiveness of RPS is whether the RPS allows generation from existing renewable resources to fulfill the requirements, or whether the standard must be filled with generation from new investments in renewable resources. These obviously have different effects - requiring new resources creates a stronger incentive for new development. Allowing generation from existing assets to "count" will weaken the incentive, and furthermore may allow windfall profits to accrue to those utilities that own existing renewable generating capacity.

States vary greatly in this aspect. While some states, including Arizona, Massachusetts, Montana, and Vermont, only allow generation from new assets to count towards the policy, most states allow generation from all units that existed at the time the legislation was passed. Many states, including Delaware, Maine, North Caroline, New Hampshire, New Mexico, New York, Oregon, Virginia, and Washington, allow generation from some certain existing units. For example, Washington's RPS states, "New renewable generation resources are defined as having first gone into commercial operation after 12/31/97. Renewable generation units that entered service before that date may not account for more than 1 percent of total retail electricity sales in any compliance year." When eligible existing capacity is large compared to RPS requirements, the strength of an RPS would be significantly overstated if we used the nominal requirement as the main measure, because the policy-induced incentive to install new renewable generating capacity is relatively small.

In order to take into account the heterogeneity in coverage and existing capacity, and thus more accurately capture the size of the new incentive generated by these policies, we propose a new variable, *INCRQMTSHARE*:

$$INCRQMTSHARE_{it} = \frac{NOMINAL_{it} * COVERAGE_{it} * SALES_{it} - EXISTING_{iT}}{SALES_{it}} \tag{1}$$

where $NOMINAL_{it}$ is the nominal requirement in state i in year t, $COVERAGE_{it}$ is the proportion of sales of the utility industry in state i covered by the RPS at time t, $SALES_{it}$ is the total retail sales in state i in year t, and $EXISTING_{iT}$ is the renewable generation in year T that, if generated in later years, would be eligible to fulfill the RPS requirement in state i. T is the date the RPS legislation/mandate is enacted[5]. This new variable, *INCRQMTSHARE*, thus represents the "incremental percentage requirement", or the mandated increase in renewable generation in terms of the percentage of all generation. For the remainder of the paper we refer to it as the *incremental requirement*.

One key challenge in deriving *INCRQMTSHARE* is to calculate $EXISTING_{iT}$, the amount of eligible *existing* renewable generation. The difficulty is due to the fact that state policies differ not only in *whether* existing capacity

[5]If a policy was passed during the first six months of the year, T is set to the previous year, otherwise T is the year in which the policy was passed. Regardless of how T is set, we always consider the RPS to become "active", in the sense that it enters into the decision-maker's calculus, in year $T+1$.

is eligible, but also in *which* technologies are counted as *”renewable”*. We calculate this variable state by state based on each state’s definition of “renewable”. [6] Thus, three cases arise in the calculation of $EXISTING$; (1) when existing capacity/generation is not allowed, $EXISTING = 0$, but (2) when all existing capacity/generation is allowed, $EXISTING$ is equal to the renewable generation from existing capacity in period T. However, in the third case, when states allow existing generation only in certain cases, we need to take a case-by-case approach. For example, in the state of Washington (mentioned above), we define existing renewable generation as the renewable generation in year 2006 from plants installed between 1998 and 2006 (the year Washington passed its RPS) plus the minimum of either (a) the 2006 renewable generation from plants installed in or before 1997 or (b) 1% of electricity sales in 2006.[7]

3.3 REC trading

Most RPS policies are enforced through a credit-trading mechanism. When electricity is generated from a renewable source in states that have a renewable energy credit program, there are two resulting products - the electrons that are fed into the grid, and the environmental attributes associated with producing reduced-carbon or carbon-free electricity. In most states, these environmental attributes are accounted for in the form of renewable energy credits, or REC’s. Each REC represents one MWh of electricity generated from an eligible renewable energy resource. In some cases, the REC’s are bundled with the electricity that they are associated with - this is often the case when an independent power producer has contracted to sell the electricity to a given utility. But in some cases, the REC’s are instead retained by the independent power producer, and presumably are sold at a later point in time. At the end of a compliance year, the administrator of the program calculates each utility’s required amount of renewable generation, based both on the legislated percentage and the share of state’s sales belonging to that utility. A utility then has a specified amount of time to purchase the REC’s necessary to meet its requirement if it is “short”. Treatment of REC’s varies across states, and the way these REC’s are treated will result in variation of the impact of an RPS policy (Lyon and Yin, 2008).

