Price Efficiency Differences Between Public and Private Utilities: An Empirical Analysis of US Electric Utilities

Yechan Shin *†

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Abstract

The natural monopoly problem for public utilities can be solved in two ways: regulated private firms or public ownership. This paper attempts to analyze the economic efficiency differences between the two solutions by utilizing a fixed effects model on a panel data of US electric utilities between 1999-2018 to estimate the price efficiency differences between privately owned utilities and public-owned utilities. The estimates show that although privately owned utilities are less efficient than public-owned utilities, for-profit utilities are more efficient than nonprofit utilities, due to relative economic inefficiency of electric cooperatives.

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1 Introduction

Since the attention-grabbing California energy crisis of 2001, both lawmakers and consumers have heard the furious debates over electricity pricing, deregulation, and competition within this natural monopolistic business sector. The politics behind the numerous regulatory policies involved with natural monopolies have been divisive and numerous; even as of now, there are no solutions that are universally accepted.

American electric utilities have come a long way since their inception in the 1880s, with various waves of regulation and deregulation throughout the years. The introduction of economic regulations in the United States began during the 1870s and paved the way for municipal regulation of electric utilities during their formation years; municipal regulations allowed individual municipalities to control electric utilities through market forces, thus creating the first instance of regulatory practice in the electric utility sector (Viscusi et al., 2018). After a long period of only local and state regulations, federal regulations of electric utilities were established in 1935, which lasted for almost the rest of the 20th century. Starting in 1992 with the Energy Policy Act, many deregulatory policies ended the federal regulatory period for the electric sector. Some states soon followed, starting with California; by 2020, 17 states and Washington D.C. have deregulated their electric sector to some degree, allowing some limited competition within the sector.

The regulations surrounding electric utilities and all other natural monopolies are implemented due to the fact that monopolies can wield significant power that harms competitiveness in their sector, and also because natural monopolies are not able to be broken up, both of which lowers economic efficiency. Professor Sunding (2019) of University of California, Berkeley, states that throughout the years, changes in the electric sector gave rise to two prominent viewpoints on the appropriate way to control electric utilities: the first argued for privately owned firms from which governments impose oversight, such as a rate of return regulation; the second argued for the public ownership of these firms, as to solve the for-profit nature of private natural monopolies. These viewpoints, combined with the heterogeneity of regulatory practices in different regions and states, gave rise to both public-owned electric utilities ("POUs") and investor-owned electric utilities[1] ("IOUs") in the US (Viscusi et al., 2018).

From state deregulations, various energy crises, and ownership status of firms, questions on various economic efficiency of electric utilities, such as cost and price, have been raised and researched. Majority of research have been done on the effects of state and federal deregulations on various efficiencies and outcomes, but not much recent research has been focused on the efficiency differences between ownership types of electric utilities, and especially none have incorporated new developments in the sector. Thus, I add further discussion to the literature by exploring empirical retail price efficiency differences between the POUs and IOUs in the US over the last twenty years (1999-2018).

2 Literature Review

Previous research has focused on both theoretical and empirical studies on the efficiency differences between the ownership types of electric utilities.

[1]Privately owned utilities and investor-owned utilities are used interchangeably in various papers, and mean the same thing; this paper will also adhere to this.

Although empirical research as a whole has not reached a consensus on efficiency differences between ownership types, theoretical research generally finds private firms to be more efficient. Other papers have explored efficiency differences between the types of private firms (i.e. cooperatives are nonprofit yet private, while others are for-profit and private), and have researched the effects of firm categorization.

A benchmark study by Fare et al. (1985) utilizes data from 153 electric utilities (123 IOUs and 30 POUs) from 1970 to assess the relative cost efficiency differences between privately owned firms (IOUs) and publicly owned firms (POUs). They utilize data from Atkinson and Halvorsen, which lack prices; their inputs (such as labor and fuel) are measured in units instead of prices, and their output is also measured only in units (millions of KiloWatt-Hour). They then estimate prices of inputs and the output using other sources and statistical measures, which in turn are used to measure cost efficiency of firms through "nonparametric, linear programming approaches" (Fare et al., 1985). This study finds mixed results, where POUs are more efficient in some measures, and IOUs are more efficient in others.

Another commonly cited empirical study by Atkinson and Halvorsen (1986) utilizes the same data as Fare et al. (1985) and incorporates likelihood ratio tests, to find no evidence of efficiency differences between the ownership types. Specifically, they find that they are unable to reject their null of equal cost efficiency, consistent with what Fare et al. (1985) found; in addition, they find that both ownership types are price inefficient in their study. However, similar to Fare et al. (1985), this approach of using shadow cost functions and its implied efficiency measures is not robust, as this specification implies that electric utilities run with perfect cost-minimization abilities. Their use of cross-sectional data for only 153 firms from 1970 also makes it difficult to conclude robust results, and is also not extrapolatable to the present day.

Studies using methods inspired by Atkinson and Halvorsen (1986) have achieved contrasting results. Koh et al. (1996) utilizes a methodology used by Atkinson and Halvorsen (1986) for data from 1986 for 182 firms (121 IOUs and 61 POUs), with only minor changes. They find that publicly owned electric utility firms are more efficient at low output levels, which is not consistent with results found by Fare et al. (1985). Despite there being no major regulatory or economic changes in the electric sector between 1970 and 1986, nor changes in the methodology, data from those two years produce different findings. These differences may arise due to the small sample size in their data.

Kwoka (2005) utilizes a fixed effects model regressing an indicator variable on ownership type, with controls on the dependent variable of cost; similar to other papers, costs are imperfectly inferred using average price of inputs and other statistics. Using panel data from 1991-2001 with 543 unique firms, Kwoka finds that public firms "have an advantage in the end-user-oriented distribution function," meaning that public utilities may do better in the distribution of electricity (e.g. setting up and maintaining electric lines and meters) than private firms. He also finds that private firms may have lower costs in generation of electricity, and concludes that more research is needed. This paper improves upon previous research by utilizing a panel data set with more firms than previously seen. However, as with many other papers, the dependent variable is constructed using general estimates and statistics, and not with individual firm level financial data. As such, the results may not be as robust as it could have been otherwise.

Boylan (2018) utilizes panel data from 1964-2014 of 1,030 firms with a simple OLS model to measure the effect of ownership type on political distortions. Political distortions, measured through firms' ability to quickly react electricity prices with respect to changes in inputs (costs), can be seen as a measurement of firm efficiency. The model measures the change in price of electricity based on firm ownership type, and political events, among other regressors. The paper finds evidence that IOUs are quicker to react prices to cost changes, deeming IOUs more efficient vehicles in political distortions.

