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What's Powering Wind? The Effect of State Renewable Energy Policies on Wind Capacity (1994-2012)

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> "Pop quiz: what source of power doesn't come out of the ground,
> doesn't burn and isn't radioactive? …
> The answer is wind power, the technology that has become
> synonymous with going green" (Walsh 2009).

I. Introduction

This paper examines the influence of two important state renewable energy policies, Renewable Portfolio Standards (RPS) and Green Power Purchase (GPP) programs, on wind capacity in the electricity sector in the United States from 1994 through 2012. Both programs are designed to promote the adoption of renewable generation, but the programs differ in their design and implementation. An RPS is a requirement that utilities in a state provide a certain amount of electricity from renewable energy sources. The amount of electricity generation that must be supplied from renewables varies in percentage and in the year of required implementation (See Table 1).[1] GPP programs, on the other hand, are offered by utilities and provide consumers the opportunity to increase the amount of renewable electricity that is generated through payment of an additional fee on their utility bill. The additional funds are used by utilities to provide an offsetting amount of renewable electricity generation in the amount of the customer's overall electricity use.[2]

The sample period, 1994-2012, encompasses the expansion of commercial scale wind generation beyond states such as California, which participated in the nascent wind energy market in the 1980s. Since then wind energy has grown into a more geographically dispersed and established industry. This growth is motivated by a complex set of factors, including increasing concerns over climate change and energy security. Due to the lower cost of wind generated

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[1] Across states, these policies vary in their requirements for implementation of intermediate renewable mandates, by the mix of renewables that are required, and by the inclusion of restructuring requirements. Additionally some states require newly developed renewable generation, generally put into production after 1999 and some require that the generation take place within the state while others do not (Wiser, Bolinger, and Barbose, 2007, p. 6).

[2] The amount of the fee and the specific rules of the programs vary by utility.

electricity as compared with solar, wind has become the dominant non-hydroelectric renewable energy source for electricity generation.

Previous work by Bird et al (2005) provides a descriptive examination of the factors that are influencing wind capacity development across states. They argue that state tax and financial incentives along with RPS are important policies for promoting wind capacity adoption. In addition to state level policies, Bird et al (2005) contend that lower costs for wind projects are due to federal tax incentives including the Federal Production Tax Credit (PTC).[3] Subsequent to the descriptive literature, several papers have empirically examined the role of renewable energy policies in promoting renewables development, and the findings have been mixed (Carley 2009; Delmas and Montes-Sancho 2011; Shrimali and Kniefel 2011; Yin and Powers 2010). Carley (2009) using a 1998-2006 48-state panel finds that there is no effect of initial RPS implementation on renewable electricity generation, but that the years after an RPS lead to an increased amount of renewable generated electricity. In contrast, Delmas and Montes-Sancho (2011) analyzed capacity rather than generation and found that RPS led to declining renewable electricity capacity using a 1998-2007 panel of 650 utilities across 48-states. The authors also analyzed the Mandatory Green Power Purchase (MGPP) policy and find that it positively influences installed renewable capacity. MGPP programs are state mandates that require utilities to offer GPP programs. Shrimali and Kniefel (2011) also focused on renewable capacity and found a negative impact of RPS on the ratio of non-hydro renewable capacity over total net generation using a 1991-2007 50-state panel. Lastly, Yin and Powers (2010), using a 1993-2006 50-state panel, find that RPS has a positive influence on the percentage of non-hydro renewable generating capacity, but the finding is predicated on the construction of an RPS stringency index.

[3] In order to identify the effects of the state level policies, a state and year fixed effects model is analyzed, which precludes the identification of the effect of the PTC. State level production incentives are considered.

Rather than analyzing across renewable energy sources, I focus on wind capacity alone. As compared with other modern renewable energy sources (i.e. solar, geothermal), wind is the only renewable energy source to make significant inroads into the electricity generation market. In addition, RPS are adopted at the state level and each state's policy varies on key characteristics. These include the magnitude and timing of the final renewables mandate (see Table 1), the sectors which are required to meet the RPS mandate (i.e., investor owned, municipal, or cooperative utilities), whether the renewable generation must occur within the state, and the inclusion of restructuring requirements.[4] Because I am analyzing the average effect of RPS across states with disparate state level policies, determining the effect of these policies on a diverse set of renewable energy sources would be hampered by the diversity in the policy and the outcome variable. In addition, by focusing on wind capacity, I am able to implicitly control for the confounding effects of wind resource availability on policy adoption and policy outcome. I construct an alternative sample that focuses only on states that have commercial scale potential for wind capacity development, the Top Wind sample (See Figure 1 for a list of states and their wind potential).[5] This restricted sample limits the resource heterogeneity in the sample states and allows for improved identification of the policy effects. Lastly, as a robustness check, I use an IV strategy in order to strengthen my identification of the state policy effects.[6]

Other papers that have focused on wind include Menz and Vachon (2006) and Hitaj (2013). Menz and Vachon (2006) using a cross-sectional analysis find that RPS and state Mandatory Green Power Purchase programs (MGPP) are positively related to increases in wind

[4] For several states, such as Texas, the law mandating RPS was part of a larger bill that also deregulated the electricity market.
[5] Previous literature including Carley (2009), Delmas and Montes-Sancho (2011), Shrimali and Kniefel (2011), Yin and Powers (2010) was focused on renewables generation or capacity and therefore a restriction to states with significant wind potential was not required. Hitaj (2013) uses an IV approach to address endogeneity concerns.
[6] The instruments used in the analysis are a subset of those used by Hitaj (2013). However, Hitaj used a linear IV strategy as a robustness check, while I implement an IV Tobit fixed effects specification due to the truncated nature of the dependent variable (See the Empirical Section for more details).

energy development.[7] Hitaj (2013) provides a county-level analysis of several state-level renewable policies over the period 1998-2007. She finds that RPS did not have a significant influence on wind capacity.[8] Like Shrimali and Kniefel (2011), Hitaj constructs a linear extrapolation of the RPS mandate instead of using a binary indicator. While several states have intermediate mandates, a linear assumption may not be representative of the true policy implementation.[9] In order to more fully examine the role of RPS, I have analyzed both a binary indicator and a linear extrapolation of the RPS.