- Some states, including California, Iowa, Illinois and Hawaii, simply do not allow REC trading or out-of-state REC trading. In these states, the obligated utilities are required to meet a certain standard through their own generation or through power purchase agreements.
- Some states allow out-of-state REC’s, but heavily incentivize in-state generation. This is usually done either by creating set-asides, where a certain portion of a utility’s obligation must be met with in-state REC’s, or

[6] Note that this state-by-state calculation that the varying technologies into account is only performed for the variable $EXISTING$. For the dependent variable, we use a uniform definition of renewable technologies that is explained below.

[7] We recognize that there is an implicit assumption that the amount of generation from existing capacity will continue to be the same for every year after T. This could be violated if renewable capacity is decommissioned after year T, or if, for example, renewable capacity was “online”, but not operating at full capacity in years prior to T. However, given the relative newness of most renewable generating capacity and the low operating costs associated with most renewable technologies, this assumption should have minimal effects, whether on our proposed measures or our regression results.

multipliers, where in-state REC's get extra credit. For example, in Arizona, a MWh of electricity generated from in-state renewable capacity is credited as 1.5 REC's, whereas the same amount of electricity generated out-of-state is credited as normal.

- Some states impose very restrictive conditions on the eligibility of out-of-state renewable generation, which in essence disallows out-of-state generation. For example, in Texas, out-of-state resources are technically eligible to generate Texas REC's, but the output of the facility must be readily capable of being physically metered and verified in Texas by the program administrator.
- Finally, some states allow free trade of REC's and provide no preferential treatment to in-state REC's.

RPS policies that fall into the first three categories listed above are presumably adopting such provisions in an effort to ensure that any economic and environmental benefits (for example, increased demand or "green jobs") resulting from RPS passage do not leak across the border to other states. Without these in-state constraints, utilities may purchase either renewable electricity or REC's from out-of-state resources, therefore mitigating the strength of an RPS in promoting in-state renewable development. Of course, imposing in-state-requirements may raise the question of violating U.S. Constitution's Commerce Clause(Wiser, 2006). This is also an interesting question but beyond the scope of this paper.

4 Empirical Framework

The primary objective of this paper is to to determine the effectiveness of state-level RPS policies in incentivizing investment in new renewable energy. Alternatively put, to what extent can the recent growth in renewable capacity in the 50 states be attributed to RPS policies?

In order to accurately answer this question, we exploit a lengthy panel of data that allows us to control for unobserved state and year heterogeneity. This is akin to a change-in-changes approach - with state and year fixed effects we control for existing differences between the states as well as exogenous technological progress, giving us consistent coefficient estimates. We estimate several models of the form

$$RENEWSHARECAP_{it} = \alpha_i + \gamma_t + \xi Z_{it} + \delta W_{it} + \beta X_{it} + e_{it} \tag{2}$$

where $RENEWSHARECAP$ is the percentage of generating capacity in a state that is non-hydro renewable, α_i represents a state-specific intercept, γ_t represents year fixed effects, Z_{it} represent other state policies that are designed to encourage renewable investment, and W_{it} represents various social and economic variables that might have an impact on the development of renewable energy. Finally, X_{it} is a measure for the RPS policy that varies both within and between states. In some specifications, we interact X_{it} with a dummy variable that indicates the existence of an in-state requirement, in order to allow the effects to vary according to this feature. Because the error terms are likely to be correlated across time within a state, and because we expect the variance to differ between states, we estimate standard errors that are clustered at the state level.

We constructed our dependent variable, the percentage of generating capacity in a state that is non-hydro renewable ($RENEWSHARECAP$), using the data we discuss in the next section. This measures the relative size of the renewable electricity industry in each state. X_{it} takes different forms in different specifications; in addition to the nominal requirement and incremental requirement measures discussed above, we also use

- RPS is a binary variable that equals 1 if a mandatory RPS law is effective in a given year, and 0 otherwise[8]. If an RPS was legally disputed (as was the case in IA until 1997), we set $RPS = 0$. This is the measure used in Menz and Vachon (2006) and Adelaja and Hailu (2008).