Theoretical studies have demonstrated the advantages of private firms when considering economic efficiency differences between regulated private (natural) monopolies and public ownership. Alchian (1965) argues that public-owned firms exhibit a decrease in specialization of advantages when compared to private counterparts, leading to relative inefficiency. Although private firms are not always efficiency maximizing in all aspects of business (e.g. Averch-Johnson effect from Averch and Johnson (1962), where they argue that regulated monopolies will indulge in overcapitalization, leading to inefficiencies not found in public firms), Atkinson and Halvorsen (1986) has shown that, ceteris paribus, private firms lead in efficiency compared to their public counterparts.

Few studies have explored the relationship and efficiency differences between the types of private firms. Peters (1993) utilizes attenuation theory in order to argue for the efficiency differences between "non-profit" utilities and “for-profit” utilities[2]. Attenuation theory, according to Peters, finds for-profit firms to be more economically efficient due to inherent behavioral differences between for-profit and nonprofit firms. However, his paper finds no empirical differences between two types of firms. Berry (1994) argues that property rights theory predicts that firms without tradeable ownership shares (cooperatives and POUs) will be managed less efficiently than their counterparts (IOUs without cooperatives). His empirical findings, using similar methods as Atkinson and Halvorsen (1986), show that this prediction holds. Both Peters (1993) and Berry (1994) show important distinctions between the private utilities; due to the fact that electric cooperatives operate with similar objectives to POUs than IOUs, there are significant efficiency differences between electric cooperatives and typical IOUs. Their findings point out that previous research that group electric cooperatives as private firms or IOUs may have skewed results due to mis-categorization.

3 Data

All data used in this paper comes from the U.S. Energy Information Administration (EIA). Natural gas price data are reported as state averages[3] for a given year, and are from the EIA's annual “Natural Gas Price Report.” Similar to Boylan (2018), all other data are from EIA's “Annual Electric Power Industry Report.” Limited by the availability of data, I restrict the

[2]Nonprofit utilities here refer to POUs and electric cooperatives, and for-profit utilities are IOUs without cooperatives. Although electric cooperatives are considered private firms (IOUs), they are a non-profit, and thus Peters groups them with POUs, which are nonprofit entities by nature.

[3]Since natural gas price data are averages for a state and year combination, inferences from this variable is limited to state level only.

sample to the period from 1999[4] to 2018, with 3,177 unique firms[5] spanning all 50 states and Washington, D.C, resulting in 57,513 unique observations.

There has been no standard way to measure efficiency differences between ownership types. Early literature have used shadow cost differences, and later literature have used retail price differences in the absence of robust cost data. As there still exist no firm-level data on actual costs, I use retail price of electricity per megawatt-hour ($\$/MwH$), constructed using revenue and power sold, to measure economic efficiency differences between ownership types. This measurement of efficiency is preferable for several reasons: first, using shadow cost functions similar to previous papers implies that firms operate with perfect cost-minimization, which is not a very good assumption, since not all firms are run with perfect oversight; second, retail price of electricity is the measurement that most legislators and firms use to study benefits of deregulation and other changes, according to Viscusi et al. (2018). Given our lack of cost data, our price efficiency estimates will capture more effects than pure cost efficiency. This is not an undesirable effect, however, as more emphasis is given to benefits to retail customers and not how efficiently firms can operate, since public welfare is more relevant for policymakers' decisions.

Following Peters (1993) and Berry (1994), I differentiate electric cooperatives and the rest of IOUs. I test my model using both a "private" dummy variable (co-ops are private) and a "for-profit" dummy variable (co-ops are not for-profit) later in this paper.

Table (1) shows overall summary statistics, while tables (5) and (6) in

[4]Deregulation data span from 1994-2019 since we use lagged variables.

[5]This paper counts a firm and state combination as a unique firm; thus, if a certain electric utility operates in two states, then there are two unique firms. This grouping is due to differences in state regulations.

the appendix show summary statistics with the classification given above.

Table 1: Overall Summary Statistics

	Mean	Std. Dev	Min	Max
Revenue/Power	92.94617	87.25194	-36.13882	16000
Total Customers	47131.45	235177.4	0	5268369
% of Residential Customers	81.29096	18.40819	0	100
% of Commercial Customers	15.46728	14.31748	0	100
% of Industrial Customers	2.47263	11.36376	0	100
Natural Gas Price	3.697906	2.92539	0	11.16
Deregulated Dummy	.2531595	.4348253	0	1
Observations	57525			

The *Revenue/Power* variable's negative minimum value stems from PG&E and Southern California Edison in 2001, the two firms involved in California's 2001 Energy Crisis, when both suffered heavy losses.

4 Methodology

I hypothesize that regulated private utilities are more efficient than public-owned utilities, and that for-profit utilities are more efficient than non-profit utilities. Theoretical studies have shown favor for private utilities (relative to public-owned utilities) and for-profit utilities (relative to nonprofit utilities) as shown in Atkinson and Halvorsen (1986), Peters (1993), and Berry (1994).

I use a state and year fixed effects model to analyze the efficient pricing differences between ownership types[6] of utilities:

$$
\begin{aligned}
Y_{ist} = {} & \beta_1 Private_{ist} + \beta_2 TotalCustomers_{ist} \\
& + \beta_3 Residential_{ist} + \beta_4 Commercial_{ist} + \beta_5 Industrial_{ist} \\
& + \delta_1 NaturalGas_{st} + \delta_2 NaturalGas_{s(t-1)} \\
& + \delta_3 Deregulated_{st} + X_{st} + \lambda_s + \upsilon_t + \epsilon_{ist}
\end{aligned} \tag{1}
$$

where Y_{ist} is the ratio of Revenue to Power (in $\$/MwH$), X_{st} are lagged[7] Deregulated Dummies, λ_s refers to unobserved state heterogeneity, υ_t represents unobserved time heterogeneity, and ϵ_{ist} is the error term.

Equation (2) uses the same model as equation (1), but analyzes differences between for-profit and nonprofit[8] utilities:

$$
\begin{aligned}
Y_{ist} = {} & \beta_1 ForProfit_{ist} + \beta_2 TotalCustomers_{ist} \\
& + \beta_3 Residential_{ist} + \beta_4 Commercial_{ist} + \beta_5 Industrial_{ist} \\
& + \delta_1 NaturalGas_{st} + \delta_2 NaturalGas_{s(t-1)} \\
& + \delta_3 Deregulated_{st} + X_{st} + \lambda_s + \upsilon_t + \epsilon_{ist}
\end{aligned} \tag{2}
$$

The regressand in both equations measures the retail price of electricity per megaWatt-hour, and as such negative coefficients imply cheaper electricity, or more efficient retail pricing. Following Kwoka (2005), we incorporate total customers as an economies of scale control, and natural gas prices as a control since natural gas is a substitute for electricity and also an input to generate electricity. I also incorporate a 1-year lagged natural gas price variable to account for any macro business changes that may occur due to

[6] Note that electric cooperatives are considered private, as previously mentioned.

