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ORIGINAL ARTICLE

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Abstract Jarrell (J Law Econ 21:269–295, 1978) found that electricity prices fell more slowly in states that adopted state regulation before 1917, suggesting that regulators were "captured" by the interests of the regulated electric utilities. An alternative explanation is that state regulation more credibly protected specialized utility assets from regulatory opportunism than did the municipal franchise contracting that preceded it. We test this alternative hypothesis using a panel of data from the *U.S. Electrical Censuses* of 1902–1937. We find that the shift from municipal franchise contracting to state regulation was associated with a substantial decrease in investment propensity, an outcome supporting the capture hypothesis.

Keywords Regulatory capture · Transaction cost economics · Electric utilities

JEL Classification K2 · L5 · L9 · N4 · N7

1 Introduction

Electricity is perhaps the quintessential regulated industry, yet the historical roots of its regulation remain imperfectly understood. This lack of clarity exists despite the existence of a small but fascinating literature on the subject. In a pioneering paper that initiated the empirical study of regulation, Stigler and Friedland (1962) argued

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that the behavior of electric utilities subject to state regulation was not significantly different from that of other utilities.[1] Jarrell (1978) pointed out that interpreting this result was difficult, since utilities not subject to state regulation remained subject to municipal franchise contracting, which had preceded state regulation historically. He showed that not only was state regulation adopted earlier in states with lower rates, these early-adopting states subsequently saw their electric rates fall more slowly than those in other states; he thus characterized state regulation as a classic example of capture by the regulated industry.

More recent work suggests that because municipal franchise contracting was rife with corruption, state regulation was seen as more likely to protect the massive quasi-rents created by large-scale investment in generation capacity. If so, then the relative increase in prices under state regulation could have been necessary to support investment, and state regulation can be seen as a better form of long-term relational contract.[2] Knittel (2006) used an empirical hazard model to shed new light on the drivers of early adoption of state regulation, and found they included not just low prices, but also capacity shortages and low residential electricity penetration rates. This suggests that a desire to increase investment may have been an important factor driving the adoption of state regulation. Neufeld (2008), in a similar empirical analysis, finds that states with a higher level of capacity per capita (proxying for larger appropriable quasi-rents) adopted state regulation earlier. This suggests that a desire to protect existing investments may have been an important factor driving the adoption of state regulation. Both papers imply that state regulation was expected to provide better protection for investment than did municipal franchise contracting.

We take a complementary approach to prior work, using panel data over the period 1902–1937 to estimate directly the effect of state regulation on investment behavior. A focus on investment behavior is helpful in distinguishing between the views of state regulation as an instrument of capture and state regulation as a better contractual means of protecting specialized investments. If state regulation was an instrument of capture, it should have allowed utilities to increase their monopoly power, raising price and restricting quantity; with lower quantity sold, utilities would have needed *less* generation capacity.[3] If state regulation was adopted because it was a more effective form of relational contract, removing power from the hands of corrupt municipal officials and providing utilities with a greater assurance of recovering their capital investments, it should have induced them to invest *more* in generation capacity, *ceteris paribus*. While both the capture and contract theories are consistent with an increase in price, they differ sharply in their predictions

[1] As described in Peltzman (1993), Claire Friedland later found that the paper had underestimated the impact of regulation on prices by an order of magnitude, though the statistical significance of the result remained marginal.

[2] Goldberg (1976) and Williamson (1976) both argue that regulation can be thought of as a form of long-term relational contract. Priest (1993) argues that a close reading of municipal franchise contracts reveals many similarities to regulation. Crocker and Masten (1996) survey the literature on long-term contracts and its implications for public utility regulation.

[3] We thank Roger Noll for pointing out this aspect of the capture theory.

regarding capacity. Thus, our empirical analysis offers a new approach to assessing whether capture or contract better explains the early years of state utility regulation.

The remainder of the paper is organized as follows. Section 2 presents a brief overview of the factors causing the transition from municipal franchise contracting to state regulation, and then assesses the potential effects of the transition, with emphasis on the implications for investment behavior. Section 3 discusses the data and the econometric challenges presented. Section 4 discusses the empirical specification to be tested, and Sect. 5 presents our empirical results. Section 6 concludes.

2 Causes and consequences of the transition from municipal franchise contracting to state utility regulation

This section prepares the way for our empirical specification, providing first a brief review of the process of transition from municipal franchise contracting to state regulation, and then an assessment of the ways in which the transition might have affected investment propensities.

2.1 Causes of the transition

In the latter half of the nineteenth century, the high cost of copper wire, along with the fact that direct current (DC) electricity experienced severe voltage drops with distance, meant that electric generating stations could only supply customers within a small radius of the plant. Under these conditions, and in light of the fact that electric companies needed access to public streets in order to install a distribution infrastructure, the municipality was the natural unit for political governance of electric power.[4] As described in detail by Priest (1993), Troesken (2006), and Neufeld (2008), the institutional system that developed was municipal franchise contracting, in which a local municipality would grant a franchise contract to a particular firm for a fixed period of time.