- $RPSTREND$ is a state-wise cumulative sum of RPS, and denotes the number of years that the RPS has been effective.[9] Menz and Vachon (2006) use an analogous measure in some specifications.

In addition to RPS policies, states have also developed and implemented many other policy instruments to encourage installation of renewable generation. We include the following alternative policies in Z_{it} as controls.

- One popular alternative policy is known as a mandatory green power option, under which each utility in the state is required by law to offer its customers the choice of opting to "buy" green power. Consumers opt to pay a premium on their electricity bills, and then the utility must procure enough generating assets or RECs to provide an amount of renewable electricity equal to the amount purchased by those consumers who have chosen this option. $MGPOPTION$ is a binary variable that equals 1 if such a law exists in that state and year. As of April 2009, eight states have a mandatory green power option law.

- Another type of policy designed to encourage development of renewable electricity is known as a public benefits fund. These are state-level funds established and maintained by the state public utility commissions in order to support energy efficiency and renewable energy projects. The funds are collected either by charging consumers a small amount, or by requiring payments from the utilities themselves. $PUBBENFUND$ is a binary variable that equals 1 if, in a given year, a state maintains a public benefits fund that has as part of its mandate the support

[8] We set $RPS = 1$ if the law became effective on or before June 30 of that year. This is the coding rule we adopted for any policies evaluated in this paper. We also experimented with setting this variable equal to 1 if an RPS had just been passed, rather than in effect, and found qualitatively similar results.

[9] To date, no RPS has been repealed.

of renewable energy projects, and 0 otherwise. As of late 2008, 19 states maintain a public benefits fund that supports renewable energy.

- A third type of policy designed to encourage development of renewable electricity is called net metering. Net metering allows for the flow of electricity from consumer-sited installations back to the grid, so that excess generation at such installations can defray the cost of a customer's bill. These laws provide an additional incentive for small, customer-sited generation. $NETMETERING$ is a binary variable that equals 1 if, in a given year, a state has a net-metering law on the books. As of late 2008, 42 states have such a law on their books.

- The last type of policy we control for in this paper is referred to as interconnection standards. These are standards that facilitate the contracting process, making it easier, at both the technical and procedural level, for customer-sited generation to be installed. $INTERCONSTAND$ is a binary variable that equals 1 if a state has codified interconnection standards to facilitate customer-sited renewable energy installation. As of late 2008, 37 states had such laws on their books.

Besides these policy variables, we also include some social and economic variables in the regression analysis, as they arguably might have an impact on the development of renewable energy.

- Electricity Price. Electricity price,$ELECPRICE$, could influence demand for renewable energy resources. On one hand, high electricity prices may reflect the need for the state to seek out alternative energy sources and ensure a viable long-term energy supply, implying that such states would be more likely to develop renewable energy. On the other hand, it may be more difficult to pass on the extra costs of shifting to renewable energy to customers when electricity prices are already high. This suggests that renewable energy could face more resistance in states with high electricity prices. The sign of the overall effect is ambiguous.

- State Income. The transition to renewable energy may cause an increase in electricity prices. States with higher incomes will be more capable of affording the increased price, and therefore are presumably more likely to develop renewable resources. To account for this, we include the median income for 4-person families in each state from 1994 to 2007 in the analysis, which is denoted as $STATEINC$.

- League of Conservation Voters (hereafter, LCV) Scores. In states where citizens have stronger environmental preferences, there may be higher demand for renewable energy development. Following previous studies (e.g. Maxwell, Lyon and Hackett, 2000), we use the average LCV scores of Senators and Representatives in each state,$LCVSCORE$,as a proxy for the environmental preferences of the citizens in the state. Each year, the LCV selects environmental issues that exemplify the environmental agenda with the help of a panel comprising the main U.S. environmental groups. The organization then creates an index by counting the number of times each representative or senator in Congress votes favorably for the "environmental agenda" (e.g., tropical forest conservation or fighting global climate change). The index ranges from 0 to 100, with 100 representing a record of voting with the environmental agenda in all cases.