[7] 1, 2, 3, 4 and 5 year lags

[8] Note that electric cooperatives are considered nonprofit, as also previously mentioned.

changes in operating costs from the previous year.

EIA data divides retail customers into four distinct categories: residential, industrial, commercial, and miscellaneous (e.g. highways). We incorporate all but the miscellaneous category as a percentage of total customers for each state-firm-year observation in our model to avoid multicollinearity. Since the above control variables are in percentage terms, it is of note that the interpretation of their coefficients should be of a linear-logarithmic model.

Deregulating dummy variables indicate whether a state has deregulated its electric utilities that year. All 17 deregulated states and Washington D.C. (as of 2020) go through their deregulation process during the sample time frame, and as such, time or state fixed effects cannot be used to incorporate deregulation effects on retail prices of electricity. Although the impacts of deregulation are not a key focus of this study, Viscusi et al. (2018) has stated the possible beneficial effects of deregulation on retail prices, and as such, it has been a focus on various legislations pushing for deregulations. Effects of regulation changes are often lagging, and as such I incorporate t-year lagged deregulation dummy variables in the model, where $t \in \{1, 2, 3, 4, 5\}$.

To analyze efficiency differences in percentage terms, I also use a logarithmic version of equation (1):

$$
\begin{aligned}
ln(Y)_{ist} = {} & \beta_1 Private_{ist} + \beta_2 TotalCustomers_{ist} \\
& + \beta_3 Residential_{ist} + \beta_4 Commercial_{ist} + \beta_5 Industrial_{ist} \\
& + \delta_1 NaturalGas_{st} + \delta_2 NaturalGas_{s(t-1)} \\
& + \delta_3 Deregulated_{st} + X_{st} + \lambda_s + \upsilon_t + \epsilon_{ist}
\end{aligned} \tag{3}
$$

where X_{st}, λ_s, υ_t, and ϵ_{ist} are the same as before.

Equation (4) is just the logarithmic-linear change of equation (2):

$$\begin{aligned} ln(Y)_{ist} = {} & \beta_1 ForProfit_{ist} + \beta_2 TotalCustomers_{ist} \\ & + \beta_3 Residential_{ist} + \beta_4 Commercial_{ist} + \beta_5 Industrial_{ist} \\ & + \delta_1 NaturalGas_{st} + \delta_2 NaturalGas_{s(t-1)} \\ & + \delta_3 Deregulated_{st} + X_{st} + \lambda_s + \upsilon_t + \epsilon_{ist} \end{aligned} \tag{4}$$

To account for differences between cooperatives, for-profit IOUs, and POUs, I use dummy variables for each of the above types:

$$\begin{aligned} Y_{ist} = {} & \beta_1 Cooperatives_{ist} + \beta_2 POUs_{ist} \\ & + \beta_3 TotalCustomers_{ist} + \beta_4 Residential_{ist} \\ & + \beta_5 Commercial_{ist} + \beta_6 Industrial_{ist} \\ & + \delta_1 NaturalGas_{st} + \delta_2 NaturalGas_{s(t-1)} \\ & + \delta_3 Deregulated_{st} + X_{st} + \lambda_s + \upsilon_t + \epsilon_{ist} \end{aligned} \tag{5}$$

For differences between the three ownership types identified by Peters (1993) and Berry (1994), we'd expect $0 < \beta_1, \beta_2$.

5 Results

Models specified in the Methodology section were estimated below in tables (2), (3), and (4), using all firms in the sample. In addition, these models were estimated after omitting any electric utility that did not have data for the entirety of 20 years in my sample, as a way to omit poorly performing firms for reasons such as: they may have been just established, are ceasing operations, or are running into regulatory issues. These estimates are shown in tables (7) and (8) under Appendix.

I begin by estimating equation (1) and equation (3) in table (2) to find the price efficiency differences between the conventional definition of private and public electric utilities.

Table 2: Pricing Efficiency of IOUs and POUs

VARIABLES	(1) $Revenue/Power$	(2) $ln(Revenue/Power)$
Private	5.787***	0.0380***
	(0.716)	(0.00310)
Total Customers	-2.59e-06*	-2.26e-08***
	(1.41e-06)	(6.09e-09)
% of Residential Customers	55.71***	0.828***
	(5.625)	(0.0290)
% of Commercial Customers	25.38***	0.0304
	(5.934)	(0.0302)
% of Industrial Customers	10.28	-0.169***
	(6.265)	(0.0314)
Natural Gas Price	-0.101	0.000791
	(0.182)	(0.000788)
1-Yr Lagged Natural Gas Price	-0.442**	-0.000398
	(0.184)	(0.000795)
Deregulated	-0.348	0.0185
	(5.784)	(0.0250)
5-Yr lagged Deregulated	-1.756	-0.0529***
	(2.896)	(0.0125)
Constant	43.36***	3.742***
	(5.693)	(0.0292)
Observations	57,513	57,442
R-squared	0.226	0.480

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As seen in column (1) of table (2), privately owned electric utilities exhibit a moderate and statistically significant increase in retail pricing of electricity, displaying less price efficiency than public-owned counterparts. Column (2) gives percentage figures, where my estimates state that privately owned utilities have on average 3.8% higher retail pricing than public-owned utilities. The impact of pricing differences between ownership types equate to an additional \$63.49 for the average residential household's yearly electricity bill[9]. Estimates show that utilities exhibit minor economies of scale (about a \$2.59/MwH reduction for each additional 1 million customers), as is expected for natural monopolies. Increasing the proportion of residential customers have a moderately negative and statistically significant impact on price efficiency, as is expected[10]; commercial customers exhibit the same effect as residential customers, perhaps for similar reasons. The 1-year lagged natural gas price variable shows a significant and negative impact to the retail price, which suggests that natural gas may have more of a substitute good effect than a cost of input effect. Deregulation has an insignificant negative effect on retail pricing of electricity.

Table (3), which shows the estimates from equation (2), show that for-profit electric utilities have a lower and statistically significant retail price compared to nonprofit utilities; this is the converse of the estimate shown in table (2), and is equal to a reduction of \$46.14 for the average US household yearly electric bill. As for-profit utilities are the same as privately owned utilities, except for the removal of electric cooperatives, the discrepancy between these two estimates result from poor price efficiencies of electric cooperatives. This result is unsurprising, considering that electric cooperatives are generally much smaller in size, serve less-than-desirable

[9]According to U.S. Energy Information Administration (2019), the average US household uses 10.972 MwH of electricity a year; given the \$5.787/MwH increase in retail pricing for private utilities, this equates to an increase of 10.872MwH x \$5.787/MwH = \$63.49 a year for the average US household electricity bill.