1.1 Background

Wind is an abundant renewable energy resource in the United States. It is estimated that wind energy could supply 20% of the electricity in the United States (Elliott, Wendell, and Glower 1991, p. B-1).[10] In order to emphasize the theoretically feasible supply of wind energy, it is often noted that "the wind potential of just three states – North and South Dakota and Texas – could supply all the country's electricity" (Gipe 1995, p. xiii - xiv). The impressive U.S. wind potential findings in this 1991 report are reinforced by a 2010 wind potential study. The wind potential estimates in the new report exceed those presented previously due in large part to improvements in wind technology. While the potential findings are only theoretically feasible,

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[7] Due to their limited number of cross-sectional observations, Menz and Vachon (2006) were not able to exclude states that do not have sufficient wind potential for commercial wind generation. (See Figure 1 for wind potential by state.)

[8] While county level analyses may add additional variation, because my focus is primarily on state level policies, I use a state-year panel. In addition, the county-level analysis resulted in a sample in which 99 percent of the observations in the outcome variable were zero (Hitaj, 2013, p. 402). As in this paper, a Tobit was used to address the truncation, but the degree of truncation is reduced to 54 percent for the Full Sample and 35 percent for the Top Wind sample for the state level analyses in this paper.

[9] For instance, the Colorado RPS was effective in 2004 with an initial intermediate mandate of 3% in 2007, increasing to 5% 2008 and incrementally increasing to 20% in 2020. A linear extrapolation would instead by constructed as a constantly annually increasing mandate. For example, a 20 percent RPS mandate 5 years in the future would be constructed as increasing at a constant rate of 4 percent a year.

[10] Wind potential calculations indicate the amount of wind that a state or region is theoretically capable of producing under a specific set of assumptions, excluding transmission limitations. The calculations are based on an assumption of 5 MW/km^2 of installed capacity.

they provide an upper bound on the wind energy potential in the Unites States and demonstrate that the historical level of wind energy development is small in comparison with the resource available.

1.1.1 History of Wind energy development in the United States

Commercial wind capacity development in the United States began in the 1980s. It was the first time in U.S. history that wind projects included multiple wind turbines sited together rather than implementing a single turbine at each site (Gipe 1995, p. 13). It was during this time that the notion of a wind farm developed. The impetus for wind capacity development was the same as that for all renewable energy, a “scramble to develop alternative energy after the oil embargoes of the 1970s” (Gipe 1995, p. 2). The initial commercial wind capacity development in the 1980s was limited to a few states, primarily California.[11] The mid-1980s represented the first peak in wind capacity development. This peak however pales in comparison to the growth in wind capacity that has been seen since then.[12]

A lull in wind capacity development in the early 1990s was followed by a period of significant wind capacity additions beginning in the late 1990s (AWEA 2009). By 2000, wind projects were dramatically increasing in size compared with their 1980s counterparts. Total wind capacity was also increasing, by 2003, U.S. wind capacity had maintained an average annual growth rate of 24.5 percent for the previous five years and as of 2005, the United States was the worldwide leader in wind capacity additions (AWEA 2003, p. 2). This trend continued through 2012, the wind energy industry continued to expand, with a 29 percent average annual five-year growth rate (AWEA 2012).

[11] According to the AWEA projects database Minnesota had one small wind project, < 1 MW in 1987. All other commercial scale wind projects prior to 1992 were in California.

[12] The 1980s peak coincided with the expiration of federal energy tax credits in 1985 and California energy tax credits that also expired in the mid-1980s.

While wind projects have been sprouting up throughout the United States, the increase in U.S. wind capacity is not matched by a correspondingly dramatic increase in renewable electricity production from wind. Wind power in 1999 provided less than 1 percent of total U.S. electricity (AWEA 1999, p. 1). This remained true though 2006 and by 2012, wind generated 3.5 percent of the nation's electricity (AWEA 2006, p. 2).[13] Despite this small increase in the percentage of total electricity generated from wind, it has made inroads in terms of new generating capacity. From 2000 to 2004, wind contributed only 4 percent of all new electricity generating capacity in the United States and since then there has been a steady rise. In 2005, wind's contribution increased to 12 percent. By 2012, wind accounted for 43 percent of new electricity generating capacity. In 2012, capacity additions from wind were the top source of new capacity additions, exceeding those for all renewable and non-renewable sources (Wiser and Bolinger 2013, p. iv).

II. Data

The goal of this paper is to determine the influence of RPS and GPP policies on wind capacity after controlling for a variety of electricity market factors. Figure 2 demonstrates that of the total U.S. cumulative wind capacity, capacity was predominantly added by states that had or subsequently passed a GPP or RPS policy. States that adopt these policies are often the same states that have added wind capacity and this correlation has led to the naïve conclusion in some popular literature that the policies are leading to wind capacity adoption. This analysis is focused on determining whether the correlation, in fact, indicates that the policies on average lead to greater wind capacity development.

[13] http://www.eia.gov/totalenergy/data/monthly/archive/00351411.pdf

The period for the analysis covers the years 1994 through 2012, a period of rapid growth in wind energy development and a time of rapid change in terms of both the regulatory environment and energy market. While the dramatic rise in commercial scale development did not occur until 1998, 1994 represents the first year when a state other than California implemented projects of greater than 1 MW with the exception of two projects in Hawaii in the 1980s (AWEA 2009).[14,15] Figure 3 demonstrates the marked 1998 increase in wind capacity development and its more marginal rise beginning in 1994.

There are two samples that are analyzed for this project, the Full Sample, all U.S. states, and the Top Wind sample, states that are ranked in the top 20 in wind potential. Wind potential is a set of measures that provide information on the amount of wind that a state is capable of producing. A key reason that wind potential was a constraining factor in sample definition is that the policies that I analyze are not wind specific, they are focused on renewables generally. In particular, states with RPS or GPP, but without commercial scale wind potential are not included in the Top Wind sample. While the policies in these states may influence renewables development generally, it would not be expected to lead to increases in wind capacity within the state.[16] In addition, as mentioned previously, wind resource availability may influence RPS or GPP adoption.

