The Impact of Wind Development and Deregulation on Midwestern Electricity Firms: A Comparative Analysis

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* *Disclaimer:* Self-citation by candidate number (201616, 2019) refers to work submitted for fulfillment of GY499 Extended Proposal previously graded in Spring 2019. The work cited from GY499 is used exclusively for the literature review and while there is significant overlap in the topic of the dissertation proposal to the topic of the final dissertation, the direction has change and previous literature review material on firm theory and electricity market developments was re-used.

Contents

Table 1: Important Acronyms

Acronym	Name	Definition
USDA	United States Department of Agriculture	US government agency overseeing rural development, including electrification programs and renewable energy development
DOE	United States Department of Energy	US government agency providing grants and funding for specific electricity projects for cooperatives
SPP	Southwestern Power Pool	Non-profit based in Arkansas, originally a regionally-pooled utility, later expanding to become a reliability corporation. Today it operates as an RTO/ISO overseen by FERC, designed to "ensure power reliability, transmission infrastructure and competitive wholesale prices for electricity"
RTO	Regional Transmission Operator	An electric transmission systems operator, voluntarily formed and independent organization to oversee the interstate sale of electricity between states on the US grid
ISO	Independent System Operator	Similar to an RTO, an ISO oversees the wholesale electricity market and maintains reliability of the grid, formed at the recommendation of FERC, coordinating the operation of the grid within a state or across states to meet standards of reliability
FERC	Federal Energy Regulatory Commission	Independent agency that regulates transmission of electricity, natural gas, and oil; ensures that customers receive efficient service and reasonably priced electricity
NRECA	National Rural Electricity Cooperative Association	Electricity cooperative trade association, formed in the 1940s after rural electrification of US was prioritized. They represent public utilities and member-owned cooperatives for lobbying and organization

NERC	North American Reliabiliy Cooperation	Nonprofit corporation ensures the reliability of the interconnected power systems of US and Canada through technical standards, monitoring and enforcement. NERC serves as the national electric reliability organization for the US as of 2006, declared by FERC with eight regional entities delegated power over different geographic proportions of the grid
BA	Balancing Authority	Balance supply and demand at all times on the grid, where energy can be sold or bought. SPP has consolidated to operate one BA
IRC	ISO/RTO Regional Council	Industry-wide collaboration by ISOs and RTOs began in 2003 with nine members
CRR	Congestion Revenue Rights	A financial instrument which hedges against the risk associated with buying energy where there is congestion along the transmission lines, so it locks in a price or charge for users who buy rights in the day-ahead market
FERC-888	FERC Order No. 888	Federal act designed to "Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities"
IES	Intermittent Electricity Sources	Any electricity source which is not constantly available, usually renewable energy sources, constrained by forecasting
PTC	Production Tax Credit	US federal income tax credit which is given for each kilowatt hour of renewable energy produced. As of 2017, it is 2.4 cents a kilowatt hour rebate, often applied to wind production

1. Introduction

1.1 Background

Electricity grid operators are increasingly concerned with the compatibility of intermittent resources and an infrastructure system originally designed for conventional energy sources [Nelson et al., 2012]. In the midwestern United States, wind availability makes renewable generation feasible, but connecting it to users in a cost-effective way has been challenging. [Lamadrid et al., 2016]. States in this region have lagged behind others in terms of renewable energy policies, including Renewable Portfolio Standards (RPS), carbon reduction goals, and proactive policies for renewable financing [Joskow, 2012]. While production-based incentives for renewable energy are more popular in the United States–covering 55% of retail sales [Callaway et al., 2018, Wozabal et al., 2016], financial incentives and lower technology costs are responsible for much of the deployment of renewable energy on the grid. Without a favorable policy environment, much of the capacity for renewables is left by the wayside.

Figure 1.1: Wind Turbines (2000) [EIA, 2019]

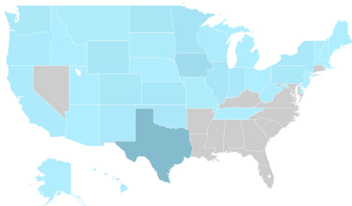

Figure 1.2: Wind Turbines (2006) [EIA, 2019]

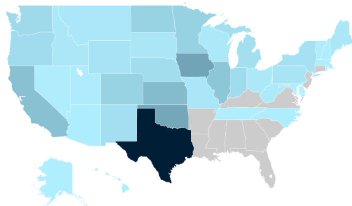

Figure 1.3: Wind Turbines (2013) [EIA, 2019]

Despite the growing available supply of wind as a source of renewable energy, the largest issues pertaining to the deployment of renewables can be understood along two dimensions: spatial and temporal. The former arises because wind generation capacity is highest in areas removed from where electricity demand occurs [Severin Borenstein, 2002]. The latter is the result of the intermittency of renewable energy, where supply peaks and dips dependent on weather and climate factors which cannot be controlled or fully predicted. Both issues require rapid and advanced infrastructure development to provide reliable transmission of energy [Joskow and Tirole, 2005, Severin Borenstein, 2002, Gowrisankaran et al., 2016, LaRiviere and Lu, 2017]. Previous literature has found that renewable energy, while providing economic benefits via emissions reductions [Tyner and Herath, 2018, Callaway et al., 2018], may increase short and medium run supply costs due to the aforementioned issues of intermittency and the constraints on grid operators in providing a consistent amount of electricity to meet demand [Owen, 2004, Gowrisankaran et al., 2016, Tyner and Herath, 2018]. The current method of increasing the amount of renewable resources on the grid is reliant on rents received from anticipated congestion through capacity markets, or the buying and selling of rights related to transmission use. This is to ensure reliability as well as fund the high capital costs of renewable energy projects. But, these markets continue to grow more competitive as transmission infrastructure decays and more generators join the market. These markets spike the operating costs of renewables, and the long run optimality becomes unsustainable for an increasing amount of wind and solar on the grid [Fabrizio et al., 2007].

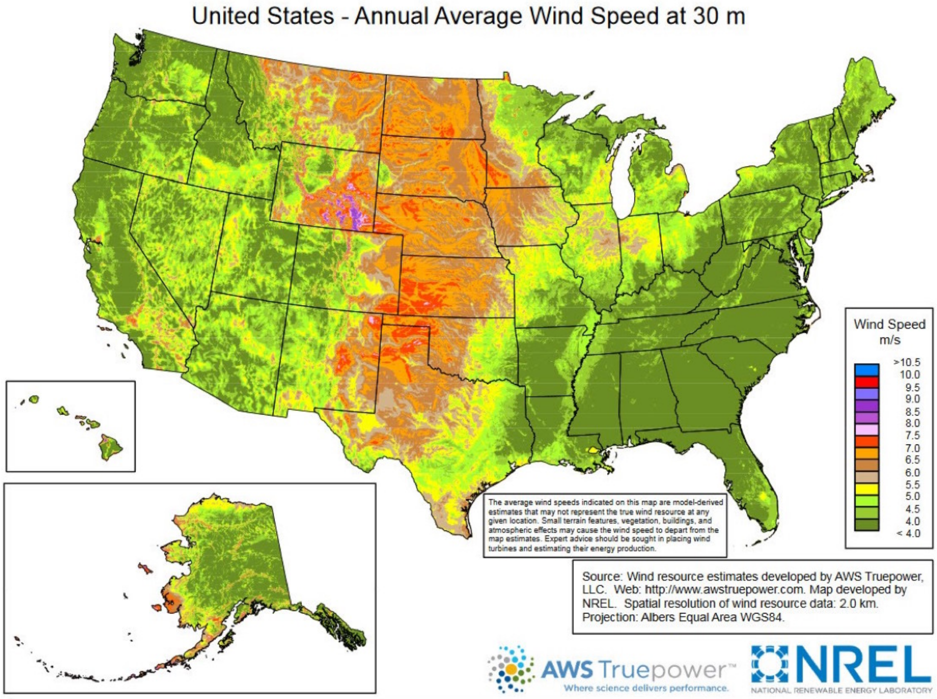

Figure 1.4: Average Wind Speeds [NREL, 2019]

Renewable energy development is taking place against the backdrop of electricity market deregulation, which, since its beginnings in the mid-1990s, has spread across different regions of the North American grid system [Joskow, 2003]. This process of deregulation is primarily motivated by increased consumer choice and efficiency yields due to competition and subsequent reductions in costs and retail prices [Fabrizio et al., 2007, Severin Borenstein, 2002, Nepal and Jamasb, 2015]. Efficiency gains theoretically take place through multiple avenues, such as new constraints on managerial behavioral and increased market competition forcing inefficient providers to exit the market (Nickel 1996 as cited in [Fabrizio et al., 2007]). Much of the literature on energy economics has investigated the short and long-term effects of the US electricity market restructure[Severin Borenstein, 2002, Joskow, 2003, Fabrizio et al., 2007, Joskow, 2012, Nepal and Jamasb, 2015, Severin Borenstein, 2015]. While these analyses take into account different market conditions or regulations, they fail to acknowledge the differences between firm ownership models.

Given the simultaneous changes in the electricity grid and the variation in market participants in the electricity industry, the distribution of costs and benefits among firms and their consumers deserves investigation. The difference in social welfare of public and private providers of electricity, given the inelastic nature of price, non-storability, and homogeneity in product have made it an interesting study of much economics literature [Borenstein, 2012]. By expanding the focus to a comparative analysis of cooperatives, public, and private, rationale can be made for firm's market performance conditional on their attributes. The difference between firm ownership and subsequent optimization provide the theoretical underpinning which warrants investigation into how benefits of a wholesale market may vary among consumers conditional on their provider. The dynamic nature of the energy market requires a deeper understanding of how firms who have been historically integral in the electrification and service of rural consumers will fare with increased competition, intermittent resources, and new technologies.

In line with this research, the objective of this paper is to investigate how this market reformation interacts with increased development of intermittent resources for different firms operating in the electricity sector. Given that renewable generation capacity is a question of supply, and that the geographic and demographic features of the midwest are rural and dispersed, sustaining fair prices and reliable energy from a higher capacity renewable grid is pertinent to policy and financial developments.

1.2 Research Objective

This research will investigate potential impact of the rollout of the Integrated Marketplace in the Southwest Power Pool (SPP) on on residential electricity prices conditional on the firm structure. This research seeks to test whether this is a causal implication for firm type and residential pricing after the introduction of a wholesale electricity market. Looking at the differences in prices over time between firms will be the first component while the second investigates whether, during the period of deregulation, an increasing share of wind in the electricity generation mix in the SPP has any significant effects on residential prices of consumers serviced by cooperatives. While economic theory has provides the justification for the efficiency gains that may be realized with the development of a market, whether there exists disparities dependent on firm type has not been investigated. Because the SPP has so recently become an Integrated Marketplace, this research provides a novel investigation into the economic impacts of deregulation for this grid region of the US. The objective of this research is to perform a two-part econometric analysis of firm-level data to investigate the effects of added deregulation over time by firm ownership and the impact of added intermittent electricity sources (IES) on cooperative consumers in the SPP.