By the turn of the century, a series of technological advances led alternating current (AC) to emerge as the new technological standard. A key advantage of AC power was that it was more amenable to transmission over distance, as transformers could step up the voltage for transmission purposes, and step it down again for distribution to the ultimate user. As a result, large generating units could be located in inexpensive areas away from urban population centers, and scale economies could be more fully exploited.[5] Figure 1 shows that by 1917, the minimum efficient scale of operation for electric power generation was at least 200,000 megawatt-hours per year, enough

4 Epstein (1985) provides a contractual rationale for government involvement in utility regulation, in which a municipality grants a utility the right to use public streets in exchange for allowing municipal control over pricing.

5 See David and Bunn (1988) for an insightful account of technological change in electricity and its implications for the structure of the industry.

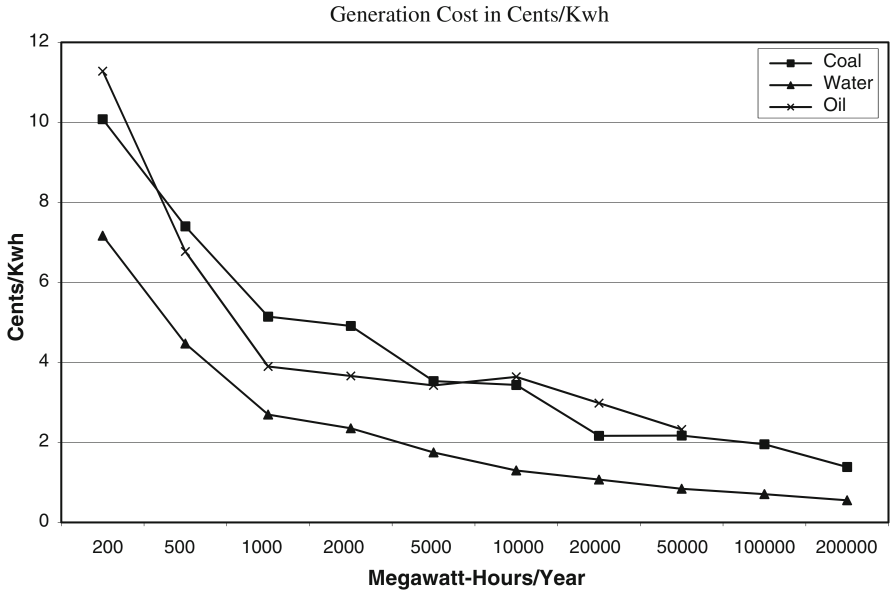

Fig. 1 Economies of scale in electricity generation, 1917. Source: United States Bureau of the Census (1917–1937, Table 96, p. 129)

to serve a third of the population of the average state.[6] The minimum efficient scale of an electric utility had grown much larger than the demand of a typical municipality.

As the new central generating station technology was being rolled out, the governance institutions used in the U.S. were changing as well. Massachusetts had been the first state to adopt state-level regulation of electric utilities, which it did in 1887. Twenty years later, other states began to follow. New York adopted state regulation in 1905, with Wisconsin and Georgia adopting in 1907. Vermont, Michigan and New Jersey adopted state regulation in 1908, 1909 and 1910, respectively. Then between 1911 and 1915, another 22 states switched to state regulation of electric utilities. In less than a decade, the new institution had swept the country and become the dominant mode of governance for electric utilities.

The speed and timing of this transition have led some scholars to suggest that it was ideologically driven, as part of the Progressive Era of American politics. Indeed, Miller (1993) points out that there was a surge in state-level regulation of the insurance and securities industries between 1907 and 1913, just at the same time state regulation

[6] The data we use are described in detail in Sect. 3 of the paper. This graph presents data from Table 96, p. 129, in the 1917 Census of Electric Utilities, which shows total expenses per kilowatthour (kwh) for plants of various sizes. In 1917, the amount of electricity used by the average customer was 281 kwh per year. Hence, the number of customers that could be served by an efficient-sized plant was 711,744. The average population per state in 1917 was 2,175,923, indicating that the average state needed approximately three efficient-scale plants.

of the utility industry peaked. Progressive politics surely played an important role in the transition to state regulation.

Despite the importance of national political trends, there were important economic forces involved as well. Electric utilities made large sunk investments in relationship-specific capital, which created quasi-rents that were exposed to the risk of opportunistic behavior by the municipalities with which they contracted. Anecdotes abound of municipalities threatening to allow new entry into a company's franchise territory if bribes were not paid (Jarrell 1978; Knittel 2006; Neufeld 2008). Many states also passed laws granting cities unilateral power to adjust rates when contracts expired, allowing municipal opportunism in the form of rates too low to cover firms' quasi-rents (Troesken 2006). Thus, state regulation was considered a governance structure that might provide greater protection for investments in electric capacity (Knittel 2006; Neufeld 2008) and by the 1920s most states had made the transition to state regulation. It is to the consequences of that transition that we now turn.

