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DEREGULATION, GOVERNANCE STRUCTURES, AND EFFICIENCY: THE U.S. ELECTRIC UTILITY SECTOR

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The business strategy literature offers apparently opposite views of the ability of vertical integration to cope with the uncertainty related to changing regulatory environments. In this paper, we analyze how the process of retail deregulation affects the comparative efficiency of governance structures, which range on a continuum from fully vertically integrated structures to market transactions. Based on the analysis of 177 U.S. electric utilities from 1998 to 2001, our results show that the process of retail deregulation has a negative impact on firms' productive efficiency, as measured using Data Envelopment Analysis. Furthermore, firms that are vertically integrated into electricity generation, or that rely on the market for the supply of their electricity, are more efficient than firms that adopt hybrid structures combining vertical integration and contracting. This research has important implications because it shows the coexistence of different types of governance structures that cope efficiently with regulatory uncertainty through different mechanisms.

INTRODUCTION

The business strategy literature proposes apparently conflicting strategic options for firms to deal efficiently with environmental uncertainty and a changing regulatory environment. Transaction costs economics (TCE) argues that vertical integration reduces the transaction costs associated with uncertain market exchanges (Williamson, 1971, 1985). It suggests that vertical integration is more efficient than arm's-length market relationships for frequent transactions that are marked by a high level of specialized assets and uncertainty. Other organizational scholars, however, argue that loose (i.e., less vertically integrated) structures are more effective under conditions of high environmental uncertainty (Lawrence and Lorsch, 1967; Pfeffer and Salancik, 1978). They argue that the costs of implementing vertical integration can be substantial (Hill and Hoskisson, 1987). This is due in part to the lack of direct competitive pressure on the cost of intermediate products, which tends to encourage an increasing level of organizational slack (Cyert and March, 1963). This is also because vertical integration creates complex problems of control and coordination among highly interdependent activities and may result in managerial inefficiencies (D'Aveni and Ilinitch, 1992). Furthermore, the firm choosing an integrated governance structure in an uncertain environment may find it difficult to manage and relatively difficult to dissolve (Rumelt, 1995). Environmental uncertainty may result in excess capacity in some of the elements of the value chain, thus creating an

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imbalance of capacities along the value chain (Harrigan, 1985). Mobility and exit barriers may serve to further increase strategic inflexibility, trapping firms into keeping obsolete technologies and strategies (Harrigan, 1981). By contrast, non-integrated firms do not face such inertia and may focus all of their resources on adopting the know-how and technologies tailored to the new environmental demands (Delmas, 1999).

These are two apparently opposite views of vertical integration. This paper is an empirical assessment of the comparative efficiency of governance structures in an environment marked by high regulatory uncertainty. We analyze the governance structures of 177 major U.S. electric utilities from the start of the retail deregulation in 1998 to 2001. We compare the efficiency of utilities on a scale from vertically integrated firms which generate 100 percent of their own electricity to market strategies where utilities buy 100 percent of their electricity on the wholesale market.

The political and regulatory environment can be an important source of uncertainty for organizations. The ability of the government to credibly commit to and favor private investment is one factor that plays into such regulatory uncertainty (Levy and Spiller, 1994; Bergara, Henisz, and Spiller, 1998; Delmas and Heiman, 2001; Henisz and Zelner, 2001). The government can also create uncertainty by changing the regime of property rights that governs firms' abilities to capture the profits of their operations (Teece, 1986). This is the case with the deregulation of the electric utilities industry, where property rights associated with utilities' assets were redefined—exclusive franchise rights have been revoked and competitive market principles substituted in their place. As deregulation unfolds, a large number of what were previously seen as parameters with low uncertainty in the regulated environment become parameters with high uncertainty in the deregulated environment. As a result, firms need to spend time and resources to adjust to increased competition in output and output markets, as well as to the new institutional environment. Since deregulation may operate by a process of experimentation, where incremental changes occur and may be reversed or escalated at any time, the possibility of deregulation itself creates also an uncertainty. When the deregulation process is incomplete, managers face uncertainty concerning the path that deregulation is taking. In the period 1998–2002, for example, several states in the United States started a deregulation process and later decided to delay or suspend the process.[1]

Russo (1992) demonstrates how regulation in the electric utility sector influenced the choice of governance structure—such as the level of vertical integration. Dyner and Larsen (2001) argue that in a deregulated environment the increasing uncertainty in most, if not all, major inputs to the planning process creates a need for changes in the way electricity companies think about their strategy. Firms need to learn how to function in the new operating environment and to rearrange their organizational structure accordingly. The question of which governance structure is best suited to cope with regulatory uncertainty and adapt to changes in the regulatory environment becomes fundamental.