1.3 Article Structure

This article begins following this introduction, in section two with the literature review, analyzing the question from the perspective of each subdiscipline of economics. In section three the methodology and data for the empirical analysis are discussed. In section four, the results from the empirical model are discussed. In section five, a discussion of those results with a comparison to my predictions based on our theoretical framework is undertaken. And finally, in section six a conclusion summarize the findings of the study, how these findings fit within the larger academic conversation, and what the implications are for the policy makers and firms in the midwest electricity sector are which can be taken away from this analysis.

2. Theoretical Overview

2.1 Literature Review

Existing literature can be broken down into the following subsections: electricity market transition and its effects, industrial organization and firm theory, market failures associated with IES, and the economics of electricity pricing. To begin, an overview of the different firms involved in electricity generation and distribution is described on economic theory as well as the context for this analysis which is the midwestern United States regional grid operator, SPP.

2.1.1 Topics in Energy Economics

Energy economics is a growing subfield of environmental economics with work spanning from externalities of fossil fuels, pricing, and the economic analysis of the electricity sector and its policies [Tyner and Herath, 2018]. Policy analysis is particularly critical as renewable energy subsidies, taxes, and credits are needed to be priced accordingly to their social benefit. The social benefit derived from renewable energy is from a lower GHG stock or health related benefits from reduction in pollution from fossil fuel emissions [Callaway et al., 2018, LaRiviere and Lu, 2017, Fabra and Reguant, 2014, Cullen, 2013]. Pricing economic policies related to energy hinges on the quantification of the externality, but as its not essential to this paper a more extensive look can be found in [Tol, 1999], [Nordhaus and Boyer, 2000], [Pearce, 2002], [Tirole, 2008]. This question of the associated costs of emitting fossil fuels in energy economics has ballooned in scope to include particular case studies, short and long run analysis, and additional externalities related to the structure of the electricity market or physical infrastucture of energy generation, distribution, transmission, and storage. While renewable energy, particularly wind, is a critical energy source for mitigating climate change through reducing emissions from the electricity sector, its deployment is constrained by technology, associated costs, heterogeneity of quality, and transmission systems [Dai et al., 2016]. Works on the external economic costs imposed by IES on the grid, including congestion costs, is a major subject of the energy economics literature as it relates to renewable energy development and the physical capacity of the transmission systems for energy. Congestion externalities are mitigated through rents endowed to those who purchase transmission rights in the day-ahead market, trading the rights to transmit future loads [Joskow and Tirole, 2005, Lesieutre and Eto, 2003]. This additional cost of transmission congestion reflects "the net cost of replacement power" which must be generated to cover missing supply, in order to match demand [Lesieutre and Eto, 2003]. This is just one method for capturing the external economic cost of intermittent resource. But, other suggestions for how to capture the social costs of different energy sources include Life Cycle Analysis or inclusion of environmental externalities in energy costs which in turn would be used for transmission and energy system planning [Owen, 2004]. Wholesale markets with CCR trading should assist in increasing the efficacy of balancing electricity supply and demand on the grid.

2.1.2 Policy Developments in the US Electricity Sector

The grid is composed of RTOs who ensure reliability of service under FERC authority [Severin Borenstein, 2002, Joskow, 2003]. Electricity wholesale markets now operate across most of the United States as a marketplace for energy generators and distributors to buy and sell energy among themselves within these regions. The SPP has been operating a consolidated BA since 2014, as having one BA is necessary for the running of the operating reserves market [SPP, 2015].

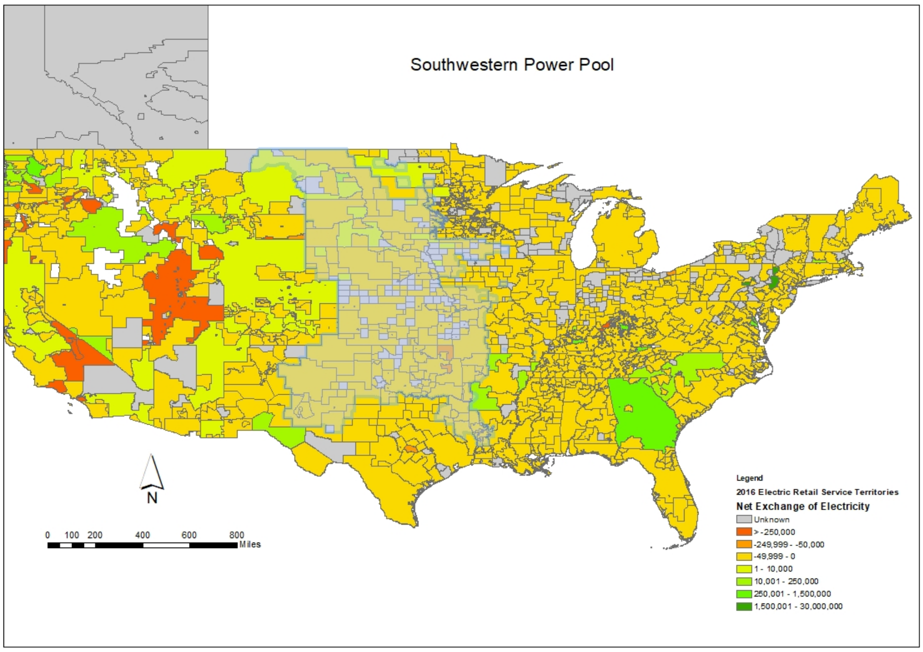

Figure 2.1: 2016 BA-BA Net Exchange

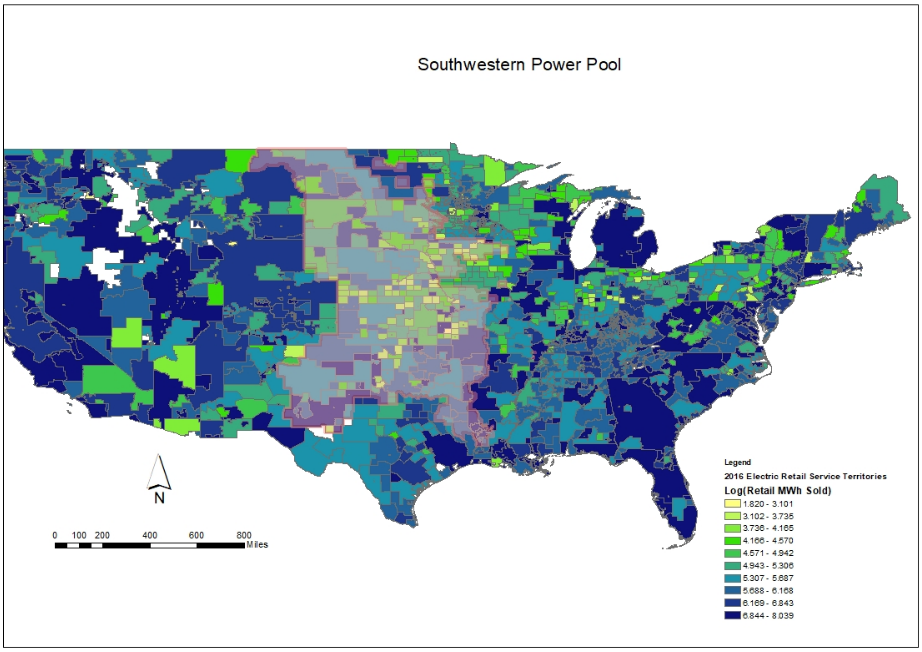

Figure 2.2: 2016 Log Retail MWh Sold

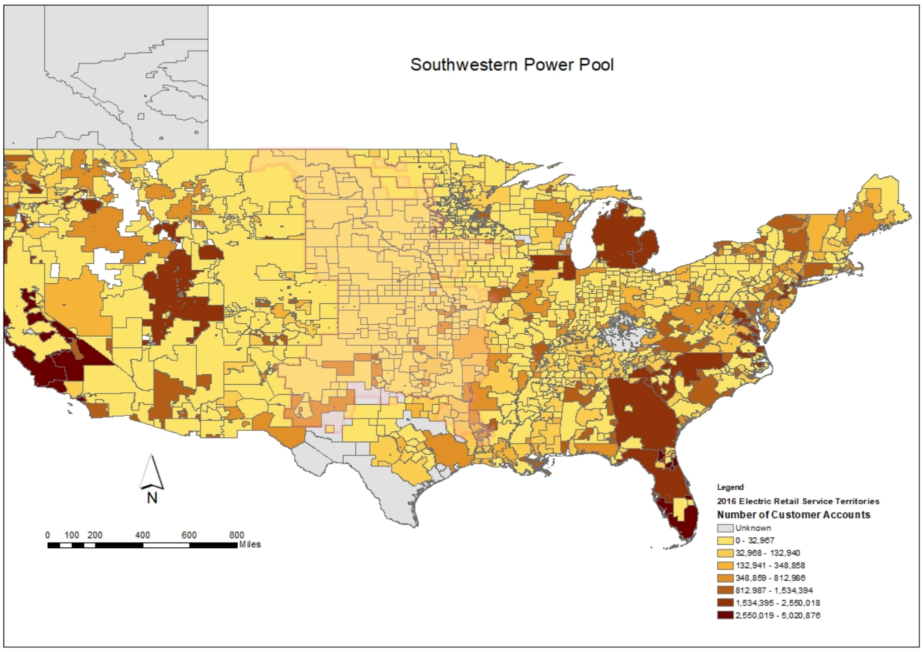

Figure 2.3: 2016 Number of Customer Accounts

While the SPP was one of the founding members of NERC in the 1940s, today it operates as the sole BA and ISO/RTO for fourteen states in the midwest United States. The SPP became an RTO approved by FERC in 2004, and now it is the US's most recently added ISO and wholesale electricity market, with its addition of day-ahead, real-time, and operating reserve markets in 2014 [FER, 2017, SPP, 2017]. It is the first ISO to merge with a federal power marketing administration in 2015, almost doubling its coverage area with the addition of three utilities: Western Area Power Administration – Upper Great Plains (WAPA-UGP) region, the Basin Electric Power Cooperative, and Heartlands Consumer Power District [FER, 2017]. While the SPP is one of nine US RTO/ISOs overseen by FERC, they provide reliability services and market enhancement for the grid although they do not own any of the transmission lines [SPP, 2015]. The SPP also oversees other BAs and transmission operators one of thirteen reliability coordinators in the Eastern Connection of the US grid [SPP, 2017]. 20 of 96 original participants in the SPP are cooperatives, and therefore make a large share of the market [SPP, 2017].