2.2 Consequences for investment of the transition to state regulation

Although Jarrell (1978) assumed away any potential differences in efficiency between municipal and state regulation, Goldberg (1976), Williamson (1976), and Priest (1993) all argue that different forms of regulation might have different implications for economic efficiency. This presumption is strongly supported by the voluminous theoretical and empirical literature on contracts, which finds that the particular structure of contracts can have important effects on the willingness of parties to make relationship-specific investments.[7]

What, then, were the key differences between municipal and state regulation and their implications for investment behavior?

As mentioned earlier, corruption was widely recognized to be a serious problem with municipal franchise contracting. State regulation offered the hope of improvement on this score. Regulation required a more public process of deliberation with better record-keeping; the resulting transparency could empower interest groups representing customer interests and make bribery more difficult to hide. In addition, regulatory commissions were supposed to be filled with reputable men whose competence and objectivity was hoped to be a check on corruption. The political prominence of the new state-level regulatory commissions meant that commissioners may have had greater incentive to maintain a reputation for competence and even-handedness.[8] All of these factors stood to reduce the risk of corruption and bolster the confidence of industry investors that they would be treated fairly. They should have led to an

[7] Crocker and Masten (1996) summarize the key insights from this literature.

[8] A regulator facing multiple firms risked undermining investment incentives on the part of all the firms under its jurisdiction if it set a non-compensatory price for any one of them. Indeed, Lyon and Mayo (2005) find empirical evidence of such "reputational spillovers" in the electric power industry during the 1980s: when regulators disallowed full cost recovery for utilities building nuclear plants, other nuclear power owner-operators in the same state cut back on their investments. Shimshack and Ward (2005) find similar evidence of regulatory reputation spillovers in the enforcement of environmental regulations by state agencies.

increase in investor confidence that increased investment under regulation, all other things equal.

State regulation might also have been a more efficient mode of governance, with lower transaction costs than municipal franchise contracting. As Knittel (2006, p. 206) put it:

> Given the increase in the geographical breadth of utilities, municipal regulation required more and more utilities to contract with multiple sets of regulators. In contrast, provided the municipalities fell within the same state, state regulation required only one regulatory contract, thereby decreasing transaction costs and the uncertainty associated with generation investments.

In addition, technological change and increasing minimum efficient scale of production meant that generating capacity could be used by multiple cities. This created a common pool problem that required coordination across municipal regulators, presenting the opportunity for coordination failures and exacerbating the risk of opportunistic behavior by individual municipalities.[9] If state regulation did indeed become a relatively more efficient mode of governance as the minimum efficient scale of utility operation grew, this would further bolster the argument that state regulation should be associated with greater investment in electricity generation capacity.

In contrast to these arguments for state regulation as a better form of relational contract, there was also a possibility that the scale economies of AC power would create large, powerful firms that had the ability to dominate state regulatory proceedings. The process of regulation is relatively technical in nature, especially when it comes to the financial accounting issues associated with new investments. Regulated firms with large sums at stake in the regulatory process had incentives to hire the best legal and financial representation available to make their case with regulators. Opposing interest groups, and the regulators themselves, may have been "outgunned" by the regulated firms. Indeed, Jarrell (1979) argues that regulated firms were able to increase their profits by manipulating accounting details to obtain inflated book values for their assets. Thus, it is possible that the move to state regulation also enhanced the potential for regulatory capture by the utilities. This would have given utilities greater ability to exploit their monopoly power, leading to higher prices, less output, and less investment in new generation capacity.

Our focus on investment behavior allows us to distinguish between efficient governance and regulatory capture in a way that is impossible if one focuses on prices. Both efficient governance and capture could imply an increase in prices. However, the two have very different implications for investment. More efficient governance would imply an increase in investment under state regulation, *ceteris paribus*. Regulatory capture, however, would imply a decrease in investment. This implication is robust

[9] Of course, one could also argue that the negotiating power of a municipality against a utility already supplying service to all surrounding areas was reduced by the company's presence in other areas, since this robbed the municipality of a credible threat to award the franchise to someone else." However, as Troesken (2006) points out, many states granted municipalities unilateral power to sets rates, so that even if the municipality could not credibly threaten to revoke the franchise, it still had the power to set rates at punitively low levels.

across various models of regulation.[10] Notably, in the traditional Averch–Johnson model of regulation an increase in the allowed rate of return implies a decrease in investment.[11] Although the result may seem paradoxical, it is actually quite simple: an increase in the allowed rate of return lets the firm more fully exploit its monopoly power, which it does by raising prices and restricting output. Restricted output in turn implies lower investment. If one is instead convinced by Joskow (1974) more nuanced description of the political economy of rate-of-return regulation, in which regulated prices remain in place until either the firm or consumer groups petition for a rate review, it remains the case that an increase in the price allowed by regulators implies a decrease in investment. Again, the result follows directly from the fact that a higher price results in restricted output, which implies lower investment.[12]

3 Data

Our primary data source is the series of reports issued by the U.S. Census Bureau on *Central Electric Light and Power Stations*, which were published at 5-year intervals from 1902 to 1937. These volumes, used also by Stigler and Friedland (1962), Jarrell (1978), Hausman and Neufeld (2002), Knittel (2006) and Neufeld (2008), provide information aggregated at the state level, and broken out by whether utilities are municipally or privately owned. Variables reported include total output in kwh, and generator capacity in kilowatts (kw).