[10]Servicing residential customers require more operating costs than industrial and highway customers, since residential customers use far less power relative to their maintenance and infrastructure upkeep when compared to large-scale industrial and highway customers.

Table 3: Pricing Efficiency of For-profits and Nonprofits

VARIABLES	(1) *Revenue/Power*	(2) *ln(Revenue/Power)*
For-profit	-4.244***	-0.176***
	(1.189)	(0.00511)
Total Customers	9.43e-07	6.42e-08***
	(1.49e-06)	(6.36e-09)
% of Residential Customers	55.43***	0.837***
	(5.628)	(0.0288)
% of Commercial Customers	25.23***	0.0869***
	(5.941)	(0.0299)
% of Industrial Customers	10.74*	-0.144***
	(6.268)	(0.0311)
Natural Gas Price	-0.113	0.000526
	(0.182)	(0.000781)
1-Yr Lagged Natural Gas Price	-0.458**	-0.000617
	(0.184)	(0.000788)
Deregulated	-0.246	0.0101
	(5.787)	(0.0248)
5-Yr Lagged Deregulated	-1.317	-0.0395***
	(2.899)	(0.0124)
Constant	46.24***	3.758***
	(5.691)	(0.0289)
Observations	57,513	57,442
R-squared	0.225	0.489

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

rural areas, and more residential customers than other ownership types[11], both of which result in worse price efficiency, as shown in table (3). Further breakdown of price-efficiency differences can be seen in table (4) where estimates show the efficiency differences between for-profit firms, cooperatives, and public firms. The result of nonprofit utilities being less price efficient than for-profit utilities is consistent with results shown by Berry (1994).

All other estimates shown in table (3) are consistent with estimates shown in table (2), except for the total customers variable. Economies of scale cannot be observed under this new specification, as the coefficient is

[11]Comparing "total customers" and "% of residential customers" figures for "for-profit" and "private" firms in tables (5) and (6) reveals this relationship.

not statistically different from 0.

Table 4: Pricing Efficiency of Cooperatives and POUs

VARIABLES	(1) *Revenue/Power*	(2) *ln(Revenue/Power)*
Cooperative	9.486***	0.237***
	(1.292)	(0.00552)
Public	1.453	0.143***
	(1.218)	(0.00520)
Total Customers	8.32e-07	6.29e-08***
	(1.48e-06)	(6.32e-09)
% of Residential Customers	54.83***	0.832***
	(5.623)	(0.0286)
% of Commercial Customers	27.93***	0.120***
	(5.941)	(0.0298)
% of Industrial Customers	9.980	-0.151***
	(6.262)	(0.0309)
Natural Gas Price	-0.110	0.000558
	(0.182)	(0.000776)
1-Yr Lagged Natural Gas Price	-0.446**	-0.000472
	(0.184)	(0.000783)
Deregulated Dummy	-1.064	0.000499
	(5.782)	(0.0246)
4-Yr Lagged Deregulated	2.918	0.0288*
	(3.844)	(0.0164)
5-Yr Lagged Deregulated	-1.113	-0.0371***
	(2.896)	(0.0123)
Constant	42.29***	3.583***
	(5.776)	(0.0292)
Observations	57,513	57,442
R-squared	0.227	0.496

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table (4) below shows estimates resulting from separately categorizing for-profit firms, public-owned firms, and electric cooperatives, as derived in equation (5). The main variables of interest (and change) are cooperatives and public; we omit for-profit firms, as to avoid multicollinearity. Cooperatives are statistically much more expensive for retail customers, with cooperative's coefficient being roughly twice the magnitude of Private and For-profit in tables (2) and (3), respectively. Public utilities are statistically indifferent from 0, although it does have a positive coefficient; this result implies that, excluding electric cooperatives, POUs and IOUs are not any more efficient than the other. After omitting firms without 20 years of data, however, both cooperatives and public-owned firms show significant and positive estimates, as shown in table (7). All other estimates in table (4) are consistent with results seen in table (3).

6 Discussion

The results are consistent with both attenuation theory and property rights theory as discussed by Peters (1993) and Berry (1994), respectively. Although we cannot reject the null of privately owned electric utilities being more price efficient than public-owned utilities, we can reject the null that for-profit electric utilities are more price efficient than nonprofit utilities. As I showed in table (4), this result is directly derived from the classification of electric cooperatives. The key finding in this paper is that cooperatives have the worst efficiency measurement out of all utility types, and as such, they drastically influence whatever group they are included in. Previous studies that have failed to control for electric cooperatives in some way may be subjected to biased results, and could be one of the reasons that the literature has failed to find a consensus on empirical efficiency differences between firm ownership types. My results suggest that one of the most effective ways to increase efficiencies of electric utilities (and thus retail pricing) may be to redirect more regulatory efforts to rural cooperatives instead of IOUs.

This paper does not face external validity concerns of previous papers, since the sampled data are not shadow functions, and contains a full and complete data on all US electric utilities in our sampled years. As such, results presented in this paper paint a full picture of the current electric sector. Future research should be mindful of the impact of categorization and actual data on the findings of efficiency differences.

Estimates given above also reveal other interesting aspects of electric utilities. For instance, economies of scale cannot be observed for most of our models. This may be due to the fact that larger utilities may go through more regulations or obstacles, such as regulatory lag or X-inefficiency, but more research is needed to establish certainty. Additionally, we can see that the composition of customer types make a significant difference to the pricing of utilities. Residential customers, which utilize less electricity per customer than other types, have a negative and significant impact on the price efficiency of firms, which is not contradictory to conventional thought. Natural gas, being both a substitute for electricity and an input to generate electricity, can theoretically have either a negative or positive impact on price efficiency of electricity. My estimates show that overall, the substitute good effect wins over the input factor effect, as the coefficient of natural gas price is negative when regressed against electricity price; however, restricting the sample to firms with 20 years of data shows that natural gas price has the opposite effect, which may arise due to innate differences between "poorly performing" firms and "stronger" firms. For example, it may be that the "poorly performing" firms use less natural gas to generate electricity than "stronger" firms, which would explain the coefficient differences.

Another interesting aspect is that deregulation, as a whole, is not significant for price efficiency of utilities. It may be that the 17 states and Washington D.C. have not implemented deregulation in ways consistent with theory (e.g. California 2001 energy crisis), or that we simply need more time to observe the effects of deregulation. Only after eliminating firms without 20 years of data, in table (7), do we see that the variable measuring 5-year lagged deregulation has a significant and positive effect on price efficiency of electric utilities. It may be that deregulation is only effective for established firms five years after the matter; in any case, further research is required to definitively state the impacts of deregulation, and I leave the matter for further study.