2.1.3 Electricity Cooperatives & Firm Theory

The research on cooperative firms is limited in scope relative to the academic exploration of vertically integrated firms (Landon (1983), Henderson (1985), Roberts (1986), and Hayashi, Yeoung-Jia Goo and Chamberlain (1997) as cited in [Greer, 2008]). Often the focus is on agricultural cooperatives, which differ in that the goods are storable and demand is not inelastic (Cazuffi 2012, Milford 2012 as cited in [Hanisch et al., 2013]). Electricity cooperatives deserve more attention given in some European countries they are being touted as *gatekeepers of the energy transition* [Özgür Yildiz et al., 2015]. While these regions vary from the typical areas serviced by cooperatives in the US by size, geography, and renewable energy potential, the cooperative business model's effect on is still relatively unexplored. It is important to see if rural cooperatives can survive the energy market transition or if they were a temporary solution to electrification [Greer, 2003]. It is possible rural cooperatives provide more benefits to developing countries or countries that are smaller with more homogeneous sources of electricity [Özgür Yildiz et al., 2015]. But given the vast geographic area and high percentage of rural consumers that cooperatives serve in the US, investigating US cooperative energy provider potential is key to rural development policy in the US.

Cooperatively owned utilities are different from other utilities on four main components: institutional make-up, geography, consumers, and philosophy [Berry, 1995, Greer, 2003, Greer, 2008, Yadoo and Cruickshank, 2010]. Particular to institutional make-up, the ownership model of the firm is distributed across its members, where all members partake in decision-making and profit-sharing. Cooperatives are not structured to endow managers—agents—with the same form of property rights, and as a result, the behavior of cooperative firms focus disproportionately on short-run goals of cost minimization and not long run goals of profit maximization (De Alessi 1987, Berry 1995, Clagget, Hollas & Stanstall 2005 a cited in [201616, 2019]). Agents choose to maximize social welfare, providing as close to at-cost electricity service, reinvesting any revenue in the company's operational expenditures or credits returned to members [Claggett et al., 1995, Greer, 2003]. Consumers are also different in their demand and usage of energy. While most are rural consumers who spend a larger percentage of their income on electricity than urban counterparts, the number of commercial and industrial users also continues to increase as corporations enjoy more control of their energy mix for high-energy use projects that they may self-fund through a cooperative more easily, like a recent data storage center contract between a Georgia co-op and Facebook [Merchant, 2018].

This difference in institutional makeup can be translated as a divergence in the agent(s)'s behavior who run the firm. A cooperative's optimization problem differs in that utility among each member may depend on other members' utility [Özgür Yildiz et al., 2015]. This is the economic intuition for why the maximization problem differs. A member's commitment to the organization adds a non-pecuniary component to the optimization problem, and is what differentiates it from other organizational forms (Fulton, 1999; and Fulton and Giannakas, 2001 as cited in [Marwa, 2014]). The organizational form is built with respect to philosophy, so fairness and equity in electricity access is central to the business in its operation. Through this role, cooperatives have taken in providing broadband access to many rural Americans and encouraging members to undertake energy efficiency measures to lower other member's bills [Goodenbery et al., 2019]. Reliability is central to cooperatives, so they tend to over purchase electricity and oversupply labor, resulting, consequently, in higher prices [Greer, 2003].

The focus on reliability of service comes from the geographic difference among cooperative and non-cooperative energy consumers. Cooperative users of energy are mostly rural and disadvantaged historically in their access to electricity [NRE, 2017, Greer, 2008]. Today, cooperatives own 42% of the transmission lines nationwide and serve 13% of the nation's meters [NRE, 2017]. They earn approximately $45 billion in revenue annually, not far behind municipalities which earn $60 billion [NRE, 2017]. With an higher revenue shre, utility firms can invest in longer term back-up capacity or low-cost generation, such as wind [Joskow, 2019]. But, when firms do not have access to capital, they may struggle. [Greer, 2003] finds that there are substantial gains to cooperatives merging in a deregulated environment to avoid coincidence peak pricing or defer loan repayments. [Greer, 2003] is the only comprehensive study of how cooperatives fare under deregulation, but this paper uses 1996 data to look at the effects of the FERC-888. Much has changed since this initial deregulation measure approved by FERC. More recent policy initiatives for a deregulated electricity market require analysis to see if cooperatives are hindered by deregulation. [Greer, 2008] urges a more cautious approach to deregulation, particularly with respect to pricing mechanisms used to promote economic efficiency which negatively impact non-vertically integrated cooperatives as their costs remain the same and revenues slim in these arrangements.

With respect to firm theory literature, studies have found a statistically significant difference between cooperatives and municipalities in their pricing structure [Hollas, 1994]. Inefficiencies result from decentralized property rights [Hollas, 1994]. The literature coalesces on the point that rural electricity cooperatives do not price efficiently, [Hollas, 1994, Claggett et al., 1995, Greer, 2008] and therefore higher price margins for cooperative consumers result [Hueth and Jang, 2016]. As the electricity system transitions to a deregulated environment, the effect of these dynamic polices on cooperatives becomes an important topic of analysis.

Cooperative firms face a different set of economic constraints in their optimization problem, as well as capital constraints and a higher prioritization of reliability [Greer, 2003]. As electricity distributors, cooperatives are unique in their dual motive operation as private entities with an alignment of social motives more similar to a public entity. Cooperatives often work as quasi-vertically integrated utilities, with the option to buy or sell power elsewhere [Greer, 2003]. They primarily serve rural consumers. In the case of the SPP, most distribution cooperatives were formed in order to provide electricity to rural consumers across the midwest, and continue to operate today with more transmission line per customer than other utilities [SPP, 2015]. Their location is both rural in regards to development and population density, while being geographically flat and open, with high wind potential. Per these features, with the rural aspect describing potential features of demands and the flat and high-wind features corresponding to the supply side of the equation, the goal of balancing both sides is a question of policy which can be informed by evaluating the burden of costs and potential benefits of wind development for cooperatives.

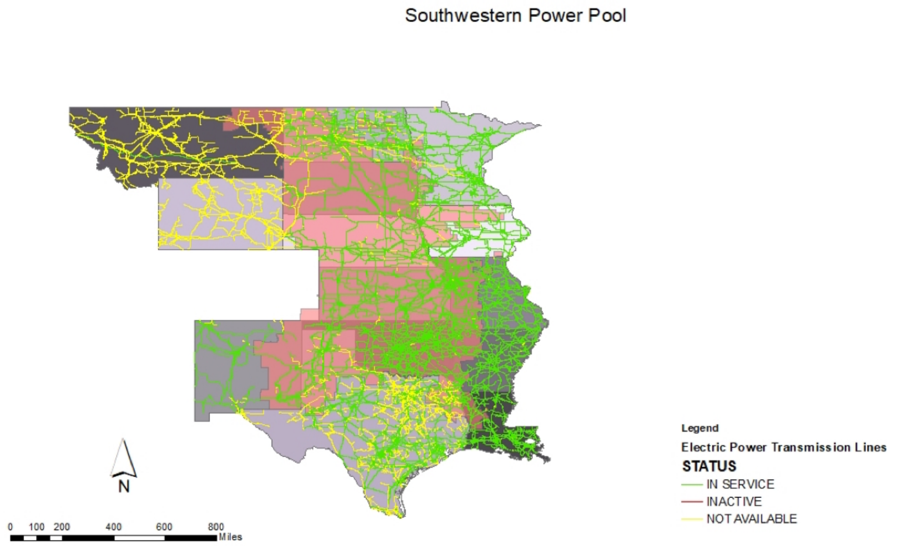

Figure 2.4: Transition Lines by Use in SPP

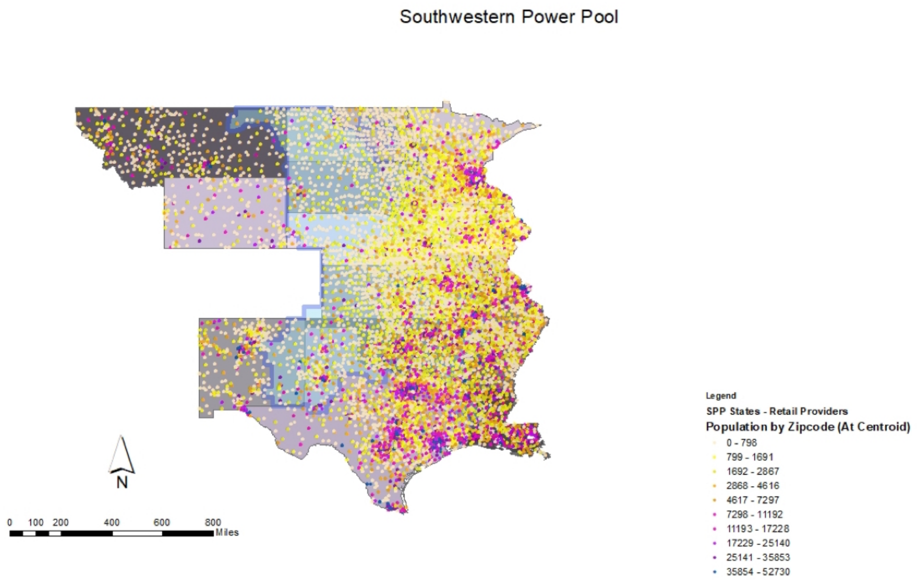

Figure 2.5: Population by Zipcode in SPP

2.1.4 Intermittent Resources, Reliability & Pricing

Wind, as the most prevelant IES in the midwestern US, has been found to decreases the average spot market price in wholesale markets, due to their zero or negative operating costs [Wozabal et al., 2016]. But, IES are also responsible for an increasingly volatile electricity price [Wozabal et al., 2016]. With the higher permeation of renewable energy, particularly wind, grid operators at RTOs who are charged with maintaining the reliability and balance of the grid, are faced with a highly technical challenge of properly forecasting intermittent energy sources in conjunction with dispatchable energy for the lowest bidder and at a balanced volume ([Mureddu et al., 2015] as cited in 20616, 2019). In the process of deregulation, the system of electricity production and distribution is broken up, and new firms have the opportunity to enter the market for energy generation. Many choose to develop renewable energy projects as they are subsidized through forms of financial alleviation (tax equity, debt) and credit (REC trading). Currently, research into the cost of IES is normally integrated in the construction of the power generator's problem in meeting supply with demand, given transmission constraints [Joskow and Tirole, 2005, Wolfram, 1999, Severin Borenstein, 2002, Gowrisankaran et al., 2016].