Finally, we include $INSTATE$ in some regressions. This is a binary variable that equals 1 if the state's RPS obligations must be met with in-state resources, and 0 otherwise. This can arise either because the RPS does not allow REC trading, or because it allows only or strongly favors in-state REC trading. We include this binary variable and its interaction with $INCRQMTSHARE$ in order to evaluate to what extent imposing an in-state-requirement renders an RPS more or less effective in promoting in-state renewable energy development.

In the next section, we discuss the data used in the regression analysis are provided in Table 2.

5 Data

In this section, we describe the data that is used to create the measures laid out in Section 3 and to perform the analysis described in section 4.

As discussed above, one key contribution of this paper is the development of a new measure for the strength of RPS. Once this variable is constructed, we can compare our measure with the more commonly used "nominal" measure. For this purpose, the key task is to calculate $INCRQMTSHARE_{it}$ as defined in equation (1), which requires information on each state's electricity market and RPS policies .

For variables measuring the relative size of the electricity industry in each state, $SALES_{it}$, we employ publicly-available data on electricity sales (EIA-861) from the Energy Information Administration (EIA). EIA data is also critical in the construction of existing eligible renewable generation, $EXISTING_{iT}$. We obtain annual generation data at the generating unit level from the EIA-906 data files.

To code the RPS policies, we use data from a variety of sources. The Union of Concerned Scientists (hereafter, UCS) maintains a database[10] on the design and implementation of existing state standards. Another excellent database that was very helpful in our data collection efforts was DSIRE, the Database of State Incentives for Renewable Energy[11]. We referred to both databases in our coding of the RPS variables, and when necessary, referred to the actual legislation and/or PUC rules to resolve any discrepancies or missing information. We use the following RPS variables.

- $NOMINAL_{it}$, the nominal percentage requirement as written into the law. Every RPS law has an explicitly

[10]http://go.ucsusa.org/cgi-bin/RES/state_standards_search.pl?template=main.

[11]http://www.dsireusa.org/

defined requirement path that evolves over the years. For the handful of states for which the law is coded in absolute capacity terms, rather than as a percentage of generation, we multiply by a constant, called a capacity conversion factor[12], that accounts for the intermittent nature of the most popular renewable technologies, then divide by retail sales in a given year, in order to convert this variable to be in the same units across all of our data.

- $COVERAGE_{it}$, the proportion of retail sales in a state-year that can be attributed to entities that are required to comply with the RPS. We use EIA-861 data to find the proportion of retail sales in each state that are undertaken by each utility or class of utility [13]. These weights are then combined with data from the laws themselves in order to obtain this variable.

- $EXISTING_{iT}$, is the amount of renewable generation in the year prior to the enactment of the RPS policy. We decide what types of existing renewable generation are eligible from the UCS and DSIRE database, and then refer to generating unit level data from EIA-906 in order to aggregate generation from existing eligible plants in year T.

We derive $INCRQMTSHARE_{it}$ based on equation 1. We finish with a balanced panel of $(51 \times 17) = 867$ observations, one for each state-year.

Table 1 shows nominal requirements and incremental requirements in 2006 for the 16 states that had a binding standard in that year. The differences between nominal requirement and incremental requirement are striking. We also rank the states based on nominal requirement and incremental requirement, and the correlation between either the measures themselves or their respective ranks is not statistically different from zero. The two measures are clearly not synonymous.

This table clearly demonstrates the potential pitfalls if the incorrect measure of policy stringency is applied in empirical analysis surrounding questions of RPS impact, regardless of the dependent variable. We argue that our new measure is more accurate, as it explicitly accounts for several key design features that affect the effectiveness of an RPS. It is not hard to imagine that studies on the effectiveness of RPS policies will be highly dependent on the choice of measure employed.

Figure 1 illustrates this point more vividly. In two states that have the most strict *nominal* requirements, Maine and California, the passage of an RPS appears to have had little positive impact on the amount of renewable capacity

[12] These state-specific capacity conversion factors are often either explicitly written into the legislation, as is the case in TX, or implicit from the history of the RPS, as is the case in IA, where part of the afore-mentioned legal dispute centered around the question of whether 105 MW of wind would satisfy the RPS, or whether 260 MW - an amount of renewable generation that would displace 105 MW of conventional capacity - was required under the law. When the capacity conversion factor was not available, we used 0.35.