The empirical literature on transaction costs has been hampered by the lack of measures of efficiency or transaction costs. In the majority of empirical research in transaction costs economics, organizational mode is the dependent variable, while transactional properties, as well as other control variables, serve as independent variables (Boerner and Macher, 2001). In contrast, our research compares the efficiency of competing governance structures. We use Data Envelopment Analysis (DEA) to measure efficiency (Banker, Charnes, and Cooper, 1984; Majumdar, 1998; Majumdar and Venkataraman, 1998; Majumdar and Marcus, 2001). DEA is a technique that measures the relative efficiency of decision-making units, in our case network configurations, with multiple inputs and outputs, but without an obvious production function to aggregate the data in its entirety. This method of multiple input/output analysis has the advantage of enabling us to compare the efficiency structure of utilities that are vertically integrated in the generation of electricity to utilities that are using the market to buy their electricity supply. DEA is emerging as a powerful tool of data analysis for the electric utility sector, as corroborated by the study of Majumdar and Marcus, who used DEA in their seminal paper on

[1] California and New Mexico are such examples. California was the first state to start retail deregulation in 1998, allowing customers to purchase electricity from a company other than an investor-owned utility. However, retail deregulation was suspended on September 20, 2001 after the energy problems of the summer. Partly in response to the problems in California, New Mexico decided to postpone retail customer choice of power supplier until 2007.

the impact of flexible environmental regulations on productivity in the electric utility sector (Majumdar and Marcus, 2001).

Our analysis shows that the process of deregulation has a short-term negative impact on firms' productive efficiency. However, we find a nonlinear relationship between vertical integration and efficiency: firms that are vertically integrated into electricity generation or that rely on the market for the supply of their electricity are more efficient than firms that adopt hybrid structures combining vertical integration and contracting. We argue that the two streams of research described above highlight two different types of strategy to cope with uncertainty. This research has important implications as it shows the coexistence of different types of governance structures that are able to cope efficiently with regulatory uncertainty through different mechanisms.

In this paper, we first develop hypotheses on the impact of the deregulation process on efficiency and on the most efficient governance structures in the new regulatory context. Next, we use a sample of firms to empirically test the proposed relationships. Finally, we discuss the implications of our results for the business strategy literature and discuss directions for future research.

DEREGULATION IN THE U.S. ELECTRIC UTILITY SECTOR

Traditionally, a U.S. regulated firm in the electric utility industry is vertically integrated, whereby the firm that generates electricity also transmits it over high-voltage lines, distributes it over low-voltage lines, and retails it to the end users. Electric utilities in regulated states generally hold exclusive rights to serve retail customers within defined geographical areas. The early structure of the electric utility industry was built upon the concept that a central source of power supplied by efficient, low-cost utility generation, transmission, and distribution was a natural monopoly. Over the last 20 years, important innovations have been achieved in the transmission of electrical power (U.S. Department of Energy, 2000). The result is that the effective economic area over which electricity can be distributed has increased significantly and the natural monopoly argument lost some of its substance.

Due in part to these changes in the capacity of utilities to serve a larger area, the process of governmental deregulation began. Although retail deregulation was not yet considered, steps were being made to open this industry to competition. As early as 1978, the Public Utility Regulatory Policies Act required utilities to purchase power from independent power producers. Subsequently, the Energy Policy Act of 1992 allowed utilities and non-utilities to own independent power producers, and expanded the Federal Energy Regulatory Commission's (FERC) authority to request utilities to provide transmission service for wholesale power transactions. While these measures encouraged the entry of independent power producers into the market, they did not allow retail competition. The process of retail deregulation began in 1996, when FERC issued Order 888, which required utilities to open their transmission lines to competitors.[2]

It is timely to study the impact of deregulation on firms' efficiency and investigate how the utilities can respond for increased efficiency. Retail deregulation initiatives in electricity markets were implemented, starting in 1998, when several U.S. states launched pilot programs allowing competition. As of 2002, 24 of the 50 states have initiated retail deregulation. Because almost half of the U.S. states are partially deregulated in the electric power sector, this is a good time to investigate the impact of deregulation on firms' efficiency. To our knowledge, there is no empirical research that assesses the short-term impact of retail deregulation on the efficiency of the electric utility industry, and compares the efficiency of governance structures in the context of an industry that is in the process of being deregulated.

DEREGULATION PROCESS AND EFFICIENCY

Although retail deregulation may have potential long-term benefits, we argue that in the short term firms face a very uncertain environment and transitory costs, which lead to decreases in efficiency. A regulated environment is marked by several unique conditions, which are no longer present in a deregulated environment, and firms need time and resources to adapt to these new conditions.

[2] See Joskow (2000) for a detailed discussion of the evolution of regulatory structure of the U.S. electricity sector.