Putting the rapid expansion of intermittent renewables together with the development of markets, studies have found significant implications for the efficacy of wholesale markets [Joskow, 2003, Wozabal et al., 2016, Callaway et al., 2018, Joskow, 2019]. In April 2019, wind penetration on the SPP grid recently topped 65%, a historical amount of renewables on at once. Iowa, Oklahoma, and Kansas hold the 2nd, 3rd, and 5th, respectively, highest amount of installed wind capacity by state in the US; all with over of their in-state energy production being wind [AWE, 2019]. Texas, with the highest installed capacity, also participates in the SPP [FER, 2017]. This is progress towards an increasingly carbon-free grid, but pricing mechanisms and the way consumers purchase electricity will continue to evolve. In a rapidly changing policy environment and higher renewable-based grid, how cooperaives compete and provide energy to its consumers is subject to adjustments possibly incompatible with its operational objectives. While the raw supply of IES introduces a lower marginal cost source of energy, the value from bringing IES online comes almost purely in the form of emissions reductions [Cullen, 2013, Callaway et al., 2018, Fabra and Reguant, 2014]. Currently, RCCs are used to compensate for the deflated revenue that generators now make in selling IES as they are able to openly trade and bet on the futures market of the availability of transmission lines to move the energy [Joskow, 2019]. This provides another mechanism, albeit unsustainable, for allowing generators to deploy high amounts of wind power in the midwestern US.

2.1.5 Gaps in Existing Literature

While energy economics is becoming a highly researched and technically rigorous field of applied environmental economics, existing literature still fails to account for certain components of the energy transition with particular attention paid to the rural US. Firstly, the SPP was recently deregulated in 2014, making the data on the welfare impacts of deregulation unresearched in the most comprehensive and recent social cost benefit of market deregulation study prepared by [Callaway et al., 2018]. Additionally, the SPP is unique in its geography due to its largely rural and dispersed customer base. The midwest is often, unfairly, ignored in the literature due to its lack of economic progress since deindustrialization and the slower realization of environmental and energy policies within these states. Therefore the SPP does not normally provide a good source of data for energy policy evaluation. Although these states may not be progressing with production targets for renewable energy or be developing cutting edge market redesigns to better integrate renewable energy and storage, the vastness of the midwest coverage area and unique supply of wind energy makes it a valuable and sensitive region in the United States with respect to the energy transition. Recent literature has distinguished between the presence of capacity of supply and the ability to harness it and distribute it cost effectively [Godby et al., 2014, Lesieutre and Eto, 2003, Maurovich-Horvat et al., 2015]. Access to areas of the highest supply of renewable energy is dependent not on availability, but mostly on the capacity of the transmission system and the market mechanisms which facilitate this movement of energy [Bathurst et al., 2002]. The midwestern US serves as an underdeveloped area of energy economic implication outside the realm of technology and engineering models for developing wind capacity. This paper is novel in its approach to looking at the SPP marketplace and the effects of deregulation on cooperative utilities.

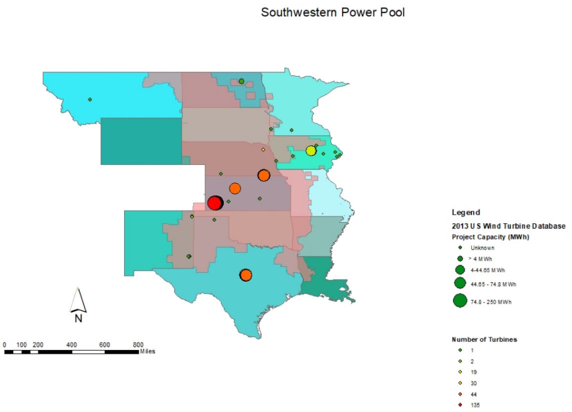

Figure 2.6: Wind Turbines 2013

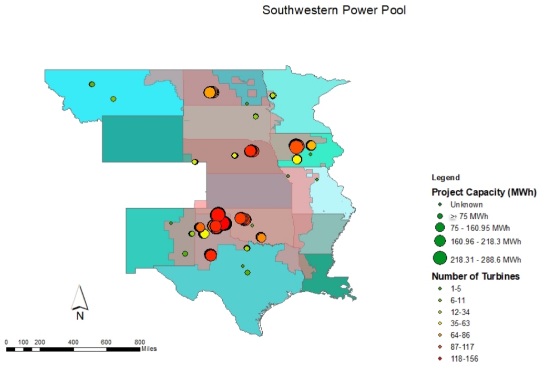

Figure 2.7: Wind Turbines 2014

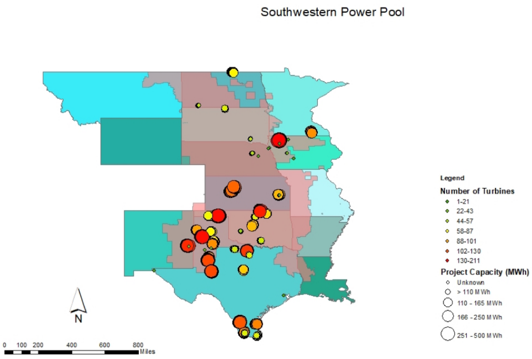

Figure 2.8: Wind Turbines (2015)

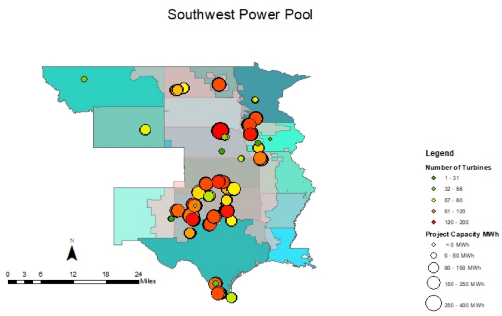

Figure 2.9: Wind Turbines (2016

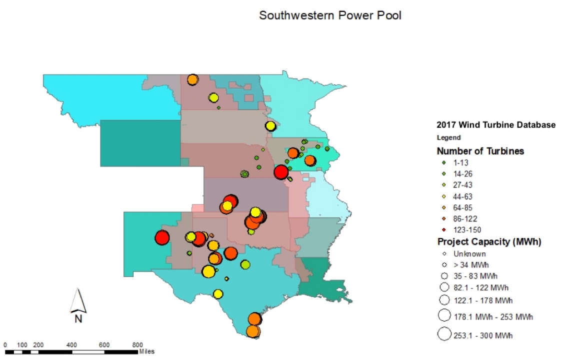

Figure 2.10: Wind Turbines (2017)

2.2 Conceptual Framework

With respect to how renewables function in tandem with deregulation, the literature focuses heavily on transmission, financial structures, and capacity building of the grid [Joskow and Tirole, 2005, Joskow, 2012, Severin Borenstein, 2015, Maurovich-Horvat et al., 2015, Bathurst et al., 2002]. This paper is a pivot in the literature to discuss the differences in outcome based on firm type, given the same question of high penetration of renewable energy and grid deregulation. Whether cooperatives in an area of such high supply are properly equipped to cost-effectively bring this energy to users in the midwest is an important questions in order for policy makers to properly implement the right support for different firms and projects, based on their ownership models and with respect to investments that can be undertaken by different market players with different advantages. The theory that this research rests upon is the existing discussion of cooperative firm behavior and other case studies short run impacts on electricity prices under deregulation.

In a wholesale market, instead of in a centralized, fixed monopoly provider setting, residential consumers should see a reduction in real price of their electricity, controlling for exogenous price shocks and other time-variant effects which may affect a firm's operating cost. Cooperative utilities participating in these markets may be looking to lower the cost of purchased power to pass on savings to member-owners, but given they often have higher labor costs and increase investments in reliability services, it may be more difficult for them to realize potential efficiency gains. Additionally, in preparing to take on more renewable energy sources, they may not be able to afford the investment into IES with lower revenue and longer baseload generator contractors, presenting barriers to the realization of efficiency gains from the market. This research isolates data on the SPP for the time just before and following the market transition. By controlling for any exogenous and time-invariant effects, the impact on residential rates is investigated.

2.3 Hypothesis

Given the existing literature on wind and its effect on prices, the findings may indicate that prices for cooperatives may remain stable or rise while other firms experience the benefits of additional revenues and stabilize or decreasing prices or conversely increase revenue. This may be in part due to that price variability, as caused by wind and other IES, increase the potential for profits given the larger expanse in potential selling price of electricity. Because of the potential profits that IES bring in and profit maximization at the heart of a private firm's optimality condition, added IES in a deregulated market may increase private revenues while negatively impacting cooperative customers [Joskow, 2019]. A comparative analysis on different firms provides the opportunity to explore any impacts on residential consumers in the midwestern US during thejoint period of wholesale market development of the electricity sector and the rapid development of wind resources.

3. Methodology

3.1 Research Design

In order to evaluate the economic impact of the market deregulation experienced in the SPP RTO/ISO in 2014, using an econometric model with panel data is a common approach deployed to assess the impact of a policy or event that occurs in one period. Panel data contains multiple entities, i, observed in at least two periods, t. In this analysis, the effects of the 2014 introduction of the Integrated Marketplace in the SPP RTO will be the policy event and the units of observation will be participating utilities. The Integrated Marketplace facilitates day-ahead sales of electricity. The consolidated BA in 2014 allowed for the introduction of the CCRs as one sole authority is necessary for a day-ahead transmission use market. Given that all utilities that buy and sell under the NERC Region overseen by SPP also exchange at the Integrated Marketplace, conducting an analysis with a control and treatment group would be impossible as all utility companies within that geographic region were affected by the new market structure. Therefore, when looking at the difference before and after the market was established in 2014 we use a fixed effects models with both state and time invariant effects to parse out the trend of residential prices over time from 2013 to 2017, conditional on firm type. Firms that experiences the effects of market participation did so because they are geographically located within the NERC region and are tied to the rules and procedures of the authority and therefore geography was a determinant of selecting into this policy, and our estimate cannot be contrasted with a counterfactual.Given the literature on firm theory discussed previously, it is likely that the causal effect varies dependent on the ownership type of the utility.