To construct the Top Wind sample, I used two measures of wind potential. First, I used the measure of wind potential constructed in 1991 (Elliott, Wendell, and Glower 1991, p. B-1).[17]

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[14] Commercial scale development began in Hawaii in 1985, in Iowa in 1992 and prior to 1985 in California.
[15] Hawaii and Alaska are excluded from the analyses, instead I focus on the contiguous United States.
[16] The cross-state impacts of RPS programs are not analyzed in this paper. While some RPS do allow for the importation of wind generation from other states, this analysis focuses only on within-state impacts.
[17] The 1991 measure was for the contiguous U.S., excluding Hawaii and Alaska. It was developed by the Pacific Northwest Laboratory under a scenario that all areas with class 3 or higher wind resources were developed. Further, certain lands that were unlikely to be developed were excluded such as lands that were protected due to environmental concerns, in certain urban, forested, or agricultural setting. This is referred to as scenario 3 (Elliott, Wendell, and Glower 1991, p. B-1).

Second, I used the updated 2010 wind potential measurements constructed by NREL (NREL 2010). The two measures differ based on technological and land use assumptions.[18] The top 20 states based on both the 1991 and 2010 wind potential measures were used to identify sample states, which due to overlap, led to a sample of 23 states. Figure 1 includes the wind potential rankings by state for the Top Wind sample using the 2010 potential information.

In addition to wind potential, the other key wind variable is wind capacity. The dependent variable, wind capacity by state and year, is collected from the Energy Information Association (EIA).[19]

2.1 Regulations

The Database of State Incentives for Renewables & Efficiency (DSIRE) was used to construct the RPS variables.[20,21] RPS is the most widely discussed and popular state program. As stated previously, it is a requirement that the utilities in a state produce a certain amount of electricity using renewable energy sources. It is widely touted as a critical factor for renewable energy development and in particular wind energy development (Cory and Swezey 2007; Langniss and Wiser 2003; Rader and Norgaard 1996; Wiser, Porter, and Grace 2004; Wiser, Bolinger, and Barbose 2007). This conclusion is noteworthy given that the design and components contained in each RPS vary across states and time. It is also a strong conclusion

[18] For instance, the 1991 measure was constructed at 50m due to the availability of wind technology at the time, while the 2010 measure was constructed at 80m.

[19] Capacity, measured in megawatts, is the amount of power that a wind turbine is capable of producing. (Gipe,1995, p.9) The EIA reports cumulative state year capacity.

[20] The database "is a comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency. Established in 1995 and funded by the U.S. Department of Energy, DSIRE is an ongoing project of the North Carolina Solar Center and the Interstate Renewable Energy Council" (DSIRE, 2009).

[21] State production incentives were also collected from the DSIRE database and analyzed. The measure included those production incentives that were established at the state level and included support for wind generation, specifically programs such as feed-in-tariffs. The policy was consistently not significant and is not reported in the results presented here in order to focus my IV identification on the two policies of interest, RPS and GPP.

given that RPS are often non-binding constraints because the year of implementation of the final renewables generation mandate is generally outside the sample time frame. In order to examine the role of RPS, I analyzed a binary indicator and a linear extrapolation using the final RPS mandate listed in Table 1. The linear RPS variable is constructed so that the mandate is applied at a constant rate from the year the policy is effective until the year of the final mandate.[22] As opposed to the binary RPS variable, the linear RPS variable implies that from the effective year of the RPS, there is a constantly increasing wind generation requirement with a maximum value defined using the policy's final percentage mandate.[23] In addition to providing a measure of RPS that takes into consideration its potentially increasing stringency over time, the linear RPS implicitly controls for variation in the stringency of the RPS policies across states.

To supplement the regulation information provided in the DSIRE database, I used data from the Green Pricing, Utility Programs by State information that is provided by the Department of Energy, Energy and Efficiency Program to construct a Green Power Purchasing indicator (DOE 2010).[24] As stated previously, GPP programs offer consumers the opportunity to increase the amount of renewable electricity that is generated through payment of an additional fee on their utility bill. While not a direct purchase of renewable energy, the programs are designed to increase the overall amount of renewable electricity generation. These programs are implemented by utilities and therefore each state can have multiple programs starting in different years. Two GPP indicators were analyzed, a GPP indicator and a GPP sum indicator. The first GPP variable, GPP indicator, is binary variable, it indicates the year that a utility in the state

[22] For example, a 20 percent RPS policy implemented in year 1 with a mandate 5 years in the future would be constructed as 4 percent in year 1, 8 percent in year 2, etc.
[23] For Texas, whose mandate is defined in terms of MW, I converted it to a percentage using 1999 total generation and an assumed capacity factor of 35 percent.
[24] The GPP programs that I analyzed are those that included wind as one of the allowable renewable sources.

adopted a GPP program. The second GPP variable, GPP Sum is an aggregate measure, it is a sum of all GPP programs active in each state and year.

In addition, because GPP programs are offered at the utility level, in order to better measure the potential influence of GPP programs, I analyzed the effect of an additional variable, residential customers per GPP policy.[25] As a proxy for customer availability of GPP programs, this variable provides an additional measure of GPP influence which takes into consideration the magnitude of GPP program influence.[26] To encourage the development of GPP programs some states have also mandated that utilities offer a green power option to their customers. MGPP programs are analyzed to determine the potentially disparate impacts of state programs directed at utilities and utility programs offered directly to consumers.

2.2 Market Factors

Data on state level electricity market factors includes total annual electricity generation and annual fossil fuels capacity from the EIA. Specifically, I analyzed coal and natural gas capacity because they are the two most common fuels used for electricity generation in the United States. In addition, I controlled for the influence of annual average wind project costs.[27] As far back as 1989, cost estimates for wind power had been estimated to be in line with conventional sources and were predicted to fall further (Gipe 1995, p. 226). The AWEA argued in 2002 that the "cost of wind power at efficient wind farms has declined to a range that is close

[25] According to data provided by the EIA, GPP programs are largely utilized by residential rather than commercial or industrial users. In 2012 approximately 96 percent of GPP customers were residential users (http://www.eia.gov/electricity/data/eia826/).