Borenstein and Bushnell (2000) point out that due to significant alterations to operational practices in the generation market and the exercise of market power, operational efficiency may decrease during the restructuring process. Competition in the wholesale electricity generation market may take time to increase because production is capital intensive and construction delays are long. Hence, entry into the market may be slow and there is a potential risk of market power in the electricity trading market. Joskow (1997) also suggests that deregulation is unlikely to lead to significant short-run cost savings, but that medium- to long-term efficiency gains may be achieved by increasing the productivity of labor and improving the performance of existing facilities.

Dyner and Larsen (2001) argue that the new conditions created by the deregulated environment require that utilities move away from traditional planning and invest in new development strategies. According to these authors, stable prices and the predictability of demand favor 'hard modeling' approaches, such as those provided by short- and mid-term forecasting and optimization. Indeed, with rate of return regulation, prices are set so that utilities can recover their costs. In this way, there is little financial risk for the utility. As deregulation takes place, however, electric utilities need to learn how to manage market risks due to wholesale price fluctuations. They can adopt, for example, new financial instruments such as weather derivatives, to hedge the risk of electricity price fluctuations due to weather conditions.[3]

In a regulated environment, the demand for electricity is relatively easy to predict since utilities have exclusive rights to serve a designated geographical area and information about existing capacities is publicly available. But with increased competition associated with deregulation, utilities face the additional challenge of determining their own demand based not only on a general need for electricity by the public, but also on the utility and its competitors' commercial strategy. Furthermore, in a deregulated environment, information about existing capacities may not be available in the public domain. Thus, as Dyner and Larsen argue, standard operations research models may fail to predict usage sufficiently to optimize their gains (Dyner and Larsen, 2001). Firms will need to learn to use softer forecasting techniques—such as strategic simulations and scenarios to predict their demand and associated generation capacity (Dyner and Larsen, 2001). In addition, firms will also have to learn how to market their product to their customers and will therefore have to increase their marketing expenses. Since sales may not increase in the short term (due to the time it takes to implement a system where customers can easily switch from one utility to another), firms may have to incur these investments in new techniques without the benefits of increased market share.

Firms will also have to use labor more efficiently in deregulated environments due to increased competition. For example, firms may have to lay off some workers and train others for new tasks. These reorganizations may cause inefficiency in the short term. Furthermore, some firms that made capital investments during the regulatory period under the rate-of-return regulation may not be able to recover these costs in a deregulated environment. These 'stranded costs', which regulated utilities were permitted to recover through their rates, may be more difficult to recover with the advent of competition (Baumol and Sidak, 1995).

Because of the transitory costs described above and the short-term inelasticity of demand, we expect that in the short term firms will face an increase in the cost of their inputs such as wholesale prices, capital, labor, and distribution costs without much increase in the size of their market. We therefore hypothesize that deregulation in the short term leads to lower productive efficiency, which is defined as the ability to obtain maximum output with given inputs (Farrell, 1957). Since there is no strict guideline on what constitutes short-term and long-term periods, we consider that the transitory period from a regulated environment to a deregulated environment can be defined as short term when the process of deregulation is incomplete.[4] We therefore analyze the period that represents the process of deregulation.

[3] Adverse weather conditions can have a significant impact on earnings. Electric utilities can use weather derivatives to hedge against their exposure to variations in weather and cover themselves against a drop in profits caused by the weather, thus reducing earnings volatility. The first global weather derivatives market transaction took place in 1997. It was executed by Aquila Energy as a weather option embedded in a U.S. power contract between Enron and Koch. Close to 5000 weather contracts with a total exposure of $7.5 billion were transacted between October 1997 and April 2001 (http://www.platts.com/features/weather-derivs/intro.shtml, accessed March 1, 2003).

[4] For example, in the United States, 5 years after the first state started deregulation no proposal for widespread structural

Hypothesis 1: In the short term, the greater the level of deregulation, the lower the level of the productive efficiency of the utility.

GOVERNANCE STRUCTURES AND EFFICIENCY

Facing the strategic prospect of the market opening up to consumer choice, electric utilities can adopt several strategies to adapt to regulatory and market changes. They can remain vertically integrated (i.e., the utility owns its own generating plants, transmission system, and distribution lines to provide all aspects of electric service) or divest some of the activities of their value chain.

Several characteristics of the electric utility sector make vertical integration a favorable option for firms in this industry. Landon (1983) argues that if electric utilities vertically divest, they may incur substantial transaction costs due to technological interdependence requirements for long-term contracting, informational and transaction requirements, and difficulties of appropriate pricing between vertical levels. First, the technological properties of electricity generation and distribution make firms very dependent on each other. Since errors made in any part of the system can affect costs at vertically related stages of the system, firms might have concerns about the abilities of the firms with which they are interconnected to provide power. These externalities may create moral hazard problems. Second, the possibility of equipment failures and primary input price fluctuations makes the supply of electricity uncertain. In addition, fluctuations of consumer consumption, due to weather variations, for example, make the demand for electricity uncertain. These uncertainties can make the design, negotiation, and enforcement of long-term contracts expensive or difficult (Kaserman and Mayo, 1991). Furthermore, because there are large fixed investments at the generation and distribution stages of electricity supply, firms might fear opportunistic behavior by the other party due to fixed investments and market power (Henisz and Zelner, 2001).