In order to best estimate the effects of the market deregulation and the added effects of wind generation on the retail prices for different firms, the analysis is broken into two components. At first, to calculate the effects of de-regulation, a fixed effects model is used to capture the change in the policy environment by controlling for the variation between firms over time. A fixed effects model with both time and state effects is used, as seen in the general form:

$$Y_{it} = \beta_1 X_{it} + \alpha_{it} + u_{it} i = 1..., n, t = 1, ...T$$

The difference between the pre and post period is calculated by using a year dummy variable, for all periods, T-1. While there is only one pre-period variable and four post-period, we are able to track the change over time.

$$Res\hat{R}ate_{it} = \hat{\beta}_0 + \hat{\beta}_1 \mathbf{X}_{it} + \hat{\gamma}_2 D2_i + \hat{\gamma}_3 D3_i + \hat{\gamma}_4 D4_i + \hat{\gamma}_5 D5_i + \hat{u_{it}} i = 1..., n, t = 2013, ...2017$$

where γ=2 is the coefficient on the dummy for 2014, and D2=dummy for the second period, 2014, to avoid multicollinearity 2013 is excluded. Time trends normally are compared as T-1 dummy variables or as time-demeaned periods, but here state effects are also included because firms differ in a non-random way. State effects are used to capture the heterogeneity in each firm. To test for heterogeneity between firms, a Hausman test is conducted. This test compares a fixed and random effects model by taking the differences of the estimated $\hat{\beta}$ values and testing for significance.

$$\hat{\beta}_{RE} - \hat{\beta}_{FE}$$

$$W = (\beta_{RE} - \beta_{FE})' \hat{\Sigma}^{-1} (\beta_{RE} - \beta_{FE}) \sim \chi^2(k)$$

Under the null hypothesis, W is tested for significance. If W is found to be statistically significant from zero, we should use the fixed effects model instead to estimate our β parameters[of Stirling, 2019]. A fixed effects model is more likely to be appropriate given that firms vary in their pricing and operational structure. Not just by firm, but also due to geography, state laws, and other unobservable characteristics. Therefore a fixed effects model will likely prove more appropriate to see the within-firm estimation of the change due to market deregulation. So, we are looking at each entity, i, demeaned, for a within β parameter estimate with T-1 dummy variables. This, given heterogeneity in firm characteristics is likely correlated with the error, is the most efficient way to obtain a parameter estimate for the change between periods within firm. The final model, run separately for cooperatives, public firms, and IOUs is below:

$$Res\hat{R}ate_{it} = \hat{\alpha}_i + \hat{\beta}_1 \overline{SAIDI}_{it} + \hat{\beta}_2 \overline{Savings}_{it} + \hat{\beta}_3 \overline{Count}_{it} + \hat{\beta}_4 \overline{WPeak}_{it} + \hat{\beta}_5 \overline{RealTime}_{it} + \hat{\gamma}_6 \overline{Year}_t + u_{it}$$

Next, the effect of added wind generation on the grid is analyzed in a spatial framework, using a distance variable calculated to find the nearest wind turbine, its capacity, and the size of the project. This distance variable will be used to analyze the effect of the proximity of wind generation to price, given that transmission and congestion constraints are normally what increases the price of wind energy. By using the distance and controlling for the population, $\hat{\beta}$ should indicate whether distance to generation station is implicated in residential price. A temporal lag variable is also created, as the month of the wind turbineś construction is unknown, so it is useful to look at a wind turbine's added capacity in the next period, when the effects of its added generation can possibly be seen.

$$Res\hat{R}ate_{it} = \hat{\alpha}_i + \hat{\beta}_1\overline{Distance}_{it} + \hat{\beta}_2\overline{Distance}_{i(t-1)} + \hat{\beta}_3\overline{Capacity}_{it} + \hat{\beta}_4\overline{Capacity}_{i(t-1)} + \hat{\beta}_5\overline{UniqueProjects}_{it} + \hat{\beta}_6\overline{Customers}_{it} + \hat{\gamma}_7\overline{Year}_t + u_{it}$$

The population represents a relatively concentrated area of demand and therefore would be more likely to be stressed in terms of usage, while less populated areas may not face the same constraints and therefore not as high pricing for wind. While the increased demand of CCRs may be due more to a temporal effect of demand instead of spatial one, this paper will only focus on the spatial parameter of constraint by using the distance variable in a fixed effects regression on just cooperative firms. Firms will be compared side-by-side in a fixed effects model to test for the effects of the SPP Integrated Marketplace on residential prices while the effects of increased IES on cooperative pricing, revenues, and investments are secondarily tested, also using a fixed effects model.

3.2 Data

The data used for this analysis is taken from the Energy Information Agency in the United States on form EIA-861. This is data for the Annual Electricity Power Industry Report that is available from 1990 through 2017 at the time of this analysis. Given the discontinuity of some data related to how data was stored and for which programs, data from 2013 onwards was used. Overall, data particular to the sales of electricity to different sectors, the number of customers, operational data and energy efficiency data at the firm level was used for 2013-2017.

The panel was assembled with five years of data at the firm-level for participants in the electricity industry across the US. The panel data was assembled with 977 unique utilities servicing the states of the SPP as provided by the EIA website. This was matched with data from the US Geological Survey, which has a comprehensive list of all wind turbines in the United States for each year from 1983 to today in which it began producing power. This data contains the spatial location via zipcode and X, Y coordinates, with additional information on both turbine and project level capacity, size, and ownership. It was sorted for 2013 onward, in order to remain within the period of analysis. Reports generated annually of firm mergers and failures are used to identify attrition in the panel data set compiled from these reports. The firms are not immediately dropped, given mergers and firm exits may not be random but be a result of the changes that are trying to be analyzed.

In order to connect the utility-level data from the EIA and the spatial-level data from the USGS, the Utility Rate Database provided by OpenEI was used. The Utility Rate Database contains zipcode-level average annual utility rates and the provider or providers which service each zipcode based on X, Y coordinates. Given this data, the zipcode centroid was matched with its nearest neighbor in the wind turbine data. When matching the nearest distance of the wind turbine to the centroid of the zipcode, 704 unique utilities were found to service the zipcodes that fall within the states serviced by SPP.

Table 3.1: Count of Zipcodes within Utiities by Firm Type

Firm Type	2013	2014	2015	2016	2017
Cooperative	51	4611	4721	4688	3267
Investor Owned	2052	4738	4595	4469	3680
Municipal	7	306	307	297	243
Total	2110	9655	9623	9454	7190

Therefore, the data was not a complete match and a total of 171 utilities, as public providers (municipalities, state, and federal government), IOUs, and cooperatives were used as the final units of observation for the analysis. By a unique EIA ID number, the group of zipcodes contained within each utility's service area are grouped and the closest and average distance of wind turbines to zipcodes are calculated for each group. The closest wind turbine (minimum distance in kilometers) to any zipcode within the utility is used to track the nearest source of wind generation to customers within each utility. Then, this information was aggregated across all zip codes within the same EIA ID coverage area, i.e. in service of a specific utility uniquely identified by their EIA ID. From this the minimum and mean of the distance in kilometers to the nearest wind turbine was calculated by year for each utility, producing a measurement of added generation by spatial proximity for each year. A temporal lag model is used later for the t-1 period in order to capture any delayed effects of the added generation capacity. From this data, the number of unique projects built that were nearest neighbors to utility districts, and the number of zip code areas serviced by year by utility were also calculated. Below are summary statistics of the data.