These data were supplemented with data from other sources, including value added by manufacturing (*Twelfth Census of the United States 1900*, plus *U.S. Census of Manufactures 1909–1937*, interpolated), and population in cities of 2,500 of more residents (*U.S. Bureau of the Census, Statistical Abstract, 1917–1937*), We also used data from Stigler and Friedland (1962) regarding the dates when state commissions were instituted. Table 1 presents summary statistics.

The fact that several data series are not available for the entire sample period 1902–1937 (per capita income, value of plant and equipment, number of customers) led us to try a number of different specifications with different numbers of observations. In the end, we opted for a parsimonious empirical specification that allows us to maximize the number of observations available for analysis.[13]

In several cases, data on certain individual states are not reported separately, in order to avoid releasing confidential corporate data. Thus, Arizona data is combined with New Mexico for 1932–1937; Georgia is combined with South Carolina in 1937;

10 It is of course necessary to control for the maturity of the utility's infrastructure in empirical work, as we discuss in Sect. 4 below.

11 Baumol and Klevorick (1970) demonstrate this result in their Proposition 5, which they acknowledge (p. 175) is "surely counterintuitive, at least at first blush."

12 The same implication follows if one thinks in terms of the maximum return consumers will tolerate before petitioning for a rate review. Lemma 1 of Lyon (1991) provides the first-order condition for the firm in a Joskow-type model of regulation. Assuming the production function is quasi-concave, comparative statics readily yield the result that capital investment declines with the maximum return consumers will tolerate.

13 Details of other results are available from the authors upon request.

Table 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
Private capacity (kw)	336	339,745	605,015	764	4,672,380
Private generation (Mwh)	335	972,000	1,820,000	1,509	15,100,000
Urban population	336	1,232,792	1,746,870	8,429	11,000,000
Real value added ($ millions)	336	446	704	2	3850
Investment/capacity ($t-1$)	294	0.86	1.08	−0.61	8.20
Change in log of urban population	294	0.14	0.13	−0.12	1.25
Change in log of real value added	294	0.15	0.27	−0.66	1.50
Private capacity utilization at $t-1$	293	0.26	0.14	0.03	2.05
Log (private capacity/urban population) at $t-1$	294	−1.84	1.08	−4.45	0.53

Washington DC and Maryland are combined with Delaware in all years; Mississippi is combined with Alabama in 1937; Rhode Island is combined with Vermont in 1927–1937; Utah is combined with Montana in 1927–1937; West Virginia is combined with Delaware in 1927–1932. Since inconsistent aggregation of data could bias our results, we treat the data as missing whenever such a combination occurs.

The resulting dataset is a panel of state-level data on privately- and municipally-owned electric utilities, with observations every 5 years for the period 1902–1937. We use a dummy variable indicating the year in which state regulation became effective. Following previous authors (Stigler and Friedland 1962; Jarrell 1978; Hausman and Neufeld 2002), we assume state regulation became effective 3 years after the legislation creating a state commission was passed.[14] Table 1 presents summary statistics for our variables.

Figure 2 presents a preliminary look at our investment rate data. It plots investment (measured as change in capacity) divided by lagged capacity, for both of the ownership structures and both of the regulatory regimes we consider. It is important to note that this is not the level of total capacity, nor the level of investment; it is an investment rate, normalized by the existing level of capacity. Furthermore, the figure shows the unweighted average of investment rates across states, not the national rate that would be obtained by summing total US investment of a given type and dividing by total US capacity of that type. Although total capacity rose continuously over this time period, total investment rose and fell, peaking in 1927. Investment rates, however, show a general downward trend for all ownership-regulation combinations, with the exception of the year 1927, which shows an increase in investment rates for privately owned utilities. A drop in investment rate is to be expected as utilities gradually built out their infrastructures and converged towards equilibrium levels of capacity per capita and capacity utilization. In general, there are not large differences between the investment rates for privately-owned and municipally-owned utilities. More relevant for our purposes, though, we see that for both private ownership and municipal ownership,

[14] We tested other lags between enactment of legislation and effectiveness of regulation with qualitatively similar results.