Several empirical studies support the advantage of vertical integration over market strategies. They suggest that substantial transaction costs may arise in exchanging power through an intermediate product-market and that downstream costs may increase as well. Kaserman and Mayo (1991) provide empirical evidence for the economic benefit of vertical integration in the generation and transmission/distribution of electric supply through an analysis of 74 privately owned electric utilities in 1981. Lee (1995) analyzed the technological efficiency benefits of vertical integration for 70 electric utilities in 1990 and concluded that separating the functions of generation, transmission, and distribution will result in loss of technical efficiency. Kwoka (2002) finds a cost savings from vertical integration for all but the smallest utilities, where the largest cost savings are present for those that are nearly fully integrated. These studies all focus on the period of pre-deregulation, however, so questions of the benefits of vertical integration in a period of deregulation remain unaddressed.

When dealing with the process of deregulation, firms face additional uncertainties as described above, which have the potential of making vertical integration even more attractive. In particular, concerning the generation of electricity, firms that are vertically integrated are less exposed to price volatility. They can internally adjust to supply and demand (i.e., they can generate more or less electricity in response to changes in demand).

However, in the case of *highly* uncertain environments, vertical integration may have some drawbacks. Most importantly, it may lead to strategic inflexibility. Both Hill and Hoskisson (1987) and Jones and Hill (1988) conclude that increases in environmental uncertainty raise the costs of hierarchical governance. In a capital-intensive industry such as the electric utility sector, firms may face high costs if the new competition results in demand uncertainty. Indeed, when demand is highly uncertain, the likelihood of insufficient sales volumes (resulting in costly excess capacity) is increased. Harrigan (1985) shows that such a case of demand uncertainty discourages the use of vertical integration. She demonstrates that variability in demand increases the riskiness of vertical integration when two or more strategic business units have become dependent on each other for product transfers. She also hypothesizes that the potential costs of using vertical integration increase with intensified competition because competitors are more likely to use price-cutting to fill their plants' capacities. Furthermore, mobility and exit barriers may augment

change has yet achieved a broad consensus and the process of deregulation is still ongoing.

strategic inflexibility and confine firms into keeping outdated technologies and strategies.

Another disadvantage of vertical integration is that it may increase the costs of processing information. D'Aveni and Ravenscraft (1994) argue that for vertically integrated subunits processing information may be more difficult than for vertically disintegrated units since with vertical integration the information has to be collected for the entire value chain and coordinated among the different steps of the value chain as opposed to revealed through market prices. Since environmental uncertainty increases the information-processing needs of organizations (Thompson, 1967), vertical integration, compared to market solutions, may put firms at a disadvantage. As we mentioned earlier, Dyner and Larsen (2001) explain that the new competitive environment in the electric utility sector may necessitate the adoption of new managerial and forecasting techniques. Firms that are non-integrated may be able to focus on these new management techniques without facing the organizational inertia associated with vertical integration. By focusing their efforts on buying power from wholesale markets rather than on generating power, these organizations may be able to rapidly develop the managerial skills necessary to cope with the new competitive environment.

Hybrid structures that combine both market and hierarchy incentives may seem to provide the perfect resolution to these concerns about vertical integration. Hennart (1993) argues that hybrid forms may be more efficient than 'pure' market or hierarchy. He explains that the total cost of using hybrid forms should be less than the total cost of using market or hierarchy alone. He concludes that this is because cheating and shirking costs increase more than proportionately as one concentrates in either pure price or behavior constraints. However, Hennart does not discuss the coordination costs associated with using both markets and hierarchy structures within a single firm. In the case of the electric utility sector, generating electricity and buying electricity on the market are two distinct operations that require very different skills and capital. A company that possesses both these lines of business is required to balance the costs and benefits associated with managing multiple business lines (Harrigan, 1985). The combination of these different activities within an organization may therefore increase the internal costs of coordination. These coordination costs may be higher when firms start to use both incentive structures as they need to adjust their organization. Since deregulation is a recent phenomenon, firms may still be incurring the cost of reorganizing their business to manage both the generation of their electricity and the purchase of electricity on the market through contracts.

Furthermore, there are important sunk costs and economies of scale associated with the generation of electricity. By combining both internal generation and the purchase of power on the market, a firm may not benefit from these economies of scale. Indeed, Kowka (2002) shows that while particular items of overhead expenses vary with the degree of integration, overhead costs in total are not substantially different.