[13] We find minimal change in these shares over the 7 years for which we have data, so we use 2006 data to construct these weights.

Table 1: Comparison of Measures of RPS Stringency

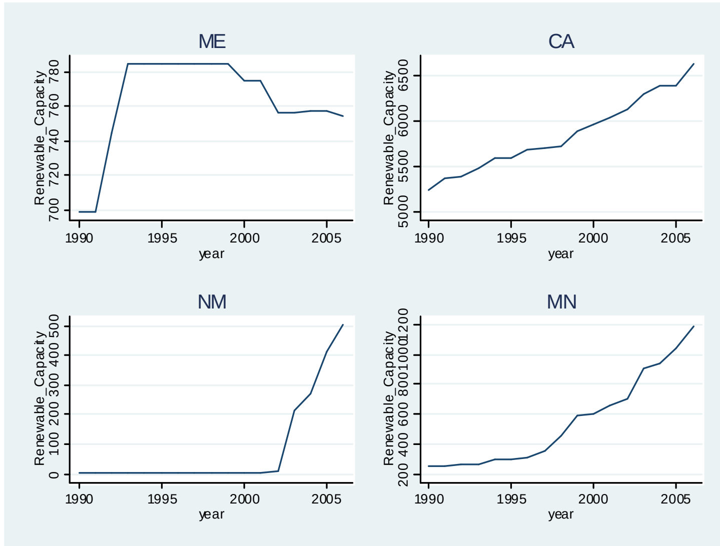
State	Nom. Rqmt	Inc. Rqmt	Rank of Nom. Rqmt	Rank of Inc. Rqmt
ME	30	0	1	14
CA	14.31	0	2	14
HI	8	1.02	3	8
NV	6	0.38	4	12
WI	5.69	1.23	5	7
NM	5	4.33	6	1
NJ	4.58	2.77	7	3
MN	4.36	2.77	8	2
TX	2.04	1.62	9	6
MA	2	1.72	11	5
CT	2	1.8	10	4
PA	1.5	0	12	14
AZ	1.05	0.62	13	10
MD	1	0.05	14	13
IA	0.86	0.67	15	9
NY	0.81	0.49	16	11

in the state. After Maine's first RPS (with a 30% requirement) was written into law in September 1997, the renewable capacity *decreased*. In California, an RPS was passed in September 2002, mandating that 20% of the state's electricity generation be renewables-based by 2010. Yet the growth thereafter appears to be a simple continuation of the pre-existing trend. In contrast, for the two states that rank as No. 1 and No. 2 based on incremental requirement, New Mexico and Minnesota, passage of an RPS appears to have had a strong and positive impact. New Mexico passed an RPS with gradually increasing requirements (starting in 2005) in December 2002, and shortly thereafter we see the first significant installation of renewable capacity in that state. Similarly, in Minnesota, a series of laws mandating installation of renewable capacity was passed starting in 1994. We see jumps in capacity in 1998, 2001, 2002, and 2006, all years in which the binding requirements increased.

In the next section, we study the effectiveness of RPS policies employing these and other measures of policy stringency. While Figure 1 is certainly illustrative, the econometric analysis in the following section includes all states and controls for other policy changes and factors that could also have an impact on our outcome variable.

For other variables we used in the analysis, the depedent variable, *RENEWSHARECAP*, is the share of capacity in a state-year that is based on non-hydro renewable technology. Using EIA-906, we build yearly data files that include all plants that were online in a given year, from 1990 to 2006. We count the capacity of all plants whose primary energy source is classified as non-hydro renewable by EIA. This includes wind, geothermal, and solar generating units, as well as several types of biomass. We then divide by the total capacity in a state for that year to obtain *RENEWSHARECAP*. Information on policies other than RPS is retrieved from DSIRE. For social and economic control variables, data on

Figure 1: **Growth of Renewable Capacity in Selected States**



electricity prices are obtained from the Energy Information Administration[14], data on state income is obtained from US census[15], and data on LCV scores is collected from the League of Conservation Voters[16]. A statistical summary of the data used in the regression analysis is provided in Table 2.