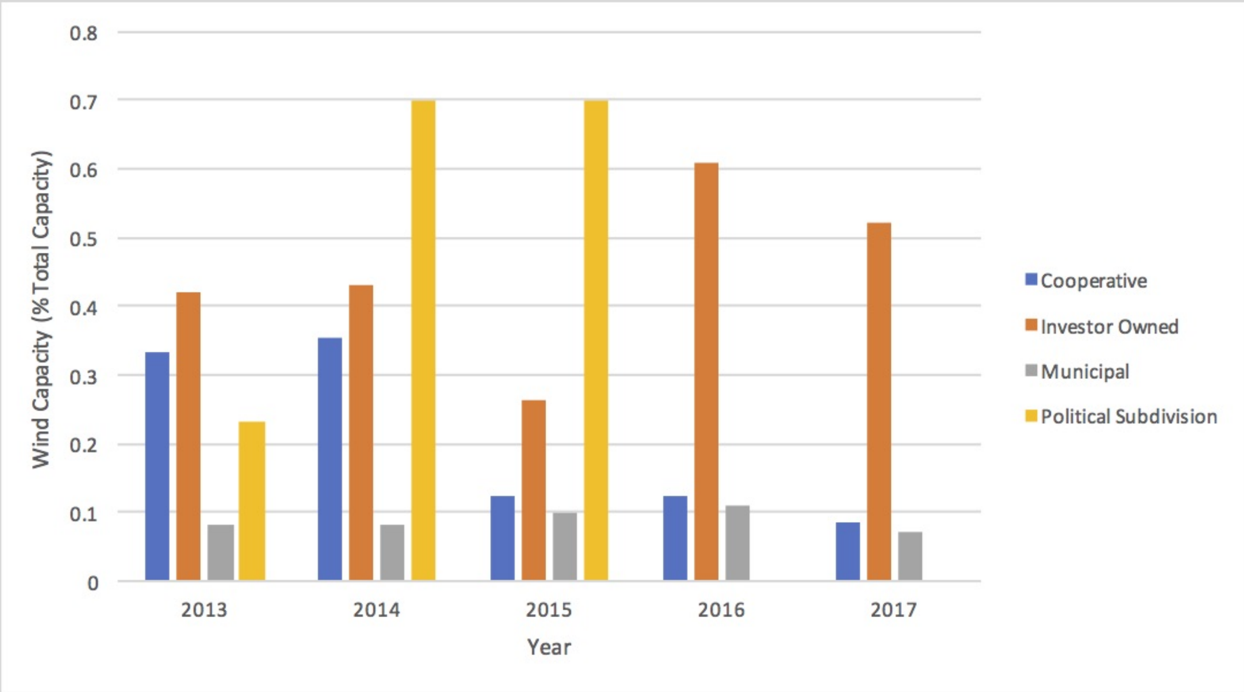

Figure 3.1: Wind Capacity

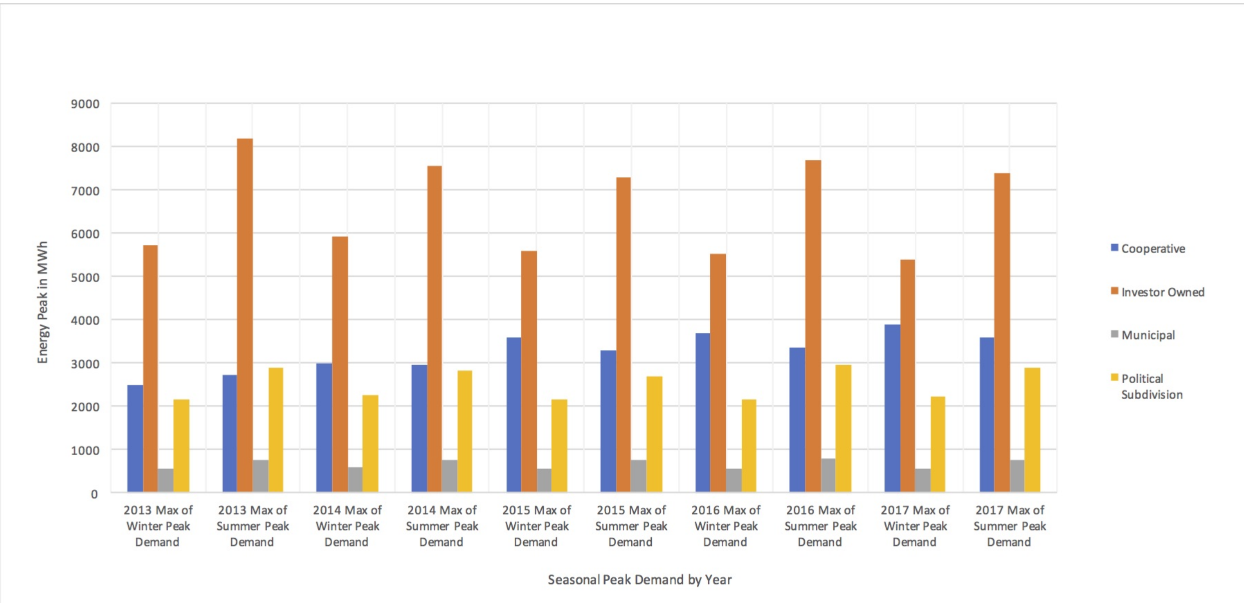

Figure 3.2: Peak Demand

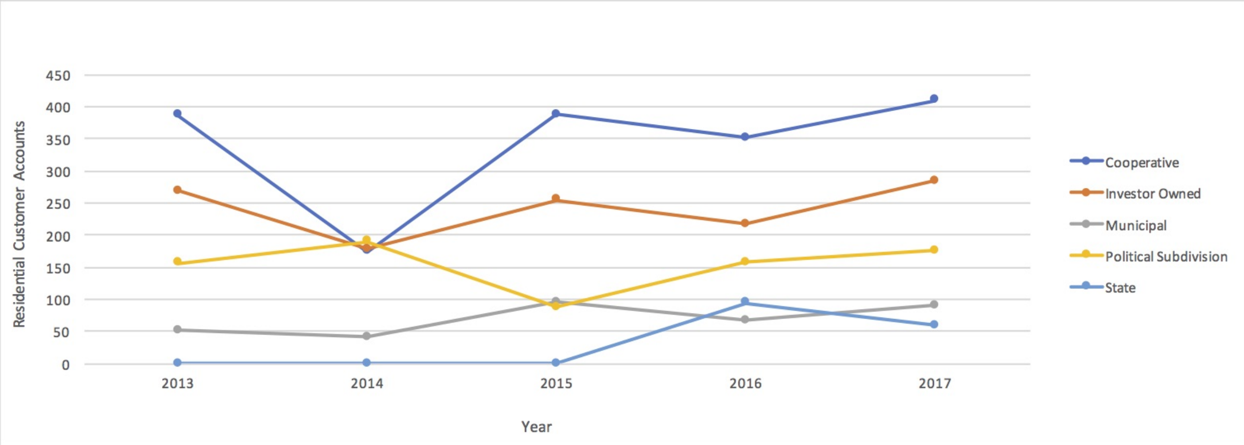

Figure 3.3: Residential Accounts

3.3 Methods & Procedures

To isolate the effect of deregulation on different firms, the econometric analysis finds a best linear unbiased estimator. Panel data with micro-level observation allows for us to more accurately understand and evaluate a policy given heterogeneity across individuals and best parse out the effects given these differences within-entity. Our analysis estimates any impacts that deregulation has on residential consumer prices, comparatively among different firm types. Models deploying fixed effects, random effects, and a pooled regression were used in order to find the best fit model as discussed in the research design. The results were compared to select a model that is most efficient and can best be justified as an unbiased estimated value for the effect between the pre and post period of the market integration in the SPP. In order to ensure that our estimated parameter value for the effect of market deregulation is BLUE, we are looking to ensure it meets the following conditions:

- the error terms are uncorrelated across time for all values of the independent variables
- the entities are randomly sampled
- large outliers are unlikely
- no perfect multicollinearity exists across independent variables

These assumptions are similar to a standard multivariate regression model, with an exception to the acceptable standard errors [Stock and Watson, 2007]. In a FE model, it is likely that within-entity correlation occurs, or serial autocorrelation, where observations within an entity are related over time. But, by controlling for these effects, errors can be separated from the entity, i and the error term, u_i. This way the remaining error is uncorrelated with the coefficients or the fixed effects estimate:

$$E[u_{it}|X_{i1}, ...X_{iT}, \alpha_{it}] = 0$$

Next, the time dummy coefficients capture the change in the regulatory environment. To test the time and entity fixed effects of the market deregulation on the residential consumer price for electricity, different variables based, on previous literature in terms of what is important to determining electricity price, are chosen and controlled for to isolate for the time varying effect of the market introduction. While most of the residential unit price of electricity is a function of firm cost, we control for both major demand supply effects that have the largest impact on price variation, which would drive the average price up or down significantly. There are a significant amount of variables which factor into determining the residential consumer price of electricity and laws which govern fair pricing. But these are controlled for via within-firm determinants in the FE model as well as by excluding data outside the SPP. The SPP functions as the ISO for all states, and therefore any rules or procedures remain fixed across entities and even if they were to change over time, the model controls for these effects because all participating firms are equally impacted.

After analyzing the effects of market deregulation, the effect of added wind capacity as an energy source on cooperatives is investigated as wholesale electricity markets generate an opportunity for an increased number of generators, the ability to increase revenue from the buying and selling of CCRs, and shifting market power. Whether there is an effect of added wind generation on cooperative utility service begins to highlight whether they are equipped to participate in a more IES-powered grid and potentially develop their own projects. Wind generation is analyzed for impact on reliability and residential prices. The distance to the nearest wind turbine to any of the zipcodes within each utility region is our variable of interest.

4. Results

4.1 Effects of Market Deregulation

The results from the initial regression are outlined below. Given the model specified in Section 3, the effect of SAIDI without MED, the reported year energy savings, number of customers, winter peak demand, real-time pricing dummy, and year dummy variables were regressed on all firms, using a fixed effects model with robust standard errors. Below is a table of what each variable represents and the units its measured in:

Table 4.1: Variable Definitions

Variable	Unit	Definition
Residential Rate	KW/Hour	Average fixed cost charged to a utility residential customer by given utility provider
SAIDI without MED	Minutes	System Average Interruption Duration Index: average amount of minutes a customer was without power, including major event days (MED)
Report Year Energy Savings	KWh	Annual Aggregate Savings in Demand from demand-side programs
Count	Number	Count of Residential Customers within a Utility District
Winter Peak Demand	MWh	Maximum Peak Load recorded for season of winter
Residential - Real Time	Binary (0/1)	Dummy Variable for whether or not consumers are offered Real Time pricing
2013-2017	Binary (0/1)	Dummy Variable for year fixed effects

Below are the results from the regression, initially run as a fixed effects model, random effects, and OLS pooled regression. While pooled OLS can be conducted to control for entity or group-specific state effects, even robust standard errors cannot control for serial autocorrelation in this setting. The pooled OLS model was used in order to get a general understanding of the time and state fixed effects in order to compare the standard errors and potential coefficient estimates.

Figure 4.1.2: Regression Comparison

	(FE) Res Rate	(RE) Res Rate	(OLS) Res Rate
SAIDI without MED	0.0000118*	0.0000122*	0.0000176
	(2.17)	(2.20)	(1.26)
Energy Savings	-7.62e-08	-0.000000101*	7.12e-08
	(-1.36)	(-2.19)	(0.88)
No. Customers	-0.000000451	2.20e-08	0.000000245***
	(-0.86)	(0.35)	(4.36)
Winter Peak Demand	0.0000106	-0.000000754	-0.0000612***
	(0.97)	(-0.08)	(-4.94)
Real-Time	-0.000956	-0.00123	-0.00628*
	(-0.63)	(-0.83)	(-2.38)
2014	0.00442	0.00481*	0.0128
	(1.68)	(2.08)	(1.62)
2015	0.00717**	0.00738**	0.0155
	(2.68)	(3.19)	(1.95)
2016	0.0120***	0.0120***	0.0213**
	(4.44)	(5.20)	(2.65)
2017	0.0152***	0.0150***	0.0244**
	(5.32)	(6.20)	(2.95)
α	0.130***	0.109***	0.114***
	(4.81)	(26.42)	(13.56)
r2	0.591	-	0.257
N	171	171	171

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

These coefficients were chosen as controls in order to capture any major demand-side effects on residential pricing and parse out the supply-side effects as attributed to the introduction of the Integrated Marketplace. As expected, Real-Time pricing does not have a real effect on the residential rate because this type of policy does not necessarily change the fixed residential charge and instead works to help consumers shave off their peak demand charges. Still it was included in order to test for whether demand-side management programs brought down fixed costs for firms, possibly if more consumers were to use them and peak demand dropped. This, in turn is related to winter peak demand. Although it is possible there could be correlation between high peak demand values and the offering of demand-side management program, winter peak demand in the SPP, according to Figure 3.2 is less variable then summer peak demand and more difficult to reduce. Therefore the problem of correlation between these two coefficients isn't apparent, but winter peak demand still tells us about a consistently high level of demand that can be reached by the utility. Also, energy savings should also bring down net demand, and influence long term pricing decisions of the firm. Finally, the number of customers is controlled for as this absolutely impacts how much utilities charged based on demand, transmission, and dispersion. We can see from the preliminary model comparison that number of customers is likely correlated with firm characteristics, as when controlled for in the FE and RE model, the number of customers is no longer significant and the t-value is extremely low. From these results, the final model is developed.

Next, the Hausman test is conducted for a comparison of the FE and RE model to ensure we get the most efficient estimator. The Hausman indicates if there is a significant difference between the FE and RE parameter estimates and that FE should be used in favor of RE model. It is likely that each firm has certain policies, procedures, and internal variables that affect only itself. These unobservable characteristics are highly heterogeneous given our high standard estimates and the significance in the value of the constant, α. This is why the FE model is used for our final regression, because it is still possible to produce an unbiased and consistent estimator for the β parameters even if $\mathrm{E}[\alpha_{it} \mid X_{it}] \neq 0$. From the results of the test, the FE parameter estimates are statistically significant from RE results. Proceeding with a FE model is justified via testing the coefficients and on theoretically grounds that entities differ based on agency behavior.

Table 4.1.3: Hausman Test Results

	(b) FE	(B) RE	(b-B) Difference	sqrt(diag($V_b - V_B$))) SE
SAIDI (without MED)	.0000118	.0000122	-3.83e-07	-
Report Year Energy Savings	-7.62e-08	-1.01e-07	2.44e-08	3.22e-08
No. Customers	-4.51e-07	2.20e-08	-4.73e-07	5.22e-07
Winter Peak Demand	.0000106	-7.54e-07	.0000113	5.82e-06
Real Time Pricing	-.0009562	-.0012251	.0002688	.0003142
2014	.0044172	.0048128	-.0003956	.0012377
2015	.0071681	.0073781	-.00021	.001347
2016	.0119847	.0120157	-.000031	.0013957
2017	.0151514	.0150253	.0001261	.0014956

χ^2 = 31.2, (Prob> χ^2) = .0001

In Table 4.1.4, the results conditional on firm type of the effects of the year-by-year change from the pre-market integration year of 2013, controlling for demand-side cost factors and fixed effects for each entity analyzed. In all, cooperatives made up the largest of the sample which is reflective of the marketplace at SPP. This reflects the actual population and therefore our sample is reflective of the true population. Initial results indicate that cooperatives in the SPP did not react with a rate change due to the marketplace rollout. While subsequently private and public utilities did see a change in price. Year-by-year effects indicate a significant effect on the residential rates charged by these utilities. For example, the difference from the base year to 2017 indicate a .0231 cent increase in residential rates' fixed prices.