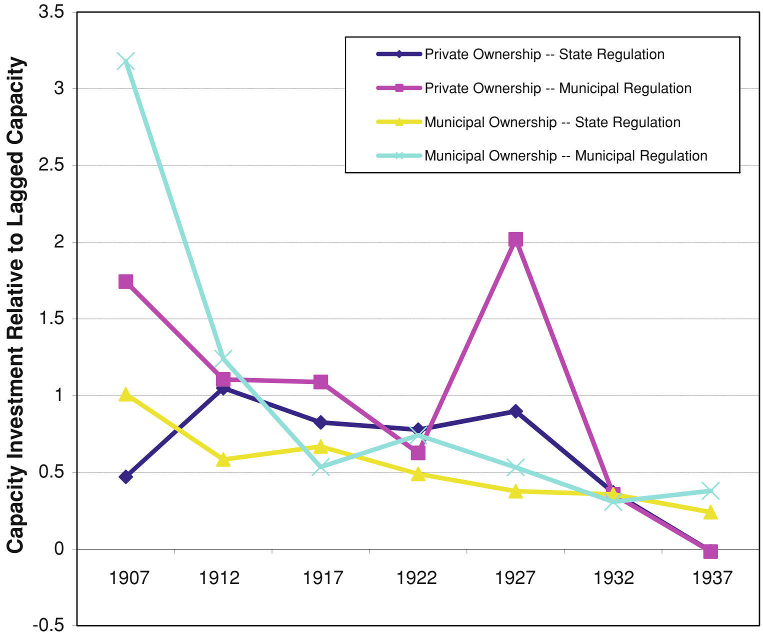

Fig. 2 Investment rates by regulation and ownership type

investment rates were greater under municipal regulation than under state regulation. While this is certainly suggestive, it does not account for such important factors as the level of capacity at the time state regulation was adopted, population growth rates, the idiosyncracies of individual states, or the peculiarities of individual years. To obtain a more precise understanding of how state regulation affected investment, it is necessary to move to a formal econometric framework, which we do in the following section.

4 The econometric model

The main question of interest in this paper is whether the investment propensity of electric utilities changed as a result of the shift from municipal franchise contracting to state regulation. Our units of observation are at the state level, and the time periods with which we work are the 5-year intervals captured in the Census Bureau data. Our basic econometric model takes the form of a treatment regression:

$$\mathbf{y_{it}} = \mathbf{X_{it}}\boldsymbol{\beta} + \mathbf{D_{it}}\boldsymbol{\delta} + \boldsymbol{\varepsilon}_{\mathbf{it}},$$

where $\mathbf{y_{it}}$ is the investment in new generation capacity in state i and period t divided by the amount of installed capacity in period $t-1$, $\mathbf{X_{it}}$ is a matrix of control variables, $\mathbf{D_{it}}$ is an indicator variable that takes the value of one if the state has adopted state-wide regulation, and $\boldsymbol{\varepsilon}_{\mathbf{it}}$ is a possibly compound error term. Because data on the value of plant and equipment are not available after 1922, we measure investment as the increase in electric generation capacity (in megawatts) since the previous period, relative to the previous period's capacity.

The literature on the transition to state regulation and previous work on investment behavior suggest a number of variables to include in $\mathbf{X_{it}}$.[15] First, the need for increased generation capacity is expected to rise with increases in the population of the utility's service territory, which we represent using the *change in the log of urban population* since most electricity demand came from urban areas. Second, the need for increased generation capacity is expected to increase with growth in the presence of manufacturing industry in a utility's service territory, which we measure using the *change in the log of real value added in manufacturing*. The strength of this effect depends on the extent to which industrial demand followed the same pattern as residential demand. While there is no good data on this point, the stylized facts indicate very different load patterns for residential and industrial customers. Residential demand peaked in the early evening, as homeowners turned on electric lights and kitchen appliances; industrial demand, conversely, peaked during the daytime hours. Third, new capacity is likely to be needed as the *utilization of existing capacity* increases. Fourth, as noted above, Neufeld (2008) presents compelling evidence that the transition from municipal franchise contracting to state regulation was correlated with large existing stocks of capacity per capita. If states' electricity investments were converging over time, this would lead to downward pressure on the coefficient on the regulatory indicator variable due to omitted variable bias. Therefore, we include the *lag of log capacity per urban resident* to ensure the consistency of our estimates.

In a panel covering as long a time period as this one, it is essential to control for time-period effects. For this reason, we include year dummies in all specifications. To control for the marked variation in economic development and geography across states, we believe it is appropriate to cluster our observations at the state level.[16] Furthermore, we exploit the panel dimension of our data to allow for the presence of time-invariant heterogeneity. In other words, we allow for the possibility that:

$$\boldsymbol{\varepsilon_{it}} = \boldsymbol{\eta_i} + \boldsymbol{\upsilon_{it}},$$

where $\boldsymbol{\eta_i}$ is a state-specific component and $\boldsymbol{\upsilon_{it}}$ is the observation-specific error. The presence of non-zero $\boldsymbol{\eta_i}$ would imply time-invariant differences in capacity growth rates across states.