[26] Detailed data on the number of customers using GPP programs from the EIA is not available over the full sample period. The EIA began collecting green pricing data in 2008 (http://www.eia.gov/electricity/data/eia826/).

[27] Project costs include average annual "turbine purchase and installation, balance of plant, and any substation and/or interconnection expenses" (Wiser and Bolinger, 2009, p. 33). In addition to project costs, the AWEA suggests that proximity to transmission lines is a key consideration for wind project development because of the increased costs associated with increased distance from transmission capability (AWEA, 2009b). The direct role that transmission line density may play in mitigating or driving wind development is left for future work. For this paper, total net generation acts as a proxy for state population growth.

to competitive with several forms of conventional power and less expensive than nuclear" (AWEA 2002, p. 7). This is consistent with the argument put forward by Wiser (2007) that declining costs since 1994 combined with the PTC, which lowers the cost of wind by about 1/3, make wind a cost effective source of energy (Wiser 2007). Average costs were following an overall declining trend through 2004 when prices began to rise above 1994 levels. They were approximately $3500 per kilowatt in 1985, but had fallen to just over $1700 per kilowatt by 1994. By 2008, the average costs had increased to just over $1900 per kilowatt, but this was still only approximately 55% of the 1985 costs (Wiser and Bolinger 2009, p. 33). According to Bolinger and Wiser (2011), the expected decline in per kWh costs of wind power due to technological improvements did not happen through 2008 and instead costs were rising dramatically. This trend reversed itself in 2010, when costs began to fall once again.

III. Empirical Specification

The empirical analysis is focused on measuring the influence of two state renewable energy policies, RPS and GPP, on wind capacity after controlling for market factors. The state-year panel allows for the identification of impacts from the policy variables that change at most annually at the state level. The state and year fixed effects specification controls for all time invariant state characteristics, and the effects of annual national economic and policy changes that influence both the RPS and non-RPS states in the sample. Still, the possibility of endogeneity exists due to unmeasured state-level heterogeneity in political and resource potential, which may lead to RPS or GPP policy adoption and wind capacity development. To address concerns over unmeasured economic or political factors, I have implemented an instrumental variables strategy. The instruments that I use are the percentage of Democrats in the State's Lower and Upper Houses. While these variables are expected to be directly associated with state renewable policy adoption, after controlling for the renewable policies and electricity market factors, they are not expected to have a direct effect on wind capacity additions.[28]

Due to the distribution of the dependent variable a fixed effects Tobit specification was implemented. The dependent variable is censored at zero with approximately 54 percent of the observations at zero for the Full Sample and 35 percent at zero for the Top Wind sample. Random effects (RE) Tobit was also considered because the fixed effects Tobit specification is potentially biased by the incidental parameters problem. Following Greene (2004), while the coefficients are estimated correctly, there is a downward bias in the standard errors. This bias decreases significantly as T increases and because T=19, it is not expected to affect the inference of statistical significance. Also, although RE Tobit is a suggested solution to the bias of the FE Tobit, Greene (2004) demonstrates that for estimation of continuous variables of interest in a Tobit model, FE Tobit is the preferred estimator (Greene, 2004, p. 143).[29]

It is important to note that the IV Tobit estimators that I've used assume continuous endogenous regressors and so only the RPS Linear and GPP Sum variables are analyzed.[30] Due to the distribution of these variables, an IV Tobit specification, with a Tobit specification in both the first and second stage would better fit the data, however, to my knowledge that specification is not available. The IV Tobit estimates should be interpreted with this limitation in mind.

The specification of the fixed effects model is:

$$Y_{it} = \propto + \beta_1 R_{it} + \beta_2 CAP_{ng_{it}} + \beta_3 CAP_{c_{it}} + \beta_4 W_t + \beta_5 Q_{e_{it}} + \varepsilon_{it}$$

where Y ~ (0, ¥**)**

[28] While it is not possible to rule out all other avenues of political influence that may affect wind capacity, I have run tests to determine if the instruments are properly excluded from the second stage. The findings indicate that they are properly excluded from the second stage in both samples; that the excluded instruments do not have a direct statistically significant effect on wind capacity additions after controlling for the policies, electricity market characteristics, and state and year fixed effects.

[29] In addition, an IV Tobit with RE specification is unavailable to verify the findings.

[30] There are 2 estimators available in Stata, the Newey (1987) efficient two-step estimator and the IV MLE Tobit estimator; I used the Newey estimator.

and i = state, t = year. Y_{it} represents the annual state wind capacity. R is an indicator of the policy variables of interest, RPS and GPP. CAP_{ng} and CAP_c are measures of natural gas and coal generation capacity.[31] Coal and natural gas are the predominant fuels used for electricity generation in the United States. W includes average annual wind project costs.[32] Lastly, Q_e, is a measure of the total net electricity generation in each state and year. Total net generation controls for dynamic changes in the demand for electricity that are disparate across states due to a variety of political, economic, and geographic factors. The state and year FE Tobit results are presented in Tables 3a and 3b; columns 1 and 2 contain the findings for the Full Sample and columns 3 and 4 contain the findings for the Top Wind sample.

For robustness, Table 4 contains the Tobit results for the instrumental variables specifications. The findings in Table 4 include results from the first stage F-test that indicate that the instruments are strong instruments for both policies. Further, for the Top Wind sample, the Wald test of exogeneity indicates that there is not sufficient information to reject the null hypothesis that there is no endogeneity for the sample.[33] This indicates that the FE Tobit specifications may be sufficient for determining the effect of these policies for the Top Wind sample. For the Full Sample, the presence of endogeneity in the sample cannot be rejected at the 10 percent level.

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[31] In addition to natural gas capacity, real commercial natural gas price was also analyzed to determine if the more dynamic changes in natural gas price were associated with changes in wind capacity. Natural gas prices were consistently insignificant across samples and the coefficients on the policy variables of interest were consistent with those presented.

[32] Turbine size (MW) was also analyzed, but was consistently not significant. The measure is available only back to 1998 and so was not included in the main results presented. The coefficients on the policy variables of interest were consistent for the 1998-2012 sample, with or without the inclusion of the turbine size variable.

[33] The p-value for the exogeneity test is 0.72 for the Top Wind sample and 0.0984 for the Full Sample.