7 Conclusion

The literature has no consensus on the empirical economic efficiency differences between ownership types of electric utilities in the US. Past studies have applied various theories to predict any efficiency differences that may arise, but have been limited on data. Using panel data consisting of 3,177 unique firms from 1999-2018, I model retail price efficiency differences between electric utility types and ownership, while avoiding mistakes of previous studies. In an effort to conduct a rigorous study, I control for many aspects of electric utilities, and use no shadow cost data, but rather actual current data from the EIA.

I find that IOUs are less price efficient than POUs, although for-profit electric utilities are more price efficient than nonprofit counterparts. Electric cooperatives, being much less price efficient than both for-profit and public utilities, cause the efficiency differences between the above comparisons. Thus, previous studies that fail to control for cooperatives may have biased results, and could be a reason for why there has been no consensus on empirical efficiency differences between utility ownership types. This paper's findings face little external validity concerns, as the sampled data contains all current electric utilities. Having sampled only data after major federal regulatory changes, conclusions reached in this paper are reflective of all past developments in this sector.

References

Alchian, A. A. (1965). Some economics of property rights. *Il Politico*, 30(4):816–829.

Atkinson, S. E. and Halvorsen, R. (1986). The relative efficiency of public and private firms in a regulated environment: The case of u.s. *Journal of Public Economics*, 29(3):281.

Averch, H. and Johnson, L. L. (1962). Behavior of the firm under regulatory constraint. *American Economic Review*, 52(5):1052.

Berry, D. M. (1994). Private ownership form and productive efficiency: Electric cooperatives vs. investor-owned utilities. *Journal of Regulatory Economics*, 6(4):399–420.

Boylan, R. T. (2018). Does private ownership reduce political distortions? evidence from u.s. electric utilities.

Fare, R., Grosskopf, S., and Logan, J. (1985). The relative performance of publicly-owned and privately-owned electric utilities. *Journal of Public Economics*, 26(1):89.

Koh, D.-S., Berg, S. V., and Kenny, L. W. (1996). A comparison of costs in privately owned and publicly owned electric utilities: The role of scale. *Land Economics*, 72(1):56–65.

Kwoka, J. E. (2005). The comparative advantage of public ownership: Evidence from u.s. electric utilities. *The Canadian Journal of Economics / Revue canadienne d'Economique*, 38(2):622–640.

Peters, L. L. (1993). Non-profit and for-profit electric utilities in the united states: Pricing and efficiency. *Annals of Public & Cooperative Economics*, 64(4):575.

Sunding, D. (2019). Chapter 10 lecture of legal studies 147: Law & economics 2.

U.S. Energy Information Administration (2019). How much electricity does an american home use?

Viscusi, W. K., Joseph E. Harrington, J., and Sappington, D. E. M. (2018). *Economics of Regulation and Antitrust*. The MIT Press.

Appendix A Additional Summary Statistics

Table 5: Private vs. Public Summary Statistics

	(1) Private				(2) Public			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Revenue/Power	100.202	64.86919	-36.13882	1655.172	87.8132	99.79089	0	16000
Total Customers	90103.55	340732.1	0	5268369	16727.44	100344	0	4535909
% of Residential Customers	81.78698	21.11144	0	100	80.94007	16.21726	0	100
% of Commercial Customers	14.78936	17.2593	0	100	15.94685	11.77823	0	100
% of Industrial Customers	2.84487	11.76427	0	100	2.2093	11.06429	0	100
Natural Gas Price	3.426425	2.942432	0	11.16	3.889959	2.897998	0	11.16
Deregulated Dummy	.2856004	.4517094	0	1	.2302098	.4209733	0	1
Observations	23834				33691			

Table 6: For-Profit vs. Nonprofit Summary Statistics

	(1) For-Profit				(2) Nonprofit			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Revenue/Power	104.6689	99.00747	-36.13882	1655.172	91.44064	85.51005	0	16000
Total Customers	272322.1	606722.8	0	5268369	18213.84	88306.88	0	4535909
% of Residential Customers	74.47205	29.93589	0	100	82.1667	16.14207	0	100
% of Commercial Customers	21.62596	26.03375	0	100	14.67633	11.78088	0	100
% of Industrial Customers	3.20441	14.31233	0	100	0 2.37865	10.9242	0	100
Natural Gas Price	3.677167	2.848773	0	11.16	3.700569	2.935102	0	11.16
Deregulated Dummy	.5089354	.4999583	0	1	.2203107	.4144602	0	1
Observations	6547				50978			

Appendix B Only Firms with 20 Years of Data

Table 7: Firms With All 20 Years of Data

VARIABLES	(1) Private vs. Public	(2) For-Profit vs. Nonprofit	(3) Co-op vs. POU vs. For-Profit
Private	7.190***		
	(0.287)		
For-Profit		-12.67***	
		(0.475)	
Cooperative			19.27***
			(0.498)
Public			7.968***
			(0.483)
Total Customers	-1.18e-06**	5.71e-06***	5.84e-06***
	(4.78e-07)	(5.12e-07)	(5.03e-07)
% of Residential Customers	40.91***	39.23***	39.41***
	(3.523)	(3.519)	(3.457)
% of Commercial Customers	-18.44***	-17.62***	-10.62***
	(3.649)	(3.646)	(3.586)
% of Industrial Customers	-4.320	-3.050	-2.995
	(3.735)	(3.731)	(3.665)
Natural Gas Price	0.216***	0.214***	0.226***
	(0.0749)	(0.0748)	(0.0735)
1-Yr Lagged Natural Gas Price	0.189**	0.188**	0.195***
	(0.0750)	(0.0749)	(0.0736)
Deregulated Dummy	0.0906	-0.413	-1.845
	(2.403)	(2.401)	(2.359)
1-Yr Lagged Deregulated	-0.831	-0.283	-0.961
	(2.685)	(2.682)	(2.634)
2-Yr Lagged Deregulated	1.023	0.922	1.685
	(2.179)	(2.177)	(2.138)
3-Yr Lagged Deregulated	0.758	0.102	-0.0151
	(1.830)	(1.828)	(1.796)
4-Yr Lagged Deregulated	-0.365	0.330	0.514
	(1.670)	(1.669)	(1.639)
5-Yr Lagged Deregulated	-4.787***	-3.690***	-3.512***
	(1.232)	(1.231)	(1.209)
Constant	54.11***	59.91***	46.03***
	(3.523)	(3.515)	(3.477)
Observations	38,908	38,908	38,908
R-squared	0.478	0.479	0.497

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Log of Firms With All 20 Years of Data