We estimate ordinary least squares (OLS) and both random- and fixed-effects models of the effect of state regulation on capacity investment. However, we report only the results of the OLS and fixed effects models below. We do this for two reasons. First, the validity of the random effects model relies on the assumption that the unobserved heterogeneity in the error terms is orthogonal to the observed variables. We find this assumption to be extremely strong. Second, for the most part, when the algorithm for

15 See, for example, Lyon and Mayo (2005), and the references therein, and Neufeld (2008).

16 This is a more conservative approach than simply allowing for heteroskedastic standard errors. It allows for the possibility that all observations from a given state are related, although observations from different states are assumed to be independent. This effectively reduces the sample size, which makes it more difficult to find statistically significant results.

estimating random effects models is applied to our data, it returns coefficient estimates identical to those given by OLS. This "degenerate" outcome occurs as a consequence of the nature of the estimation algorithm and small sample issues.

In an effort to further ensure the robustness of our findings, we explore the consequences of relaxing different assumptions implied by our baseline specification. First, we consider the possibility that the impact of the shift from municipal to state regulation was not constant across states. In particular, we consider whether utilities in more rapidly growing states were disproportionately likely to alter their investment behavior; we do so by including an interaction term between the regulation indicator variable and the change in log urban population.

Second, we relax the assumption that past behavior has no effect on current investment. We do this by including one lag of the dependent variable to allow previous investment decisions to affect current investment behavior, as has been found to occur in a variety of other investment settings.[17] This dynamic specification has the form:

$$\mathbf{y_{it}} = \mathbf{X_{it}}\boldsymbol{\beta} + \mathbf{y_{it-1}}\boldsymbol{\alpha} + \mathbf{D_{it}}\boldsymbol{\delta} + \boldsymbol{\varepsilon}_{\mathbf{it}}.$$

In this framework, the existence of time-invariant effects would mean that the estimated coefficients are inconsistent. This is because the lagged dependent variable would be correlated with the fixed component of the error term. The bias does dissipate as the length of the panel goes to infinity, but it is unclear *a priori* how large it will be with six observations per group.[18] One can rely on a large number of groups and estimate the model using one of the recently developed generalized method of moments (GMM) dynamic panel estimators.[19] However, in finite samples, these estimators have been shown to be quite imprecise.[20] For this reason, we report the results of employing Bruno (2005) recently developed method of correcting for the bias in fixed-effects estimates of dynamic panel models.

5 Results

In this section, we present a series of regressions that explore the determinants of investment in electric generation capacity in the early part of the twentieth century and the impact of the shift to state regulation on investment propensity. In Table 2, estimation (1) presents a simple OLS regression of the rate of growth in private capacity on our explanatory variables without the regulatory treatment dummy and without state fixed effects. The variables explain 38 % of the variation in investment behav-

17 See Bond and Van Reenen (2007) for a recent survey. We include only one lag because we feel that it is implausible to assume that investment decisions 10 years prior would still be affecting contemporaneous behavior. It is worth noting that allowing for past investment behavior to influence contemporaneous decisions also controls for the possibility that state capacity investments were converging over time, which might otherwise bias our estimates of the impact of state regulation.

18 See Cameron and Trivedi (2005) for details.

19 See, for example, Blundell and Bond (1998) or Cameron and Trivedi (2005) for details.

20 See Bruno (2005).

Table 2 Static models of privately-owned capacity growth

	(1) OLS	(2) OLS	(3) FE	(4) OLS	(5) FE
Regulatory dummy		−0.059	−0.460*	0.206	0.029
		[0.134]	[0.238]	[0.169]	[0.267]
Regulatory dummy * change in log urban pop				−2.390*	−3.763**
				[1.295]	[1.861]
Change in log urban population	2.651***	2.622***	2.434*	3.062***	2.804**
	[0.826]	[0.846]	[1.440]	[0.913]	[1.371]
Change in log real value added	0.377	0.393	0.390^{+}	0.409	0.311
	[0.359]	[0.372]	[0.295]	[0.381]	[0.286]
Lag of private capacity utilization	0.530**	0.557**	0.347*	0.593***	0.319^{+}
	[0.244]	[0.236]	[0.200]	[0.219]	[0.206]
Log (private capacity/urban population) at $t-1$	−0.440***	−0.433***	−1.151***	−0.418***	−1.146***
	[0.109]	[0.107]	[0.207]	[0.107]	[0.191]
Year FE	Yes	Yes	Yes	Yes	Yes
State FE	No	No	Yes	No	Yes
Observations	293	293	293	293	293
R-squared	0.383	0.383	0.481	0.394	0.499

Cluster robust standard errors in brackets
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, $^{+}$ $p < 0.2$

ior. The growth in the state's urban population has a strongly positive and significant relation to capacity growth, as expected. Consistent with the notion that states were gradually converging to comparable levels of capacity relative to the size of their service territories, we see that states with higher levels of capacity utilization tend to have higher investment rates, while those with larger existing stocks of capacity per capita tend to have lower investment rates. Both of these effects are statistically significant at conventional levels. Also consistent with expectations, the growth in real value added in manufacturing is positively associated with increased investment, but its effect is not statistically significant.