IV. Results

To begin the discussion of the regression results, I focus on one of the most widely known and discussed renewable policies, RPS. The AWEA has consistently advocated for RPS as an important regulatory mechanism for supporting the growth of wind capacity. The descriptive literature has generally supported the supposition that RPS lead to additional renewable energy development (Langniss and Wiser 2003; Wiser, Porter, and Grace 2004; Wiser and Barbose 2008; Menz and Vachon 2006). Counter to the largely descriptive literature on renewable energy development, Delmas and Montes-Sancho (2011), Shrimali and Kniefel (2011), and Hitaj (2013) find that RPS implementation does not increase renewable development.

In this analysis, my findings support the previous empirical work; I find that RPS implementation has an insignificant influence on wind capacity additions in both the Full Sample and the Top Wind sample (See Tables 3a and 3b).[34] The findings are consistent for both the binary (Table 3a) and the linear RPS (Table 3b) variables. In addition, the IV specification supports the fixed effects results (Table 4). The average effect of RPS on wind capacity additions across states was insignificant. It is important to note that states without an RPS, such as Oklahoma have added wind capacity in recent years for export to other states. While the findings indicate that state RPS are not having a statistically significant effect on within state wind

[34] The analyses were also run with optional RPS states excluded and the findings are consistent with those presented in Tables 3a and 3b. In addition, in order to control for the potentially confounding effects of electricity market restructuring, I included a deregulation indicator. The coefficient on the deregulation variable was consistently not significant and the coefficients on the policy variables of interest remained insignificant.

capacity additions, this analysis does not indicate that RPS implementation is ineffective generally.[35]

For GPP programs, there is a positive and statistically significant influence on the amount of wind capacity in the Full Sample. The results in Table 3b demonstrate that for each GPP program added there is approximately 7 MW of additional wind capacity. The findings demonstrate modest wind capacity additions from the implementation of multiple GPP programs, however, the finding is not robust. The coefficients on the binary GPP indicator, and IV estimation of the GPP Sum indicator indicate that the GPP influence is not statistically significant.[36] Also, for the Top Wind sample, the coefficients on the GPP variables are consistently not significant (See Tables 3a, 3b, and 4). [37]

In terms of the market factors, the findings indicate that total net generation and project costs have a statistically significant relationship with wind capacity. As expected, increased electricity generation is associated with increased wind capacity. Also, as hypothesized, there is a negative association with wind capacity and project costs. The findings are particularly robust for the Top Wind sample, coefficients on both variables are statistically significant for the FE and IV FE specifications. The finding is stronger in the Top Wind sample, but remains significant across samples in the IV analyses.

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[35] In order to analyze the inter-state influence of RPS would require an analysis of the Renewable Energy Credit (REC) markets and examination of firm level contracts for interstate trade of renewable electricity, which is beyond the scope of this paper.
[36] In addition, I examined the number of customers per GPP program in order to include a measure of customer availability of GPP programs, the coefficient on this variable was not statistically significant for either sample.
[37] In addition to utility specific GPP programs, the results indicate that MGPP programs implemented at the state level do not consistently influence wind capacity additions. For the Top Wind sample, MGPP programs had a statistically significant influence on the probability of adding wind capacity, however, the finding became insignificant when an IV Tobit FE specification including the MGPP variable was analyzed. Results available upon request. Note that the IV Tobit specification assumes a continuous endogenous regressor, while the MGPP variable is binary.

In order to further explore the policy variables, I have included interaction terms for the RPS and GPP variables. While they may not have independent effects on wind capacity additions, the policies are often implemented jointly and the interaction terms allow for the determination of the effects of the joint policy environment. The results in Table 5 indicate that there is a joint influence of RPS and GPP on wind capacity additions in the Top Wind sample, but the finding is not robust to the specification which includes the RPS Linear and GPP Sum indicators and is statistically significant at only the 10 percent level. Overall, the policy interaction is not robustly significant.

V. Discussion

The findings in this paper indicate that while there have been significant commercial scale wind generation capacity additions across the United States, neither RPS nor GPP programs had a significant impact on within state wind capacity. While the interstate influence of RPS was not addressed in this analysis, the popular wisdom has been that RPS were critical for generating wind capacity additions generally. GPP programs have also been lauded as successful programs for increasing wind capacity, but while they had a positive and significant influence in the Full Sample, the findings were not robust. In addition, the findings indicate that the joint effects of the two policies were not significant. While there remain open questions as to the full benefits that are generated from RPS and GPP programs, my findings do not indicate that the policies have been effective in increasing within state wind capacity on average across states over the period 1994-2012. The adoption of both programs has been predicated on the goal of increasing the amount of renewable capacity on the electricity grid and my findings do not support the popular wisdom that these programs have been successful.

VI. Conclusion and Policy Implications

This paper demonstrates that renewable energy regulations are not universally significant in influencing wind capacity development. The renewable policy environment across states is at a crossroads, particularly in terms of RPS. Recent legal and legislative efforts to repeal or weaken RPS have been undertaken in a number of states including California, Colorado, Kansas, Massachusetts, Minnesota, and Ohio (Plumer 2013; Gallucci 2013). In May 2014, Ohio legislators voted to halt the continued implementation of the state's RPS, which was passed in 2009 (Cardwell 2014). Also, although RPS survived repeal bills early this year in Kansas and North Carolina, they may be picked up again later in the year. Due to these political events and other recent findings that RPS are not increasing renewables development (Delmas and Montes-Sancho 2011, Shrimali and Kniefel 2011, and Hitaj 2013), these repeal efforts may pick up steam. This paper has contributed to the RPS literature by establishing that the previous findings on RPS apply, even in wind resource rich states. It is therefore important to note, that this paper has examined only the within-state influence of RPS and GPP policies, and leaves open questions for future work. In particular, the examination of each of the policy characteristics to determine if the design of the program is a critical factor in determining its success. As stated previously, RPS policies vary in the timing and magnitude of both intermediate and final renewable mandates, whether interstate tradable renewable energy credits (RECs) are allowed, by the mix of renewables that are required, and by the inclusion of restructuring requirements. GPP are also disparate and vary by utility, including differences in the types of renewables and the fee charged to consumers. Although this research does not find a significant effect of the policies on average, the success of the policies in promoting wind capacity may vary significantly across states. The market for wind generated electricity continues to expand and policies can be influential in promoting continued growth in wind capacity, but evidence in this paper on two of the most popular state programs indicates that the within state impacts have been limited.