Table 2: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
RENEWSHARECAP	2.393723	3.71222	0	27.36438
RPS	0.162857	0.369499	0	1
RPSTREND	0.7	1.967911	0	13
NOMINAL	0.56992	3.222084	0	30
INCRQMTSHARE	0.069755	0.318363	0	4.330064
MGPOPTION	0.031429	0.174598	0	1
PUBBENFUND	0.164286	0.3708	0	1
NETMETERING	0.347143	0.476402	0	1
INTERCONSTAND	0.171429	0.377153	0	1
ELECPRICE	7.073429	2.161039	3.43	18.33
STATEINC	57.55991	11.46092	32.594	94.441
INSTATE	0.047143	0.212096	0	1
INSTATE*INCRQMTSHARE	0.032045	0.255922	0	4.330064

[14] http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html
[15] http://www.census.gov/hhes/www/income/4person.html
[16] http://www.lcv.org

6 Estimation Results

Table 3 presents results from several estimations of equation (3), and highlights how the estimates of the effectiveness of an RPS are highly dependent on the coding scheme chosen. When the RPS is introduced into the estimation model as a simple binary variable that is turned on when "treatment" is administered, or as a cumulative count of the years a given state has been subject to this treatment, we obtain coefficients on *RPS* that are not significantly different from 0, as shown in the first two columns of Table 3. This result suggests that RPS policies are ineffective in accelerating renewable energy, which is consistent with Michaels (2007)'s claim that RPS policies are largely symbolic.

Table 3: Determinants of Renewable Capacity Share

	1	2	3	4	5
RPS	-0.047				
	[0.413]				
RPSTREND		-0.057			
		[0.200]			
NOMINAL			-0.283		
			[0.047]**		
INCRQMTSHARE				0.526	0.97
				[0.185]**	[0.307]**
MGPOPTION	3.166	3.267	2.934	2.979	2.873
	[0.623]**	[0.805]**	[0.740]**	[0.546]**	[0.514]**
PUBBENFUND	-0.661	-0.594	0.025	-0.733	-0.76
	[0.651]	[0.516]	[0.263]	[0.697]	[0.728]
NETMETERING	-0.764	-0.816	-0.581	-0.705	-0.687
	[0.475]	[0.609]	[0.223]*	[0.465]	[0.499]
INTERCONSTAND	0.588	0.627	0.41	0.525	0.493
	[0.583]	[0.688]	[0.257]	[0.587]	[0.640]
ELEPRICE	-0.157	-0.139	0.113	-0.173	-0.184
	[0.110]	[0.111]	[0.107]	[0.111]	[0.107]+
LCVSCORE	-0.002	-0.002	0	-0.002	-0.002
	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]
STATEINC	0.014	0.018	0.012	0.004	0
	[0.035]	[0.043]	[0.028]	[0.030]	[0.028]
INSTATE					0.415
					[0.511]
INSTATE*INCRQMTSHARE					-0.724
					[0.360]*
Constant	1.294	0.303	-1.961	2.053	2.438
	[2.378]	[2.404]	[1.595]	[1.836]	[1.842]
Observations	700	700	700	700	700
R-squared	0.94	0.94	0.97	0.94	0.94

Robust standard errors in brackets
+ significant at 10%; * significant at 5%; ** significant at 1%
All regressions include state and year fixed effects

In column 3 of Table 3, we instead allow the effect of the RPS policy to be a function of the nominal requirement.

As discussed above, this method has two shortcomings, in that it ignores exemptions from the RPS and it includes generation expected from existing capacity that may be eligible under the policy. So if a state introduces an RPS that is already being met, and new non-renewable capacity is erected in the state (causing the renewable share of capacity to drop), we could actually see a *negative* impact. This is in fact what we observe - the coefficient on *NOMINAL* is negative and significant.

However, in column 4 of Table 3, we instead specify that the renewable share of capacity is a function of the "incremental requirement" associated with an RPS policy. As discussed above, this measure is a much more accurate indicator of the strength of an RPS. Under this specification, we get a much more intuitively appealing result - the coefficient on *INCPCTRQMT* is positive and significant. We interpret this coefficient as follows - an RPS that mandates that the utilities serving a state increase the renewable share of generation by 1 percentage point will result, on average, in a 0.53 percentage point increase in the share of capacity that is designed for renewable resource use. We adopt these results as our preferred specification.