In the results, α is significant for the cooperatives, indicating a .135 cent increase in KwH charge on fixed rates for consumers purely because they are serviced by a cooperative utility. While this is fairly relative to the average of the variable for KwH pricing of electricity, it is indicative that there remains entity-specific errors influencing our resulting β parameter estimates on our year dummy variables. Trading in a wholesale market should adjust prices to be closer with private firms, given that cooperatives charge at-cost for electricity. While we may also attribute these to the failure of cooperative's to maximize efficiency due to their agency behavior, the firm type may be endogenous to the regression and correlated with other omitted variables which also determine residential rates, such as geography, distance to nodal points, and quality of the infrastructure. This will be discussed further.

Table 4.1.4: Fixed Effects Model for Year-by-Year Change by Firm Type

	(Coop) Avg Res Rate	(Public) Avg Res Rate	(Private) Avg Res Rate
SAIDI (without MED)	0.00000444	0.0000115	0.0000169
	(0.54)	(1.18)	(0.74)
Annual Energy Savings	0.000000360	0.000000657	-0.000000182***
	(0.72)	(1.13)	(-4.87)
No. Customer Accounts	-0.00000298*	-0.000000932	-0.000000131
	(-2.67)	(-0.42)	(-0.25)
Winter Peak Demand	0.000267*	0.000178	0.00000460
	(2.12)	(1.23)	(0.52)
Real-time Pricing (Y/N)	-0.00101	-0.000889	NA
	(-0.43)	(-0.37)	(.)
Yearly Dummy Control Variables			
2013 (excluded)	-	-	-
2014	-0.00938	NA	0.00747*
	(-1.62)	NA	(2.99)
2015	-0.00453	0.00340*	0.00815*
	(-0.82)	(2.41)	(3.06)
2016	0.00270	0.00693***	0.0124**
	(0.51)	(4.77)	(3.94)
2017	0.00339	0.00931***	0.0231***
	(0.60)	(5.40)	(5.84)
Constant (α)	0.135***	0.110*	0.140
	(12.00)	(2.32)	(0.93)
N	79	68	24

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.2 Effects of Wind Turbine Distance

Next, the effects of the distance to wind turbines is analyzed as this paper intends to better construct why the differences in pricing exist for cooperatives and whether the spatial dimensions can be parsed out. Below is a table of summary statistics for the cooperatives which were able to be matched to a nearest windturbine. Many of these are concentrated in the states Kansas, Iowa, and the Northern part of Texas which participates in the SPP, so the cooperatives in these states hold a higher share of the data.

Table 4.2: Summary Statistics for Cooperative Utilities

Variable	n	Mean	S.D.	Min	.25	Mdn	.75	Max
Distance (Min)	869	656.70	394.75	7.77	245.82	732.28	992.81	1405.01
Distance (Avg)	869	707.16	405.99	46.50	328.80	814.13	1039.53	1481.08
Avg Project size	869	50.35	42.31	1.00	9.22	47.32	76.38	211.00
Zips/Utility	495	30.51	16.29	4.00	19.00	29.00	38.00	115.00
Unique Projects	456	1.99	1.06	1.00	1.00	2.00	2.00	7.00
Avg Pop/Zip	456	4503.90	3466.27	495.36	2020.40	3522.61	5851.41	18501.21
Pop Density/Zip	456	24.93	38.29	0.50	5.95	11.53	27.03	343.48

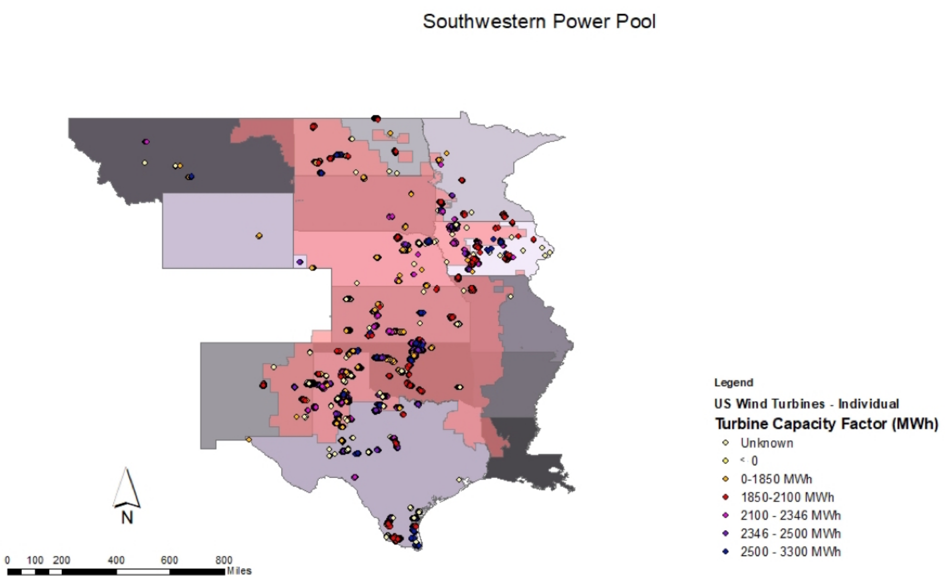

Figure 4.1: Turbines by Capacity in SPP

Table 4.2.1: Exploratory Regression of Effects on Energy Savings

	(1)
	Annual Peak Demand Savings
Megawatt Hours	-0.0000345
	(-0.48)
Res Rate	-248.8
	(-0.70)
Avg Distance	1.467
	(0.20)
Avg Distance (t-1)	0.801
	(0.11)
Avg Capacity	-0.00000980
	(-0.02)
Avg Capacity (t-1)	0.0000281
	(0.06)
α	-2287.1
	(-1.74)
N	280

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

First, results from Table 4.2.1 test for any effects of spatial proximity to wind generation. Our initial results show there is very little relationship to be uncovered with a pooled OLS model, clustering for entity-specific effects. It appears that spatial proximity to wind turbine generation plants is not a good indicator of what determines peak demand savings. The logic underlying this initial analysis was to see if proximity to wind generation capacity decreased cost of transmission or ramping up and ramping down time, resulting in higher savings. Given the null results of this preliminary investigation, another regression on the effects of the spatial variables to SAIDI with MED, the variable which serves as a metric for outages, is performed. This is done because cooperatives stress the importance of reliability in their service and may be more risk averse to outages. Therefore we test a pooled OLS regression that takes the following form:

$$\hat{SAIDI}_i = \beta_0 + \beta_1 Count_t + \beta_2 CapacityBackUp_t + \beta_3 Transmission_t + \beta_4 Distance_t + \beta_5 Distance_{t-1} + \beta_6 Projects + \gamma_t + u_{it}$$

From this initial regression, it is found there is no significance between the outage duration (SAIDI) and the distance to wind farms or wind farm capacity. From this analysis, we deduce no significance in any of the parameters when controlling for variables on the supply side which may induce more frequent outages. A major concern with the use of IES is high penetration of IES on the grid strains transmission and could potentially cause blackouts or brownouts - periods when consumers' service is temporarily suspended. By controlling for the effects of distance to wind turbines, this analysis should provide us with an estimate for the relationship between the two, but results yield insignificant findings. Whether or not they trade CCRs, the Transmission dummy, is controlled for as well to see if they have added capabilities to defend against high-load incidents. Overall, these statistics do not yield anything interesting and the final regression which looks to determine a significant effect of wind turbine distance on residential rates, the variable of interest from Section 4.1, is performed.

4.2.3 Regression Statistics for the Impact of Wind on Outages

			(1)			
			SAIDI with MED			
	b	se	p	min95	max95	var
Count	-.0040793	.0182879	.8245468	-.0409604	.0328018	.0003344
Capacity (Back Up only)	-2.326937	6.54478	.7239226	-15.52574	10.87187	42.83414
Transmission Dum	-106.6356	185.8103	.5690286	-481.3578	268.0866	34525.47
DD_avg	-.7707162	42.24031	.985527	-85.95641	84.41498	1784.244
AVG_lag	9.044328	40.80285	.8256285	-73.24245	91.33111	1664.872
Project Number	.0769646	.5534225	.8900439	-1.039118	1.193048	.3062765
α_i	-8363.357	43054.32	.8468939	-95190.67	78463.95	1.85e+09
r2	.0135319					

Next, a regression is run for 489 observations of cooperative who trade in the SPP marketplace indicate that initially, the effect on year increases residential prices and is significant at the 5% level for 2015 and increases to the .01% level for 2016 and 2017. This indicates significant time dependent shocks that can be seen when using an entity demeaned fixed effects regression.

4.2.4 Time Fixed Effects Analysis of Cooperatives

	(1)
	res_rate
Average Distance (km)	0.000740
	(1.11)
Average Distance (km) (t-1)	-0.00133*
	(-2.07)
Average Project Capacity (KW)	-0.000000139
	(-1.17)
Average Project Capacity (KW) (t-1)	-0.000000236
	(-1.85)
Project Number	0.00000435
	(0.47)
Count	-0.000000196
	(-0.28)
2014	-
	-
2015	0.00180*
	(2.48)
2016	0.00498***
	(6.69)
2017	0.00769***
	(7.99)
α	0.658
	(1.79)
N	489

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

While the results from the fixed effects model yield significant results initially, it is important to consider on what grounds the $\hat{\beta}$ for the spatial variables are interpretable. Because FE is not the most efficient analysis and this portion has reduced the sample size to only cooperative utilities who undertake the same cost-minimizing behavior, a Hausman test is conducted between FE and RE model estimates. It is likely now that heterogeneity between firms of the same type is limited, and there are more external factors that could be dealt with via an RE model. A Hausman test yields a result of $\chi^2 =$ to 4.72 with a Prob> $\chi^2 =$ .755, well above the .05 threshold of significance.

The RE model estimates are the run with a cluster for state-level variation, as there is significant differences in geography that make some states more suited for wind generation development. Because of this, state-level fixed effects are included contrarily to our market model in section 4.1 given that without state-level clustering, we would have a serious case of omitted variable bias. Therefore a random effects variable with state level clusters was introduced in this stage to isolate the effects of the spatial proximity to wind turbine generation stations.