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Tables and Figures

Table 1: RPS/MGPP Mandate by State and Year of Implementation

State	Year Effective (RPS/MGPP)	Final RPS Mandate[c]	State	Year Effective (RPS/MGPP)	Final RPS Mandate[c]
Arizona	2007	15% by 2025	Nevada	1997	25% by 2025
California	2003	25% by 2016	New Hampshire	2007	25% by 2025
Colorado	2005	20% by 2020	*New Jersey*	1999/2003	20% by 2020
Connecticut	1998/*2003*	27% by 2020	***New Mexico***	2004/2003	20% by 2020
Delaware	2005	25% by 2025	**New York**	2004	29% by 2015
Hawaii	2004	40% by 2030	North Carolina	2008	12.5% by 2021
Illinois	2011	25% by 2025	**Ohio**	2009	12.5% by 2024
Iowa	1983/2001	105 MW by 1999	***Oregon***	2007/2002	25% by 2025
Kansas	2009	20% by 2020	Pennsylvania	2005	18% by 2020
Maine	2000/2010	40% by 2017	Rhode Island	2004	16% by 2019
Maryland	2004	20% by 2022	**Texas**	1999	10,000 MW by 2025[d]
Massachusetts	2002	15% by 2020	*Vermont*	/2008	
Michigan	2008	10% by 2015	*Virginia*	/2003	
Minnesota	2007/2010	25-30% by 2020	*Washington*	2007/2001	15% by 2020
Missouri	2009	15% 2021	**Wisconsin**	1999	10% by 2015
Montana	2005/2003	15% by 2015			

a: States in **bold** are ranked in the top 20 in wind potential. The final mandates of the RPS policies have evolved over time, often becoming more stringent. The latest policy in effect during the 1994-2012 period is listed.
b: States in *italics* have also passed an MGPP program. The second year listed in the table is the effective year of the MGPP policy.
c: Percentage of electricity generated from renewable energy.
d: 10,000 MW translates to 8.5 percent of total 1999 generation using a capacity factor of 35 percent.

Table 2a: Summary Statistics – Full Sample

	Mean	Median	Standard Deviation	Minimum	Maximum
Wind Capacity (MW)	290.23	0	946.02	0	12185.00
NG Capacity (MW)	6881.37	2885.265	11447.36	0	80367.00
Coal Capacity (MW)	6747.79	5036.00	6514.31	0	25217.40
Total Net Generation (MWH)	7.65×10^{07}	5.31×10^{07}	6.90×10^{07}	4488213	4.35×10^{08}
Capacity-Weighted Average Project Costs ($/MW)[a]	1774944.00	1681000.00	341913.30	1283378.00	2481515.00
GPP Sum	1.93	0	3.26	0	17
RPS Linear	1.65	0	3.90	0	30.59

a: Project costs data is reported in real 2013 U.S. dollars.

Table 2b: Summary Statistics – Top Wind Sample

	Mean	Median	Standard Deviation	Minimum	Maximum
Wind Capacity (MW)	571.95	51	1314.48	0	12185
NG Capacity (MW)	8422.46	2936.10	15182.26	0	80367.00
Coal Capacity (MW)	7483.97	5472.00	7102.50	18.25	25217.40
Total Net Generation (MWH)	8.32×10^{07}	5.14×10^{07}	8.23×10^{07}	6136605	4.35×10^{08}
Capacity-Weighted Average Project Costs ($/MW)[a]	1774944.00	1681000.00	341913.30	1283378.00	2481515.00
GPP Sum	3.13	2	3.59	0	15
RPS Linear	1.90	0	4.53	0	30.56

a: Project costs data is reported in real 2013 U.S. dollars.

Results

Table 3a: Tobit Fixed Effects: (Marginal Effects)

Dependent Variable: Wind Capacity	Full Sample: Probability of Wind Capacity Additions	Full Sample: Expected Change in Wind Capacity	Top Wind Potential: Probability of Wind Capacity Additions	Top Wind Potential: Expected Change in Wind Capacity
RPS	-0.000688	-1.629	-0.0374	-25.04
	(-0.0629)	(-0.0659)	(-0.234)	(-0.231)
GPP indicator	0.00606	13.88	-0.126	-88.81
	(0.545)	(0.822)	(-0.850)	(-0.788)
Coal Generation Capacity (MW)	1.71×10^{-05}	0.0401	0.000142	0.0961
	(0.443)	(0.947)	(1.030)	(0.950)
NG Generation Capacity (MW)	1.16×10^{-06}	0.00272	-1.09×10^{-05}	-0.00741
	(0.810)	(1.403)	(-0.674)	(-0.641)
Total Net Generation (MWH)	2.09×10^{-09}	4.90×10^{-06}	**3.86×10^{-08}*****	**2.62×10^{-05}*****
	(0.510)	(1.366)	(4.126)	(3.861)
Capacity-Weighted Average Project Costs ($/MW)	-9.50×10^{-08}	-0.000222	**-1.74×10^{-06}*****	**-0.00118*****
	(-0.535)	(-1.551)	(-5.977)	(-5.144)
Observations	931	931	418	418
Number of States	49	49	22	22
Pseudo R-squared	0.15	0.15	0.13	0.13

Note: robust t-statistics in parentheses, *** p<0.01, ** p<0.05, *p<0.1. State and Year indicators are included with errors are clustered at the state level. Iowa is excluded because the effective date for RPS significantly pre-dates the sample period and is defined in MW, therefore, the binary RPS indicator is 1 for the sample period and RPS Linear variable is not defined. The findings are not affected by the inclusion of Iowa.