In conclusion, it is difficult to hypothesize a simple linear relationship between vertical integration and efficiency in the transitory period from a regulated environment to a deregulated environment. On the one hand, firms that are vertically integrated are more insulated from the uncertainty created by the process of deregulation than firms that are not vertically integrated. On the other hand, non-integrated utilities, which are focused primarily on buying their energy on the wholesale market and selling it to consumers, may rapidly adopt the managerial skills to write complex contracts and deal with the volatility of electricity wholesale prices. In the short run, hybrid governance structures may incur the cost of both 'pure' forms without all their benefits, thus suggesting that there is a 'U shaped' relationship between the level of vertical integration and efficiency. The hypothesis can be formalized as follows:

> *Hypothesis 2: There is a U-shaped relationship between the level of vertical integration and efficiency. Firms with a high level as well as a low level of vertical integration will be more efficient than those with a medium level of vertical integration.*

METHODOLOGY

The data we use in this research originate from the FERC Form no. 1 for 177 U.S. electric utilities from 1998 to 2001. FERC Form no. 1 is the Annual Report for Major Electric Utilities, filed by about 200 investor-owned electric companies.[5] The average 140-page report for each utility contains general corporate information, financial statements and supporting schedules, and engineering statistics.

Dependent variable

Our dependent variable is the productive efficiency of the utility. We estimate productivity using Data Envelopment Analysis (DEA) (Charnes, Cooper, and Rhodes, 1978; Banker *et al*., 1984). The DEA technique uses linear programming to convert multiple input and output measures into a single measure of relative efficiency for each observation. A piecewise linear industry best practice frontier is constructed using the observations in the sample. If a firm is on this frontier, it is considered efficient. If it is not on the frontier, its radial distance from the best practice frontier is a measure of the firm's *in*efficiency. Majumdar (1998) presents a good overview of the DEA technique, while Coelli, Rao, and Battese (1998) provide a more detailed description.

The theoretical development of DEA is usually attributed to an economist (Farrell, 1957), but became operational much later following the work by operation research specialists (Charnes *et al*., 1978). The DEA technique has been more recently used in the strategy literature (Majumdar, 1998; Majumdar and Venkataraman, 1998; Majumdar and Marcus, 2001; Durand and Vargas, 2003).

An alternative way of calculating productive efficiency is the econometric method called stochastic frontier analysis (Aigner, Lovell, and Schmidt, 1977). The econometric approach requires the pre-specification of a functional form, whereas DEA requires only an assumption of convexity of the production possibility set. However, while the econometric approach recognizes that there may be errors in data or measurement of the underlying efficiency, DEA assumes that there are no errors. Therefore, any error will be reflected in the efficiency score. Another weakness of DEA is that it defines the frontier of the most efficient firms within the sample. So if the sample is too small, the frontier may not be representative of the potentially most efficient frontier of the industry because of missing observations. This is not a big problem in our case since our sample represents 83 percent of the electric production.

Another advantage of DEA is that different returns to scale behavior can be observed in different segments of the production possibility set. This is advantageous because some firms may be operating at increasing returns to scale and others at decreasing returns to scale. The econometric approach requires the same returns to scale behavior for all firms. In addition, the extension of the stochastic frontier analysis method for estimations of multiple outputs raises computational problems as the number of parameters to be estimated becomes larger (Banker, Conrad, and Strauss, 1986). The fact that DEA considers multiple inputs and outputs makes this technique particularly appealing to study efficiency in the electric utility industry, as it allows us to compare firms that have different output mixes. For example, some firms may primarily sell low-voltage electricity to residential and commercial customers, while others sell high-voltage sales to industrial customers or for resale to other utilities. These different output mixes refer to different cost structures and DEA considers all inputs and outputs as a group, eliminating the situation where each firm claims to be a best performer on the basis of a limited view of a single output or input. Because of this, DEA has been used by several researchers analyzing the electric utility industry (Roberts, 1986; Majumdar and Marcus, 2001; Goto and Tsutsui, 1998; Sueyoshi and Goto, 2001).

Computation of productive efficiency

In the construction of our measure of productive efficiency, we build on the work of Majumdar and Marcus (2001), who analyzed the productivity consequences of flexible regulations in the electric utility sector. In our case, the productive efficiency of a firm in a specific year is computed by comparing it to all other firms in the same year.[6] We use an input-oriented productive efficiency measure,

[5] Major electric utilities include utilities with annual sales or transmission service that exceed one of the following: (1) one million megawatt hours of total annual sales; (2) 100 megawatt hours of annual sales for resale; (3) 500 megawatt hours of gross interchange out; or (4) 500 megawatt hours of wheeling for others (including deliveries and losses).