Estimation (2) adds the dummy variable indicating whether the state has adopted state regulation, and finds that the effect of state regulation is negative though statistically insignificant. The signs, magnitudes, and statistical significance of the other variables remain largely unchanged. Although statistically insignificant, the coefficient on the regulatory dummy implicitly lends support to Jarrell (1978) argument that state regulators were captured. This is because the alternative hypothesis posits that the slower-falling prices Jarrell found under state regulation encouraged private utilities to more rapidly expand capacity. Estimation (2) allows us to reject this alternative hypothesis. Estimation (2) is consistent with the idea that state investment levels were converging over time, which does not have specific predictions about the impact of state regulation once existing levels of capacity (which might be positively correlated with the regulatory shift) are controlled for.

Estimation (3) adds state-level fixed effects to more fully account for systematic unobserved variation across states. Using this approach, the estimated impact of adopting state regulation increases dramatically in magnitude and becomes statistically significant at the 10 % level. This result is consistent with the idea that there were large differences in investment behavior across states that were not well captured by the observable explanatory variables. Moreover, Hausman tests of whether or not the fixed-effects models should be preferred to the simpler, potentially more efficient OLS results strongly support the use of fixed effects.[21] The negative and significant coefficient on the state regulation dummy further reinforces Jarrell (1978) argument that state regulators were captured by industry insofar as the role of investment convergence is controlled for yet regulation's effect is still negative. Moreover, the results suggest that the economic significance of the change in regulation was very large. The sample mean for the growth rate of private capacity in states not subject to state regulation was 120 %. Relative to this baseline, the adoption of state regulation would cause growth rates to fall by almost half.

Estimation (4) adds an interaction between the state regulation dummy variable and the change in the log of population, and is estimated by OLS. The effect of the interaction variable is negative, large, and statistically significant. The general character of the other coefficients remains the same except for the fact that the main effect of the change in regulation (i.e. the coefficient on the regulation dummy) becomes positive and insignificant. Evaluating the combined effects at the sample means implies a reduction in investment of 14 %. The results continue to imply that the change in the regulatory framework is negatively linked to the growth rate of private capacity, and suggest that this effect is especially pronounced in states with faster growing populations. Estimation (5) adds state fixed effects to estimation (4), and shows that the results found there are robust to controlling for persistent unobserved heterogeneity. In fact, the magnitude and precision of the estimated coefficient on the interaction term increase. The main effect of the switch in regulation becomes much smaller in magnitude, though it remains statistically insignificant. At the sample mean level of change in the log of urban population, 0.14, and the mean investment rate in states not subject to state regulation, 1.17, estimation (5) implies state regulation led to a 5-year growth rate 51 % points lower than it would have been under municipal franchise contracting.

Table 3 contains the estimates for our autoregressive specifications of private capacity investment. Overall, the models offer strong support for the results found in our static regressions even if they do not offer conclusive evidence about the importance of controlling for past investment behavior. Estimation (1) is an OLS regression of private investment on a one-period lag of itself plus all the regressors previously used. The lagged term is negative, as expected, but not statistically significant at conventional levels. The interaction effect remains negative and statistically significant, but

[21] Hausman tests are subject to a variety of small sample issues. To confirm the inference that the fixed effects results are preferable, we explored whether or not using just one variance-covariance matrix led to dramatically different results. It did not. Moreover, we also explored whether or not the results changed when the year dummies were dropped to reduce the possibility that the variance-covariance matrices were not of full rank. This also did not lead to a qualitative change in the results. Details are available upon request.

Table 3 Dynamic models of privately-owned capacity growth

	(1) OLS	(2) FE	(3) Bruno
Regulatory dummy	0.393*	−0.005	−0.015
	[0.197]	[0.234]	[0.297]
Regulatory dummy * change in log urban pop	−3.392**	−3.594**	−3.272**
	[1.560]	[1.646]	[1.552]
Lagged investment rate	−0.01	0.042	0.128**
	[0.053]	[0.046]	[0.055]
Change in log urban population	4.455***	3.582**	3.149**
	[1.408]	[1.406]	[1.293]
Change in log real value added	−0.031	−0.094	−0.08
	[0.237]	[0.165]	[0.324]
Lag of capacity utilization	0.725***	0.783***	0.787*
	[0.219]	[0.243]	[0.403]
Log (Capacity/urban population) at $t-1$	−0.467***	−1.266***	−1.300***
	[0.126]	[0.254]	[0.147]
Year FE	Yes	Yes	Yes
State FE	No	Yes	Yes
Observations	251	251	251
R-squared	0.366	0.516	

Cluster robust standard errors in brackets except for Bruno models where standard errors are bootstrapped
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

we now find that the main effect is positive and significant. For values around the sample mean of population changes, however, the net effect of the change in regulation remains negative.