Table 3b: Tobit Fixed Effects: (Marginal Effects)

Dependent Variable: Added Wind Capacity	Full Sample: Probability of Wind Capacity Additions	Full Sample: Expected Change in Wind Capacity	Top Wind Potential: Probability of Wind Capacity Additions	Top Wind Potential: Expected Change in Wind Capacity
RPS Linear	-0.000128	-0.267	0.00113	0.765
	(-0.104)	(-0.106)	(0.0694)	(0.0695)
GPP Sum	0.00338	**7.033***	-0.00656	-4.443
	(0.576)	(1.653)	(-0.435)	(-0.434)
Coal Generation Capacity (MW)	2.07 x 10-05	0.0430	0.000144	0.0975
	(0.448)	(0.941)	(0.971)	(0.895)
NG Generation Capacity (MW)	1.21×10^{-06}	0.00251	-1.08×10^{-05}	-0.00735
	(0.881)	(1.438)	(-0.612)	(-0.583)
Total Net Generation (MWH)	2.40×10^{-09}	4.99×10^{-06}	**$3.87 \times 10^{-08***}$**	**$2.62 \times 10^{-05***}$**
	(0.523)	(1.379)	(3.840)	(3.623)
Capacity-Weighted Average Project Costs ($/MW)	-1.11×10^{-07}	-0.000231	**$-1.71 \times 10^{-06***}$**	**-0.00116*** **
	(-0.543)	(-1.513)	(-5.154)	(-4.519)
Observations	931	931	418	418
Number of States	49	49	22	22
Pseudo R-squared	0.15	0.15	0.13	0.13

Note: robust t-statistics in parentheses, *** p<0.01, ** p<0.05, *p<0.1. State and Year indicators are included with errors are clustered at the state level. Iowa is excluded because the effective date for RPS significantly pre-dates the sample period and is defined in MW, therefore, the binary RPS indicator is 1 for the sample period and RPS Linear variable is not defined. The findings are not affected by the inclusion of Iowa.

Table 4: Instrumental Variables -Tobit Fixed Effects (Marginal Effects): Second Stage

	Expected Change in Wind Capacity	
Dependent Variable: Added Wind Capacity	**Full Sample**	**Top Wind Potential**
RPS Linear	-238.0	-55.05
	(-1.117)	(-0.335)
GPP Sum	501.8	109.5
	(0.891)	(0.443)
Coal Generation Capacity (MW)	**0.367****	**0.375*****
	(1.987)	(2.752)
NG Generation Capacity (MW)	0.0275	-0.00265
	(1.156)	(-0.0420)
Total Net Generation (MWH)	**4.94×10^{-05}*****	**6.13×10^{-05}*****
	(5.526)	(3.046)
Capacity-Weighted Average Project Costs ($/MW)	**-0.00307****	**-0.00338*****
	(-2.317)	(-2.584)
RPS Linear F-test	51.17	10.32
(first stage instruments)	(0.000)	(0.000)
GPP Sum F-test	14.42	11.71
(first stage instruments)	(0.000)	(0.000)

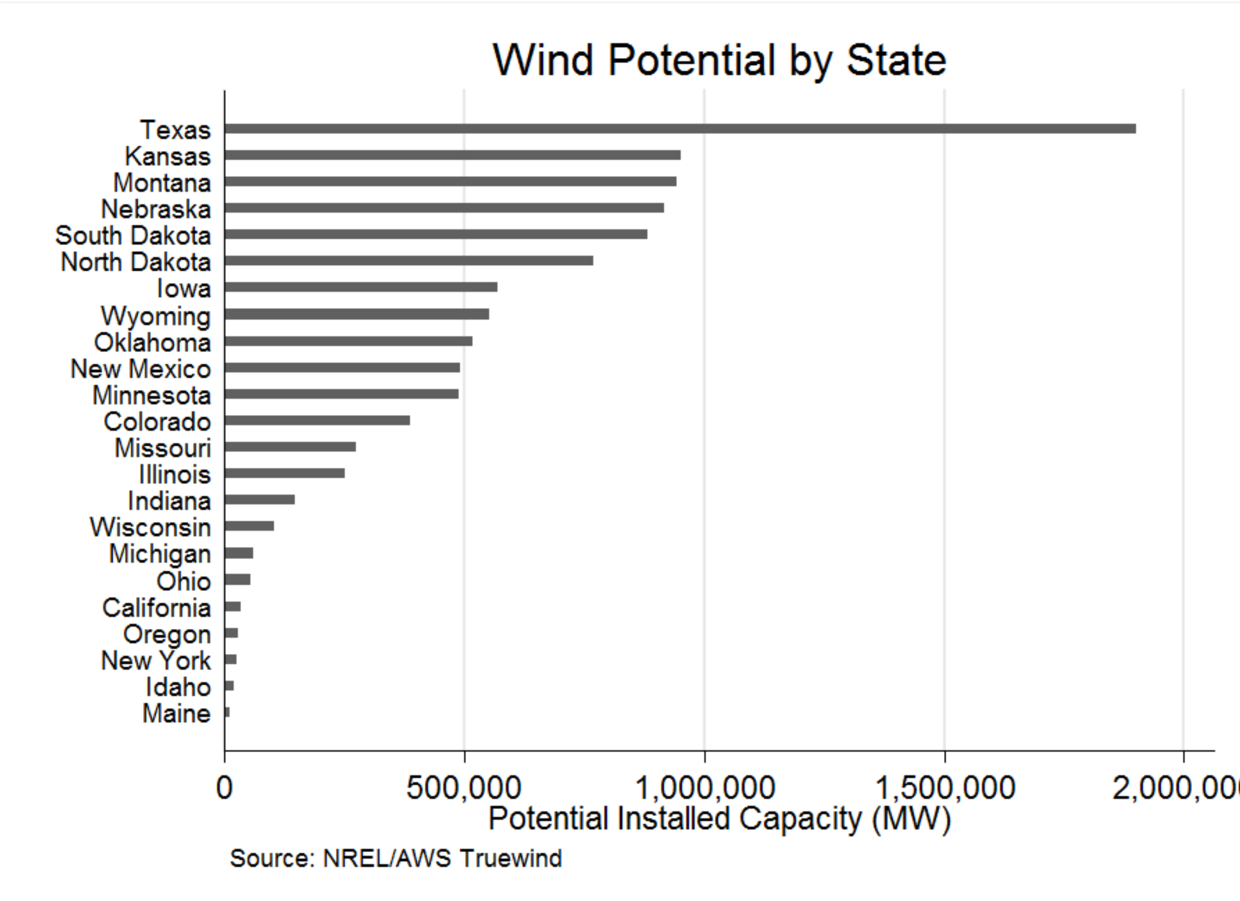
Note: robust t-statistics in parentheses, *** p<0.01, ** p<0.05, *p<0.1. State and Year indicators are included with errors are clustered at the state level. Instruments are the percentage of Democrats in the State's Lower House and Upper House. Newey's (1987) efficient two-step estimator is implemented.