VARIABLES	(1) Private vs. Public	(2) For-Profit vs. Nonprofit	(3) Co-op vs. POU vs. For-Profit
Private	0.0473***		
	(0.00353)		
For-Profit		-0.261***	
		(0.00570)	
Cooperative			0.330***
			(0.00601)
Public			0.212***
			(0.00583)
Total Customers	-3.83e-09	1.15e-07***	1.16e-07***
	(5.87e-09)	(6.15e-09)	(6.07e-09)
% of Residential Customers	0.362***	0.344***	0.353***
	(0.0518)	(0.0506)	(0.0499)
% of Commercial Customers	-0.685***	-0.612***	-0.533***
	(0.0531)	(0.0519)	(0.0513)
% of Industrial Customers	-0.727***	-0.695***	-0.688***
	(0.0541)	(0.0529)	(0.0522)
Natural Gas Price	0.00245***	0.00247***	0.00260***
	(0.000920)	(0.000899)	(0.000887)
1-Yr Lagged Natural Gas Price	0.000687	0.000740	0.000817
	(0.000921)	(0.000899)	(0.000888)
Deregulated Dummy	0.0299	0.0116	-0.00333
	(0.0295)	(0.0288)	(0.0284)
1-Yr Lagged Deregulated	0.00808	0.0128	0.00570
	(0.0330)	(0.0322)	(0.0318)
2-Yr Lagged Deregulated	-0.0172	-0.0138	-0.00584
	(0.0268)	(0.0261)	(0.0258)
3-Yr Lagged Deregulated	0.0136	0.00164	0.000392
	(0.0225)	(0.0219)	(0.0217)
4-Yr Lagged Deregulated	-0.0195	-0.00628	-0.00435
	(0.0205)	(0.0200)	(0.0198)
5-Yr Lagged Deregulated	-0.0961***	-0.0763***	-0.0744***
	(0.0151)	(0.0148)	(0.0146)
Constant	4.217***	4.266***	3.986***
	(0.0517)	(0.0504)	(0.0500)
Observations	38,882	38,882	38,882
R-squared	0.461	0.486	0.500

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As mentioned, I rerun my model after omitting firms that have less than 20 years of data in my sample. This results in 18,605 observations and 1,291 firms to drop from my sample. The R^2 increases from around 0.22

to 0.48 after dropping these firms, signaling a much higher goodness of fit with the firms left; the dropped firms may have contributed only as noise in my analysis. The main point of note with the new estimates is that table (7) column (3) shows that both cooperative and public electric utility coefficients are significantly positive. This implies that as seen from Peters (1993) and Berry (1994), $0 < \beta_1, \beta_2$ holds true for equation (5), as we expected earlier.

Appendix C Robustness Checks

C.1 Hausman Specification Test

In order to discern whether a state and year fixed effects was the appropriate model over the random effects model, I use a Hausman specification test. The Hausman specification test's null hypothesis states that the preferred model is random effects since the unique errors are not correlated with the regressors. The test returns $\chi^2 = 0.0109$, from which we can reject the null hypothesis, and conclude that the unique errors are correlated with the regressors. The fixed effects model is more efficient, and thus preferred for my purposes.

C.2 Model Stress Tests

To ensure robustness of the models presented, I check for any significant changes to the ownership status coefficients under model modification stress tests. Table (9) shows the effects of removing various control variables on the private ownership dummy variable from our model in equation (1). Tables (10) and (11) show results for the same stress test on equations (2) and (5), respectively.

The robustness checks show that the ownership coefficients do not significantly change in effect nor significance under these stress tests[12], showing that the specifications I use are robust.

[12]Note that in Table (11), although the coefficient for POUs change significance for columns (1) and (6), they are still significantly positive, same as the 20-year robustness check.

Table 9: Stress Test of IOU and POU Model

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Original
Private	6.199***	5.795***	5.782***	5.815***	5.785***	6.139***	5.640***	5.787***
	(0.709)	(0.716)	(0.716)	(0.716)	(0.716)	(0.717)	(0.708)	(0.716)
Total Customers		-2.58e-06*	-2.59e-06*	-2.58e-06*	-2.59e-06*	-3.58e-07		-2.59e-06*
		(1.41e-06)	(1.41e-06)	(1.41e-06)	(1.41e-06)	(1.41e-06)		(1.41e-06)
% of Residential Customers		55.68***	55.69***	55.61***	55.68***		61.77***	55.71***
		(5.622)	(5.621)	(5.625)	(5.622)		(5.456)	(5.625)
% of Commercial Customers		25.35***	25.37***	25.28***	25.35***		31.76***	25.38***
		(5.931)	(5.931)	(5.934)	(5.931)		(5.775)	(5.934)
% of Industrial Customers		10.18	10.26	10.09	10.25		16.57***	10.28
		(6.262)	(6.262)	(6.265)	(6.262)		(6.118)	(6.265)
Deregulated Dummy				-0.441	-0.570	-0.599	-0.291	-0.348
				(5.784)	(3.324)	(5.807)	(5.786)	(5.784)
1-Yr Lagged Deregulated				-1.196		-0.557	-1.113	-1.155
				(6.458)		(6.483)	(6.460)	(6.458)
2-Yr Lagged Deregulated				0.207		0.121	0.405	0.402
				(5.218)		(5.240)	(5.221)	(5.219)
3-Yr Lagged Deregulated				-0.188		-0.835	-0.306	-0.264
				(4.242)		(4.259)	(4.242)	(4.242)
4-Yr Lagged Deregulated				2.530		3.121	2.658	2.609
				(3.844)		(3.860)	(3.844)	(3.845)
5-Yr Lagged Deregulated				-2.270		-2.303	-1.660	-1.756
				(2.889)		(2.907)	(2.895)	(2.896)
Natural Gas Price		-0.324**	-0.106		-0.105	-0.102	-0.108	-0.101
		(0.157)	(0.182)		(0.182)	(0.183)	(0.182)	(0.182)
1-Yr Lagged Natural Gas Price			-0.440**		-0.439**	-0.462**	-0.457**	-0.442**
			(0.183)		(0.184)	(0.185)	(0.184)	(0.184)
Constant	90.38***	42.44***	43.25***	41.62***	43.40***	92.77***	37.25***	43.36***
	(0.436)	(5.611)	(5.620)	(5.663)	(5.687)	(1.145)	(5.529)	(5.693)
Observations	57,525	57,513	57,513	57,513	57,513	57,513	57,525	57,513
R-squared	0.219	0.226	0.226	0.226	0.226	0.220	0.225	0.226

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 10: Stress Test of For-Profit and Nonprofit Model