In assessing this coefficient, a couple of points bear mentioning. First, because of the intermittent nature of some types of renewable capacity, one might expect that a 1 percentage point increase in generation should actually be associated with a *much greater* increase in capacity. However, a non-trivial portion of the renewable generation produced in a given year is undertaken at facilities that are not classified by EIA as "renewable". These include, for example, natural gas plants that occasionally use landfill gas as a fuel, or coal plants that occasionally use biomass. A de-meaned regression of $PercentageofRenewableGeneration$ on $PercentageofRenewableCapacity$ yields a coefficient of about 0.68, suggesting that if an RPS was the sole force in driving renewable development and was perfectly enforced, we would expect a coefficient of about 1.47.

There are a number of possible explanations for why the coefficient we observe is significantly less than 1.47. The most obvious are (1) that the policies are not being fully enforced, (2) that utilities find it in their interest to comply through the payment of penalties rather than by installing new capacity or acquiring RECs, (3) that most states are complying with the RPS by purchasing out-of-state RECs, or (4) that much of the renewable development we see is being driven either by other policies or by changes in technology that are affecting both RPS and non-RPS states. Unfortunately, our analysis does not allow us to address precisely why the coefficient is less than 1.47.

We also examine the effect of how an RPS policy treats out of state RECs. In column 5, we introduce *RECFREE-TRADE* and its associated interaction term into our baseline specification. As one might expect, allowing out-of-state REC's mitigates the effectiveness of the RPS significantly. The results suggest that a mandated increase of 1 percentage point of the renewable share of generation will result, on average, in a 0.97 percentage point increase in states that either prohibit or otherwise discourage out-of-state RECs, and in a 0.25 percentage point increase in states that place no restrictions on out-of-state REC's. A Wald test of this latter effect reveals that the resulting impact is no longer significantly different from 0.[17]

With regards to other policy variables, it is interesting to note that on average, the mandatory green power option has both an immediate and persistent impact on the renewable share of capacity in a state. The coefficient for both *MGPOPTION* is positive and significant regardless of how *RPS* is measured. A more surprising set of results is the negative and occasionally significant coefficients on the variables associated with both the public benefits fund and the net metering policy alternatives. Social and economic variables do not offer much explanatory power for the growth of renewable capacity.

Our analysis in this article treats all policies as exogenous, which is clearly a very strong assumption that is unlikely to hold in practice. Work in progress by the authors thoroughly addresses issues of endogeneity as well as examining further dimensions of policy heterogeneity and the question of whether RPS policies to date have led to an increase in electricity prices.

7 Conclusion

As discussed in a previous section, most existing empirical research on the impact of RPS policies has taken a naive approach. This has usually included a cross-sectional approach or the use of very blunt proxies for policies that are in fact very heterogeneous.

In this paper, we have introduced a new way to measure the stringency of RPS. We argue that it is a much better indicator of the magnitude of the incentive provided by an RPS because it explicitly accounts for some RPS design features that may have a significant impact on the strength of an RPS. The difference between this new measure and other more commonly used measures is striking; some seemingly aggressive RPS policies in fact provide only weak incentives, while some seemingly moderate RPS policies are in fact fairly ambitious.

We also investigate the impacts of renewable portfolio standards on the renewable electricity development in a state using our new measure of RPS stringency, and compared the results with those when alternative measures are used. The difference in the estimates is again striking. Using our new measure, the results suggest that, on average, RPS policies have had a significant and positive effect on renewable energy development. These results cast doubt on the argument that RPS policies are purely symbolic. These findings are masked when differences between RPS policies are ignored. We also find that another important design feature – allowing "free trade" of REC's – can significantly weaken the impact of an RPS. It should come as no surprise that the importance of digging into policy

[17] This interpretation assumes that a state's RPS is already in place and is not altering its treatment of out-of-state REC's.

design details is crucial when assessing policy effectiveness. These results should prove instructive to policy makers, whether considering the development of a federal-level RPS or the development or redesign of a state-level RPS.

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