[6] Another alternative is to pool the firms in different years and compute the best practice frontier for the pooled sample. This approach assumes that technology has not changed significantly in the period of 1998–2001. Therefore, the best practice frontier is the same. Since we do not believe that this is a realistic assumption, we do not use this approach.

which seeks to reduce the input quantities without changing the output quantities.[7] Our DEA calculations also recognize that all firms may not be operating at optimal scale. Therefore, we allow different firms to have different returns to scale and the productive efficiency measure is devoid of the scale effects (Coelli, 1996). The inputs and outputs of the variable that represents efficiency are described below.

Inputs

We use the following items as inputs: labor cost, plant value, production expenses, transmission expenses, distribution expenses, sales, administrative and general expenses, and electricity purchased from other sources.[8] Our choice of inputs is consistent with the literature. Roberts (1986) suggests using electricity purchased from others, capital used in transmission and distribution in addition to generation inputs. Similarly, Majumdar and Marcus (2001) include production expenses, transmission expenses, distribution expenses, administrative and general expenses, number of employees as inputs to electric utilities, and electricity purchased from other sources.

Outputs

We consider the following outputs: quantities of low-voltage sales (residential and commercial), high-voltage sales (industrial, interchanges out, and wheeling delivered), and sales for resale to other utilities in megawatt hours. A firm's cost of supplying power to final consumers is affected by the type of customer it serves (Roberts, 1986; Thompson, 1997). High-voltage sales incur less transmission costs than low-voltage sales due to reduced operating and maintenance costs. Furthermore, wholesale sales are less costly than both low- and high-voltage sales since they typically occur on less costly off-peak hours and entail larger quantities per transaction (Berry and Mixon, 1999). We consider these three types of outputs separately because of their differing costs.

The dependent variable that measures the productive efficiency of a utility is between 0 and 1. The utilities that are on the best practice frontier of the industry all have efficiency scores of 1. Figure 1 illustrates that 45 percent of the utilities in our sample are on the industry best practice frontier.[9] Utilities on the best practice frontier are not necessarily fully efficient. This frontier merely describes the industry best practice at the time of measurement.

Independent variables

The independent variables are divided into several categories related to the level of deregulation that

[7] Productive efficiency is calculated using the Data Envelopment Analysis program written by Coelli (1996).

[8] Production expense includes maintenance cost as well as fuel cost.

[9] The average efficiency score for our sample is 0.86, with a standard deviation of 0.18. Such results are typical for studies using DEA methodology. For instance, Majumdar and Marcus (2001) report an average efficiency score of 0.78 with a standard deviation of 0.24. Similarly, Goto and Tsutsui (1998) report an average efficiency score of 0.90 for U.S. utilities for 1984–93.

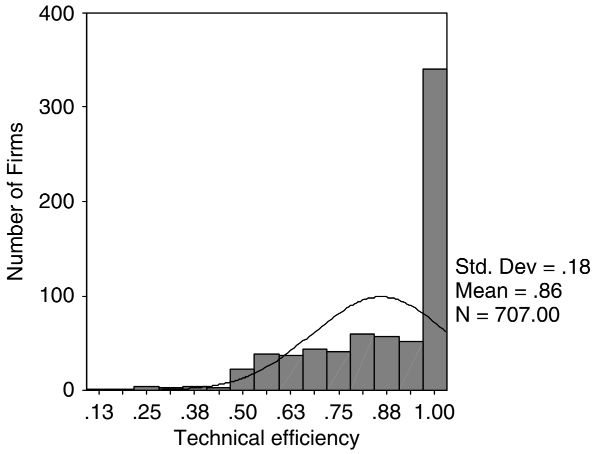

Figure 1. Distribution of the efficiency variable (pooled sample)

utilities face, the nature of the competitive environment, the level of vertical integration of utilities, the size and market share of utilities, whether firms are involved in mergers with other utilities, the amount of power generated from nuclear energy, renewable energy, and the power grid to which the utility belongs.

Deregulation

The process of deregulation is complex and varies across states. Several variables account for the degree to which the firm is exposed to deregulation. The variable DEREGULATION represents the stages of deregulation of each state for each year from 1998 to 2001. This variable is coded from 0 to 4, with (0) representing no activity; (1) commission or legislative investigation ongoing; (2) legislation orders pending; (3) comprehensive regulatory order issued; and (4) restructuring legislation enacted.[10] These four levels may not represent all levels of deregulation as some firms are operating in several states and are therefore subject to different levels of deregulation imposed by each of the states in which they are operating. In order to compensate for these differences, we base the weighting of DEREGULATION on the percentage of the electricity sold by each utility in each state.[11] For example, if in 2001 a utility is selling 80 percent of its electricity in state A with restructuring legislation enacted (4) and 20 percent in state B with legislation orders pending (2), then DEREGULATION will take the value of $4 \times (80/100) + 2 \times (20/100) = 3.6$. In addition, to assess whether deregulation is enacted in a more dichotomous way, we introduce a second variable: DEREG2. This variable takes the value of 1 if restructuring regulation has been enacted or a regulatory order has been issued, and 0 otherwise. It is weighted based on the percentage of electricity sold by each utility within the state.