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Original
For-Profit	-5.752***	-4.212***	-4.218***	-4.197***	-4.218***	-7.039***	-3.931***	-4.244***
	(1.110)	(1.187)	(1.187)	(1.189)	(1.187)	(1.178)	(1.116)	(1.189)
Total Customers		9.39e-07	9.34e-07	9.40e-07	9.34e-07	4.43e-06***		9.43e-07
		(1.49e-06)	(1.49e-06)	(1.49e-06)	(1.49e-06)	(1.48e-06)		(1.49e-06)
% of Residential Customers		55.35***	55.37***	55.34***	55.37***		62.02***	55.43***
		(5.625)	(5.625)	(5.628)	(5.626)		(5.459)	(5.628)
% of Commercial Customers		25.13***	25.15***	25.10***	25.15***		31.69***	25.23***
		(5.938)	(5.937)	(5.941)	(5.938)		(5.782)	(5.941)
% of Industrial Customers		10.58*	10.66*	10.54*	10.66*		17.20***	10.74*
		(6.264)	(6.264)	(6.268)	(6.265)		(6.120)	(6.268)
Deregulated Dummy				-0.341	-0.0955	-0.635	-0.249	-0.246
				(5.787)	(3.325)	(5.809)	(5.789)	(5.787)
1-Yr Lagged Deregulated				-0.938		-0.328	-0.828	-0.893
				(6.461)		(6.485)	(6.462)	(6.461)
2-Yr Lagged Deregulated				0.0195		-0.0405	0.212	0.220
				(5.220)		(5.242)	(5.223)	(5.222)
3-Yr Lagged Deregulated				-0.105		-0.757	-0.229	-0.184
				(4.244)		(4.260)	(4.244)	(4.244)
4-Yr Lagged Deregulated				2.567		3.217	2.700	2.648
				(3.846)		(3.861)	(3.846)	(3.847)
5-Yr Lagged Deregulated				-1.862		-1.641	-1.236	-1.317
				(2.891)		(2.909)	(2.897)	(2.899)
Natural Gas Price		-0.339**	-0.115		-0.114	-0.117	-0.120	-0.113
		(0.157)	(0.182)		(0.182)	(0.183)	(0.182)	(0.182)
1-Yr Lagged Natural Gas Price			-0.452**		-0.452**	-0.480***	-0.473**	-0.458**
			(0.184)		(0.184)	(0.185)	(0.184)	(0.184)
Constant	93.60***	45.50***	46.33***	44.42***	46.35***	95.83***	39.78***	46.24***
	(0.346)	(5.607)	(5.617)	(5.661)	(5.685)	(1.117)	(5.527)	(5.691)
Observations	57,525	57,513	57,513	57,513	57,513	57,513	57,525	57,513
R-squared	0.218	0.225	0.225	0.225	0.225	0.219	0.225	0.225

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Stress Test of Cooperative, For-Profit, and POU Model

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Original
Cooperative	11.52***	9.436***	9.433***	9.454***	9.439***	12.65***	9.238***	9.486***
	(1.211)	(1.289)	(1.289)	(1.292)	(1.289)	(1.271)	(1.227)	(1.292)
POUs	2.362**	1.406	1.416	1.400	1.417	3.603***	1.156	1.453
	(1.145)	(1.216)	(1.216)	(1.218)	(1.216)	(1.213)	(1.147)	(1.218)
Total Customers		8.23e-07	8.19e-07	8.28e-07	8.17e-07	4.04e-06***		8.32e-07
		(1.48e-06)	(1.48e-06)	(1.48e-06)	(1.48e-06)	(1.48e-06)		(1.48e-06)
% of Residential Customers		54.74***	54.75***	54.73***	54.73***		61.30***	54.83***
		(5.621)	(5.620)	(5.624)	(5.621)		(5.454)	(5.623)
% of Commercial Customers		27.82***	27.84***	27.81***	27.82***		34.31***	27.93***
		(5.938)	(5.938)	(5.942)	(5.938)		(5.783)	(5.941)
% of Industrial Customers		9.803	9.881	9.790	9.864		16.33***	9.980
		(6.259)	(6.259)	(6.262)	(6.259)		(6.115)	(6.262)
Deregulated Dummy				-1.159	-0.954	-1.491	-1.072	-1.064
				(5.782)	(3.323)	(5.803)	(5.784)	(5.782)
1-Yr Lagged Deregulated				-1.397		-0.977	-1.291	-1.352
				(6.455)		(6.478)	(6.457)	(6.455)
2-Yr Lagged Deregulated				0.371		0.373	0.561	0.566
				(5.216)		(5.236)	(5.218)	(5.217)
3-Yr Lagged Deregulated				-0.326		-0.949	-0.449	-0.403
				(4.241)		(4.255)	(4.240)	(4.240)
4-Yr Lagged Deregulated				2.841		3.461	2.966	2.918
				(3.843)		(3.857)	(3.842)	(3.844)
5-Yr Lagged Deregulated				-1.643		-1.391	-1.024	-1.113
				(2.888)		(2.906)	(2.895)	(2.896)
Natural Gas Price		-0.329**	-0.112		-0.110	-0.113	-0.117	-0.110
		(0.157)	(0.182)		(0.182)	(0.183)	(0.182)	(0.182)
1-Yr Lagged Natural Gas Price			-0.438**		-0.437**	-0.466**	-0.461**	-0.446**
			(0.183)		(0.183)	(0.185)	(0.184)	(0.184)
Constant	88.10***	41.43***	42.23***	40.56***	42.48***	89.29***	36.22***	42.29***
	(1.034)	(5.691)	(5.701)	(5.748)	(5.766)	(1.536)	(5.609)	(5.776)
Observations	57,525	57,513	57,513	57,513	57,513	57,513	57,525	57,513
R-squared	0.220	0.226	0.226	0.226	0.226	0.221	0.226	0.227

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix D Graphs

Figure 1: Price and Market Size (IOUs)