4.25: Random Effects Model

	(1)
	res_rate
Average Distance (km) (t-1)	-0.000973***
	(-12.59)
Average Project Capacity (KW) (t-1)	-0.000000201
	(-0.87)
Average Project Capacity (KW)	-0.000000125
	(-0.64)
Average Distance (km)	0.000997***
	(12.81)
Average Project Number	0.00000432
	(0.36)
Count	-0.000000245
	(-1.26)
2014	-
	-
2015	0.00175
	(1.61)
2016	0.00490**
	(2.64)
2017	0.00738***
	(4.95)
α	0.0979***
	(10.56)
N	489

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

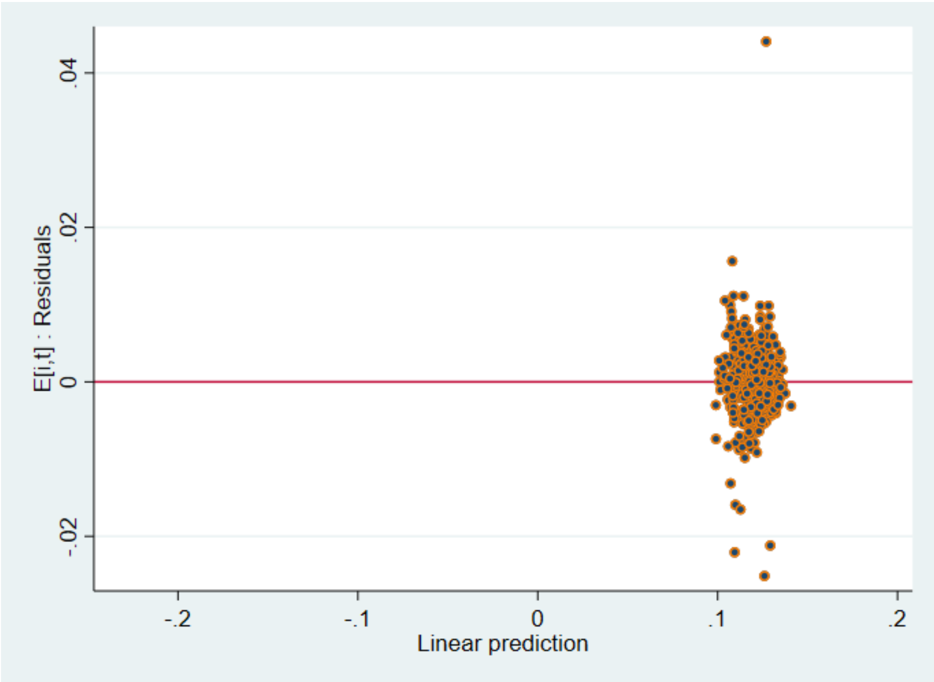

Figure 4.2: Plotted Standard Errors from Random Effects Regression

In Figure 4.2 the standard errors are not correlated with the error terms significantly to undermine the results from the RE model, as we can assume heterogeneity at the entity level is uncorrelated wit the error term. This, is in contrast to the previous section's model, there was significant heteroskedascity in the errors and autocorrelation over time, yielding a poorly interpretable parameter. But, confirmed by the Hausman test, the RE model is not significantly different from the FE model so it is used for a more efficient estimator. The results from the RE model give us a more efficient estimator of the β parameters we are hoping to isolate. From the regression results above, there appears to be a positive and significant relationship at the 1% level for the average distance in kilometers to the residential rate paid by consumers. This means for every additional kilometer in distance, on average, to a wind turbine, residential rates increase approximately .001 cents. This is a small amount, but adjusted for more realistic approach, that means every additional 10 km added to the proximity of the nearest windfarm, an extra cent is added on to the Kwh charge, which is already very low and hovers around 10-15 cents a KWh.

But, in contrast the exact opposite is true for turbines built in the previous year. So, as the average distance to a windfarm increases in the previous period, the residential rate for electricity decreases. This result is unclear and demonstrates there may be collinearity between the two variables, as is often the case with lagged variables. Particularly, the capacity and location of new wind turbines may be dependent on the project type and location of wind farms built in previous years. While we expect time dependent variables to be correlated i.e. autocorrelation [Greene, 2002] Therefore the resulting regression eliminates general time-invariant effects as correlated with our other variables of interest and is sufficient to infer an estimate of the β parameter.

Our initial findings suggest that while the introduction of the market has not greatly impacted cooperatives, the spatial distribution of wind generation and the capacity of that generation may affect residential rates. But, our estimates must be taken cautiously as in our first regression across firms heteroskedascity was present and secondarily, in our analysis of wind turbine distance on cooperatives, a case for OVB based on spatial features can be made.

5. Discussion

5.1 Policy Implications

This research provided a first insight into the impact of the SPP Integrated Marketplace on different firms participating in the deregulated electricity space. While this analysis provides interesting results for the effect of market and spatial components of wind generation on cooperatives firm in the midwestern US, policy takeaways should be limited given limitations in the analysis. Many cooperative consumers are serviced by cooperatives due to geographical constraints and not choice, but as wholesale markets work to give more consumers provider options, cooperative utilities need to remain focused on offering their members lower-cost service possibly through vertical integration or the investment in distributed generation under their sole ownership. The best way to reduce the costs passed onto residential consumers in electricity cooperatives is to reduce administrative burden [Greer, 2003]. Through the implementation of a day-ahead market, administrators in cooperatives may have had to increase cost expenditures during the learning curve of adapting to a transactional approach to energy supply. Where distribution cooperatives who are typically locked in to contracts with GT cooperatives to provide energy, having the opportunity to buy electricity on the day-ahead market may introduce an opportunity for savings but also come with short-run adjustment costs. Therefore, the results are not indicative of whether the market has consolidated and minimized costs in operations by moving to one market or added an additional layer of burden on cooperatives who now may be balancing long term contracts and the participation in the marketplace for the load-shaving or additional capacity energy. Evaluating this question by looking more particularly at the costs of each cooperative may provide a better analysis for the factors which influence pricing decisions at the firm level.

It appears renewable energy power does not affect the reliability of the service provided by cooperatives, and this presents an opportunity for cooperatives to enter into the generation of or purchase of wind energy given the PTC currently offers a rebate that is not expired and the low marginal operating costs drive wholesale prices down ad may serve to benefit cooperatives. The explanation for entity-specific differences between firm type can be confirmed as due to agency behavior, and this deserves further discussion.

5.2 Limitations

Limitations include not having a complete set of variables for all service providers. This is a product of incomplete data and the merging of multiple sources of data which inextricably linked to a larger issue in studying individual firms where data is protected or unavailable at this unit of observation. Additionally, this analysis was run for a very particular period in a certain region of the world, and my results are likely affected by some exogenous factors not controlled for, including oil prices and shifting demographics in the midwestern US.

Attrition is a problem in the panel data as some firms during the observation period merged with one another and collection of data required matching where some observations were unable to be matched for the entire period. Attrition reduces the sample size and obscures the pattern of interest and reduces the ability to make a valid causal inference from the analysis [Stock and Watson, 2007]. While weighting may be used for random attrition, given mergers are a cause of the imbalance of the panel, this would not be an appropriate solution in the case of electricity firms. Below information on the firm which did merge are included for summary purposes. As a continuation of attrition, a problem in the data was the appearance of single observations in my fixed effects model. Because there was attrition, I had observations for only one year when performing the regression on the variables of interest. While a fixed effects model attempts to remove all the difference of within-group variation, it is obvious that single observations, when left in the analysis, produce results that obscure the intercept estimates. While this is problematic for controlling for entity-specific attributes, our parameter estimates should remain.

Another feature of this analysis which is contrary to most econometric studies is that our analysis of exclusively the effects on the SPP deregulation is limited in scope and would likely fail a check of external validity given the contextual dependencies that this policy underwent. The SPP has a unique geographical and demographic makeup, which is why this analysis could not be generalized to a greater population or a different setting. While external validity is a test that statistical studies should pass in order to affirm the results may be generalized [Stock and Watson, 2007], the intention of this research is to understand the impact on a specific subpopulation or treated group, and should not be appropriated to other countries or regions who introduce a wholesale electricity market.

5.3 Further Study

This is the first look particularly at the case of deregulation in the SPP NERC region given the recent nature of the data, the results are slightly weak to make any bold claims. It would be important to improve the completeness of the data by manually building or accessing firm-level data given private or public funding to structure a balanced panel that includes each firm that participates in this market. But, given the scope of the research, the results preliminarily suggest that the spatial dimension to where wind turbines are built has an effect on the prices paid by customers, not just wholesale participant. This builds off work which suggests the PTC, while possibly being discontinued, should include a spatial component that takes into account the additional cost of transmission that is not realized in current estimates for equating costs and benefits of the PTC.

Additionally, further study that could prove to have a more specific relationship is testing for correlation between the amount of added wind generation capacity in a state and the amount firms in the state invest in back-up only generation. While the SPP grid region rapidly takes on more renewable energy sources, the value of plants which can ramp or ramp down quickly will become important as the periods when nonrenewable energy is operating at the margin will likely become higher. Alongside generation investments come the impact of added IES on the grid reliability and service under the weight of an aging transmission system. Discussed in the literature review, it is obvious that the transmission needed to support a rapidly modernizing grid with both IES on the supply side and customer-controlled demand-side responses means loads may shift more rapidly, and in the way that generation of fast ramp-up will become more valuable so will transmission capacity.

6. Conclusion

The findings of both components of the analysis are subject to the limitations of the data and the difficulty in using econometric models to parse out costs and prices in an industry which is heavily vertically integrated and does not oblige much of the standard agent theory which marginal cost pricing models used in energy economics rely on. That being said, the research affirms that differences in outcomes due to firm behaviors impact residential rate setting. Whether or not the midwestern US will most cost-effectively be able to bring live a majority IES-powered grid in a wholesale market environment given these differences may lead to vertical integration by cooperatives or more learning done by the firms. For cooperatives, it is inconclusive that they are affected by the distance to wind turbines, and this is likely attributed to the fact that in rural areas, there are more transmission lines per customer, and the load serviced to these consumers is manageable. But, the effects over time on residential price of dollars per KwH is significant in both the current and lagged periods, possibly due to the adjustment of utility firms in the market during its first few years as it is likely to experience failures and be subject to market power influences. Overall findings suggest that the difference in pricing between cooperatives, private utilities, and public entities is significant and can likely be attributed not only to endogenous features of the utility like customers, but particularly the agent behavior in prioritization of reliability and access.

As wind energy becomes a larger and more developed share of generation capacity in the SPP marketplace, investments in back-up generation, storage, or transmission become impertinent in avoiding the loss of fairly priced and reliable service to residential consumers in the midwestern US. How cooperatives will continue to fair in an increasing competitive and renewable power grid in the midwestern US will be important in order to ensure the US's large population of rural customers and users are receiving fairly priced electricity, reliable service, and the the social benefits from a more efficient marketplace.

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