Table 5: Interactions -Tobit Fixed Effects: (Marginal Effects)

Dependent Variable: Added Wind Capacity	Full Sample: Probability of Wind Capacity Additions	Full Sample: Expected Change in Wind Capacity	Top Wind Potential: Probability of Wind Capacity Additions	Top Wind Potential: Expected Change in Wind Capacity
RPS	-0.00159	-4.373	**-0.106***	-23.38
	(-0.515)	(-0.684)	(-1.697)	(-1.330)
GPP Indicator	0.00358	8.208	0.0409	8.856
	(1.013)	(1.457)	(0.284)	(0.291)
RPS * GPP Interaction	0.00634	10.17	**0.145***	31.34
	(0.854)	(1.533)	(1.670)	(1.631)
RPS Linear	-0.000111	-0.272	-0.00815	-1.771
	(-0.433)	(-0.487)	(-0.831)	(-0.818)
GPP Sum	0.000478	1.175	-0.0114	-2.468
	(0.939)	(1.603)	(-0.772)	(-0.741)
RPS * GPP Interaction	-1.07e-05	-0.0263	0.000395	0.0859
	(-0.237)	(-0.249)	(0.231)	(0.232)

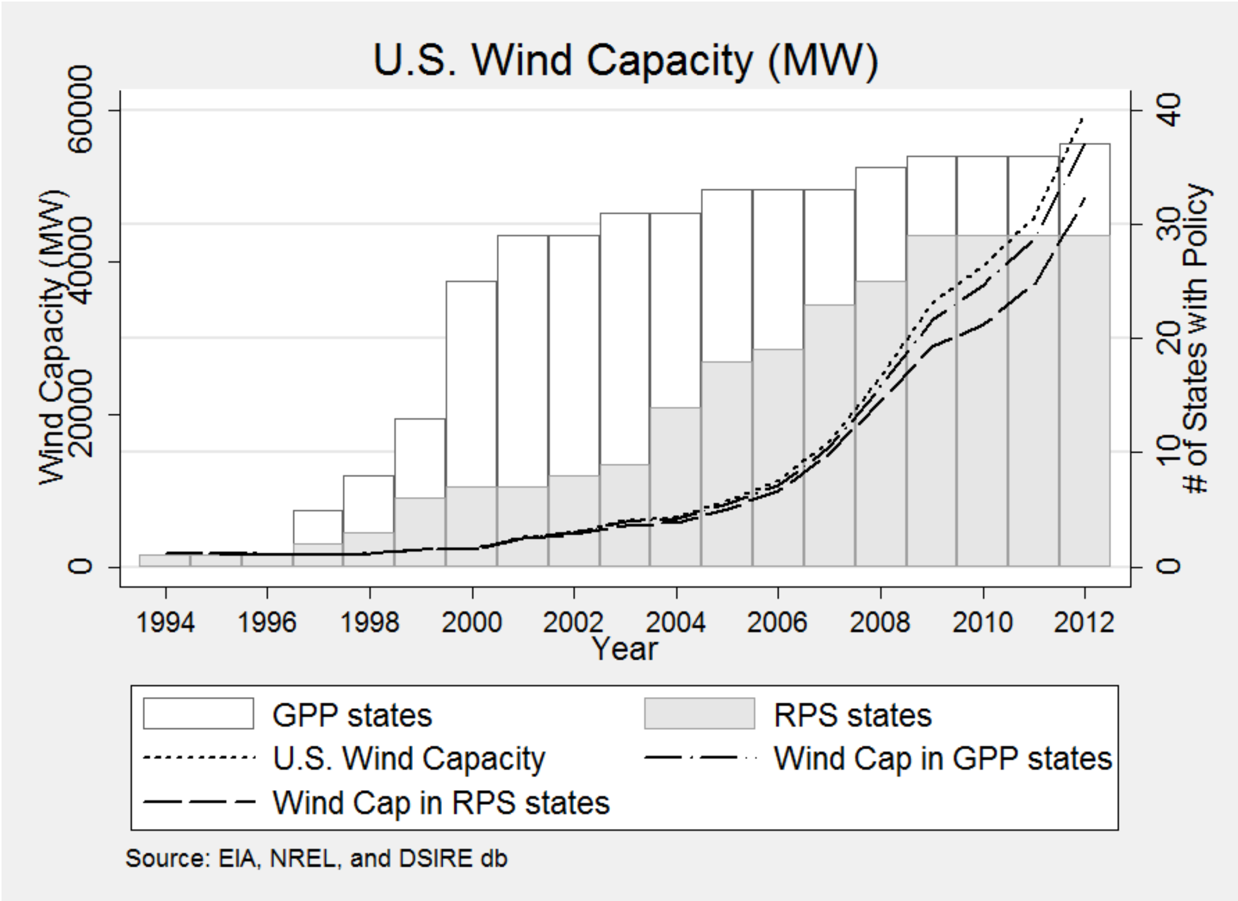
Note: The same set of controls were included in each of the regressions above. The magnitude and statistical significance of the coefficients on the market variables are consistent with those presented in Tables 3a and 3b.

Figure 1: Wind Potential



Note: While state such as Idaho and Maine have low wind potential and ranking in the figure above, using the 1991 potential, they're ranking was in the top 20, i.e. Idaho was 13th in the previous ranking and Maine was 19th.

<u>Figure 2: U.S. Wind Capacity by Policy Adopter States</u>



Note: GPP states and RPS states indicate that a state passed a GPP or RPS policy, respectively, during the sample period.

Figure 3: U.S. Cumulative Installed Wind Capacity and Added Capacity by Year