Estimation (2) is a fixed-effects regression of the autoregressive model. As noted above, its estimates are biased, though the magnitude of the bias is not clear. In this model, the lagged investment term is statistically insignificant but positive. Both the main and the interaction effects of state regulation are negative, with the latter being statistically significant. Estimation (3) presents results of a fixed-effects model using Bruno (2005) bias correction method. While the regulatory interaction term remains negative and highly significant, the lagged investment term is positively signed and statistically significant at the 5 % level. This is opposite to the standard result in autoregressive investment models.[22] A positive lagged investment term would be consistent with diverging investment rates across states. We hesitate to accept this implication and suspect it may be driven by collinearity with the other variables relating to past investment behavior. Overall, we draw confidence from the fact that the dynamic models continue to robustly show a negative and statistically significant influence of state regulation on investment, which is our main question of interest.

22 It generally is assumed that budget constraints and non-convexities in the cost of capital investment will lead to a negative correlation between previous and current investment.

In summary, our empirical results offer robust and consistent evidence that the shift to state regulation had a substantial negative effect on capacity investment behavior, even after controlling for existing levels of capacity per capita and capacity utilization. We find that private utilities significantly reduced their rate of investment, which is consistent with an effort to maintain higher prices. Interestingly, we find evidence that the effect of the change in regulatory framework was most pronounced in the fastest growing states. Indeed, our fixed-effects estimates from Table 2, Eq. 5, imply that for the average regulated state, capacity in 1937 would have been 75 % higher in the absence of regulation. For fast-growing California, capacity in 1937 would have been 195 % higher in the absence of state regulation, while for slow-growing New Hampshire capacity would have been only 2 % higher in the absence of state regulation. All of these results support the argument laid out in Jarrell (1978) that the regulatory shift permitted private utilities to capture their regulators.[23]

6 Conclusions

Although Jarrell (1978) showed that the shift from municipal franchise contracting to state regulation led to a slower decline in electric utility prices in the early part of the twentieth century, relative to those in other states, this finding alone was not sufficient to demonstrate that state regulation was a case of regulatory capture. An alternative hypothesis is that municipalities that engaged in franchise contracting were guilty of corruption and opportunism, refused to allow adequate returns to investors, and hence were unable to elicit adequate investment in new capacity. State regulation might have remedied this problem by providing a more credible commitment to protect the specialized investments of utility companies, a possibility consistent with contractual theories of regulation, but assumed away by Jarrell.

This paper has tested whether state regulation did indeed result in a stronger propensity to invest on the part of electric utilities. We found no support for this hypothesis. Instead, we found robust evidence that state regulation actually reduced the investment propensity of investor-owned utilities, controlling for existing levels of capacity per capita. From the perspective of enhancing investment, any protection against regulatory opportunism conferred by state regulation was apparently outweighed by its vulnerability to capture by regulated firms.

[23] Although not reported here, our conclusions also are robust to a wide variety of sensitivity tests. In particular, we examined whether our findings for investment rates were reflected in output. We found that, indeed, output growth slowed following the adoption of state regulation, which is consistent with Jarrell (1978) though somewhat contrary to the findings of Hausman and Neufeld (2002). In addition, we explored the sensitivity of our results to different assumptions about when state regulation took effect. We found that they were qualitatively robust though the magnitude and precision of the estimate of regulation's impact did vary somewhat, which is unsurprising given our small sample size. The specification with a 3-year lag between legislation and regulatory effectiveness provided the greatest explanatory power. Finally, we examined whether our findings are driven by outliers, by Winsorizing our data, a process that takes the most extreme values for a variable and replaces them with a value corresponding to a given percentile of observations for that variable. We Winsorized both tails of our dependent variable to the 90th percentile and 10th percentile, respectively. The regulation dummy remained negative and significant in a regression using this variable. Details on all models are available upon request.

Our findings are consistent with those of Jarrell (1978), who found that prices under state regulation fell more slowly, and output grew less rapidly, than in other states, holding all other things equal. This increased exercise of monopoly power would naturally have resulted in less need for additional capacity. Our results may seem to contradict those of Knittel (2006) and Neufeld (2008), who argued that state regulation was adopted in part because it was expected to provide better protection of utility investments. However, even if regulation was adopted with the expectation of enhanced investment, it may have failed to deliver during the period we study. One possible reconciliation of these perspectives comes from Jarrell (1979), who found that the book values of utility assets were abnormally high under state regulation. He argued this was because utilities used their influence over utility commissions to revalue upwards their asset bases. If so, this accounting maneuver could have made it appear as if the utilities were increasing their asset bases at the same time that they were actually slowing their investment rates.

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