Not only does the level of deregulation vary across states, but the type of deregulation varies across states as well. Some deregulated states require that utilities divest their generating assets, impose a price cap at the retail level, and/or allow the recovery of stranded costs. We introduce three additional variables that represent whether (i) divesture of generating assets is required (DIVESTURE), (ii) there is a price cap at the retail level (PCAP), and (iii) the recovery of stranded costs is allowed (SCOST). DIVESTURE and SCOST are constructed as follows: first we create variables coded 0 if there is no deregulation, 1 if there is deregulation, and 2 if there is deregulation plus one of the two characteristics of deregulation described above. These variables are weighted by the percentage of electricity sold by each utility within the state. PCAP is constructed as follows: first we create a variable coded 0 if there is no deregulation, 1 if there is deregulation and a price cap, and 2 if there is deregulation without a price cap. Second we weight this variable by the percentage of electricity sold by each utility within the state.

Level of vertical integration of the firm

To account for the level of vertical integration of the firm, we introduce the variable PROP_GEN, which represents the proportion of electricity sold that is generated by the utility. Because we hypothesize a nonlinear relationship between PROP_GEN and efficiency, we enter the variable as a quadratic term in the regression. Note that PROP_GEN is de-meaned (i.e., its values are from -0.5 to 0.5). We observe a change in the organizational structure of electric utilities in the period of 1998–2001. The percentage of vertically integrated firms in our sample (proportion generated internally $>90\%$) decreased from 19 percent in 1998 to 14 percent in 2001, while the number of non-vertically integrated firms (proportion generated internally $<10\%$) increased from 18 percent to 30 percent.[12]

Competitive environment

The level of fragmentation of the competitive environment may impact efficiency. We capture the fragmentation of the market by dividing the number of utilities that serve each state by the total quantity of electricity sold in the state.[13] The variable FRAGMENT represents the fragmentation

[10] The source of this information is the Energy Information Administration.

[11] This information was taken from the Energy Information Administration publication *Sales and Electric Revenue*, Table A1: Electric utilities serving ultimate consumers in more than one state.

[12] The reported trend is not sensitive to different ways of splitting the firms into vertically integrated and non-integrated. Results are similar if firms are split as 80/20 or 100/0.

[13] We obtained this information from State Electricity Profiles, Table 3, for the years 1998 and 1999 (http://www.eia.doe.gov/

faced at the firm level and is the weighted average of the fragmentations in the states served.[14]

Size and market share

Economies of scale are another important characteristic of the electric utility industry and the relevant evidence suggests that the size and productive efficiency relationship is positive (Roberts, 1986; Joskow, 2000; Kleit and Terrell, 2001). Variable SIZE captures the utility size using the log of total electricity sales in megawatt hours. If a utility is a subsidiary of a holding company, there might also be economies of scale. By combining resources and eliminating redundant or overlapping activities, utilities that belong to these holding companies can benefit from increased efficiencies in research and development, procurement, production, marketing, and administration (Kwoka, 2002). We also test the potential benefits of one utility being associated with other utilities through a holding company. If a utility belongs to a holding company, then the variable SUBSIDIARIES assigns to that utility the number of subsidiaries that belong to that holding company. If the firm is a subsidiary of a holding company that has nine utility subsidiaries in total, for instance, then the variable SUBSIDIARIES will take the value 8 for that utility.[15] Likewise, market share may also have an impact on efficiency. If a firm is among the top five sellers in a state in any of the residential, commercial, or industrial markets, then it is considered a big player in that market.[16] The variable BIGPLAYER is constructed as follows: if a firm is in the big five in any one of the states that it serves, then it is considered a big player with value 1. If a firm is a big player in two states, then the variable BIGPLAYER has the value of 2, if it is a big player in three states it has the value of 3, etc.

cneaf/electricity/st_profiles/e_profiles_sum.html). Since it is not available for the years 2000 and 2001, we counted the number of utilities using the publication from the Energy Information Administration, *Sales and Electric Revenue*.

[14] Weights are the proportion of electricity the utility sells to that state.

[15] When there is a merger, we assume that the merged companies will start behaving similarly the year following the merger. If there is a merger in 1999, for example, then the utility will become associated with the companies that belong to the holding company in 2000.