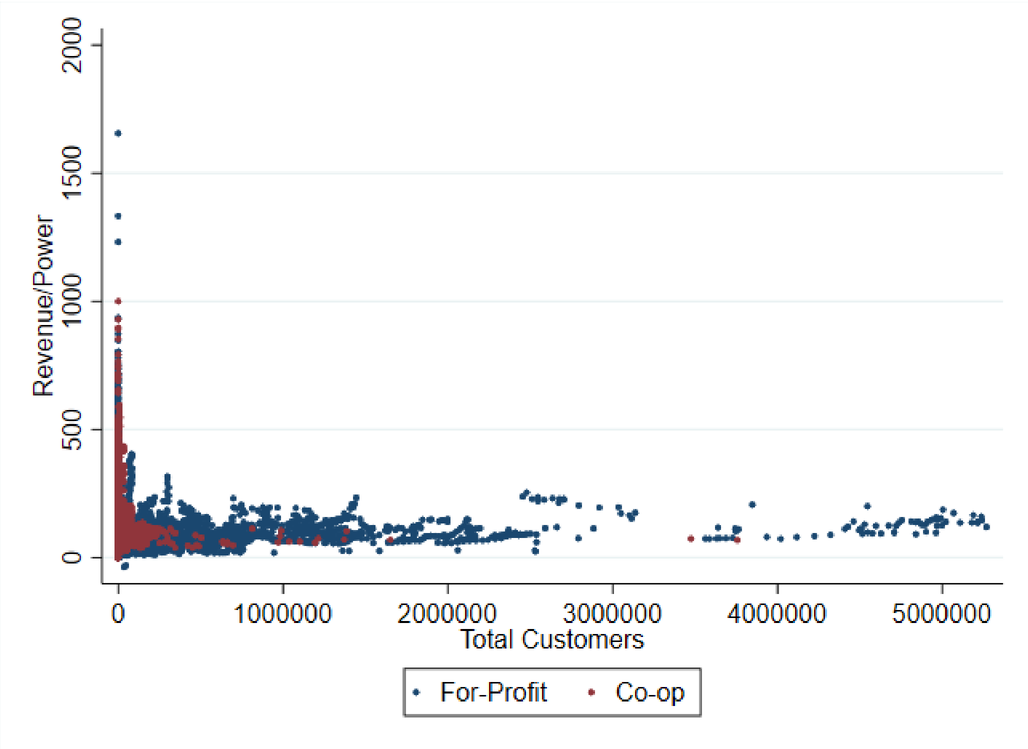

Figure 2: Price and Market Size (IOUs and POUs)

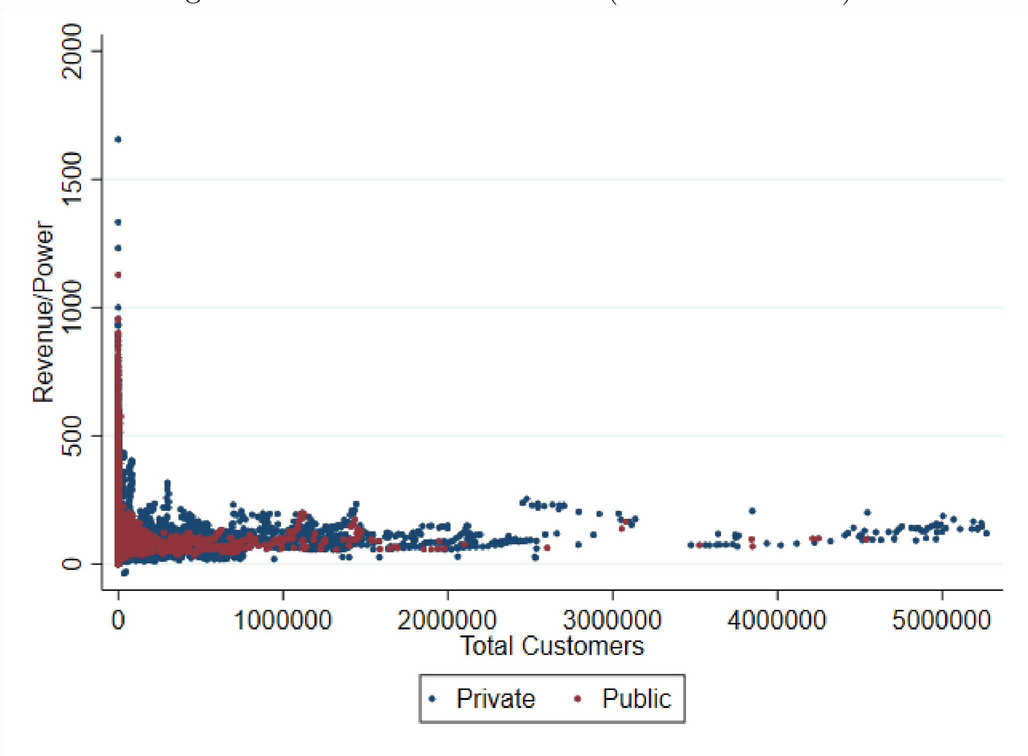

Figure 3: Effect of Deregulation on Price

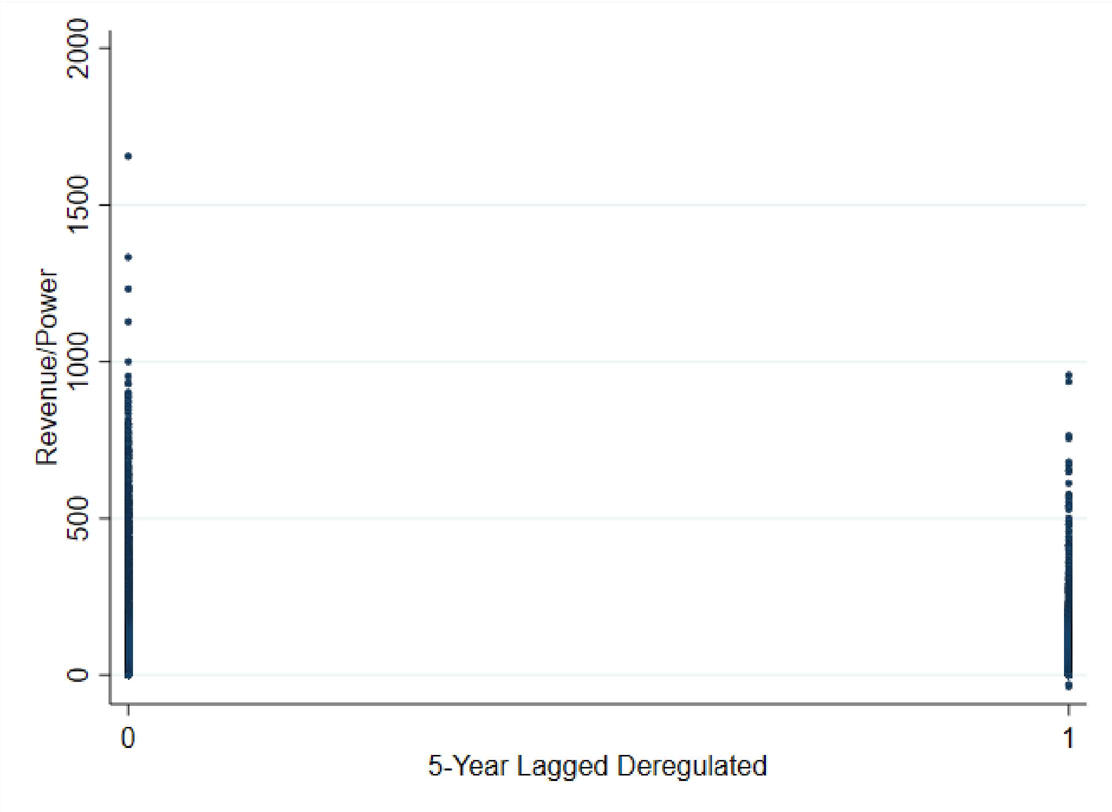

Figure 4: Residential Customers and Price