[16] We obtained this information from State Electricity Profiles, Table 3, for the years 1998–99. Since it is not available for years 2000–01, we calculated it using the Energy Information Administration publication, *Sales and Electric Revenue*.

Mergers

From 1992 to April 2000, 35 mergers or acquisitions have been completed between investor-owned electric utilities or between investor-owned electric utilities and independent power producers.[17] When a firm goes through a merger, there is uncertainty about whether the merger will be accepted and how to merge the assets of the different companies. In addition, during the merger process, there might be changes in the structure of the firm. For example, firms may decide to lay off some of their labor force or adopt similar technologies in the merged facilities. During this adjustment period, the utility may be less efficient than other firms. The MERGER variable tracks whether an electric utility is merging with other electric utilities or independent power producers. If the utility itself or its holding company goes through a merger process, then the indicator is 1 the year before until the year after the merger is completed, and 0 otherwise. For example, if the merger took place in year 1999 the indicator is 1 for years 1998–2001.

Generation technology and location

Kamerschen and Thompson (1993) argue that the production of nuclear energy leads to efficiency gains compared to fossil fuel. Variable PROP_NUC represents the proportion of nuclear power generated by the utility. We also control for the proportion of renewable power generated by the utility (PROP_REN). Different levels of efficiency could also be attributed to the specific interconnected network (i.e., power grid) to which the electric utility belongs. The three networks in the continental United States are: (1) the Eastern Interconnected System, consisting of the eastern two-thirds of the United States; (2) the Western Interconnected System, consisting primarily of the southwest and areas west of the Rocky Mountains; and (3) the Texas Interconnected System, consisting mainly of Texas. Alaska and Hawaii belong to independent networks.

Our study has limitations notably because it does not include an analysis of smaller utilities. Although our sample represents 83 percent of the electric production, and is fairly reliable because

[17] In addition, 12 mergers have been announced and are now pending stockholder or federal and state government approval (U.S. Department of Energy, 2000).

of the large sample, our analysis does not include public power utilities, smaller utilities, or independent (or non-utility) power production. Russo (2001) shows that the share of such organizations increased in the last decade and it would be interesting to compare their efficiency to our sample of firms.

Estimation method

Because the distribution of the efficiency score is censored at 1, conventional regression methods cannot be used. They fail to account for the qualitative difference between limit observations (i.e., the efficiency score of 1) and non-limit (continuous) observations. Tobit regression takes this into account. A Tobit model is a maximum likelihood method. It assumes that the distribution of the error term is normal and the estimation explicitly takes limit and non-limit observations into account (Greene, 1997). We test whether the residuals of our regressions are normally distributed. We perform the Skewness and Kurtosis, the Shapiro–Wilk and the Shapiro–Francia tests for normality which do not reject the hypothesis of normal distribution.[18] Hence it is appropriate to use the Tobit model for our data. We did not run a fixed-effects Tobit model as some of our independent variables have little time variance in this 3-year period and as a sufficient statistic allowing the fixed effect to be conditioned out of the likelihood does not exist (Greene, 2001). We include fixed-effect factors for years and geographical regions in the United States.[19]

One of the econometric challenges that we face with this study is that we do not know if states deregulate because the productivity of their firms is low, or if deregulation affects productivity. That is to say, there may be a problem of endogeneity. To control for this endogeneity, we create a variable instrument in order to explain the deregulation choice of states. Ando and Palmer (1998) analyze the factors that may influence the rate at which state legislators and regulators move towards putting retail competition in place. They suggest that the general price level of the state and the size of the group of large industrial customers within the state influence the decision to deregulate. The argument is that consumers, particularly industrial consumers, have the most to gain from competition and new entry when current prices are particularly high. They also argue that, for ideological reasons, legislature under Republican control may move more quickly toward retail deregulation than those with one or both branches under Democratic control.[20]

Building on this previous research, we use three variables to predict the level of deregulation at the state level each year (using the deregulation dummy as the dependent variable). The first is the retail price of electricity in the state, the second represents the percentage of industrial sales within a state (source IEA), and the third represents the results of the 1996 presidential election at the state level. We regress the deregulation dummy on these three variables using binomial Logit for each year.[21] Table 1 shows the regression results per year. The regressions correctly predict the deregulation dummy for 70.6 percent to 78.4 percent of the cases, depending on the year of interest. Similar to the deregulation variable, we computed the instrument variable (IV) at the firm level as the weighted average of the states served by the utility.

RESULTS

Table 2 presents the descriptive statistics and Table 3 the correlations. Our pooled sample includes 696

[18] The Shapiro–Wilk test is based on Shapiro and Wilk (1965) and the Shapiro–Francia test is based on Shapiro and Francia (1972). The Skewness and Kurtosis tests for normality are based on a combined measure of Skewness and Kurtosis of the data (D'Agostino, Belanger, and D'Agostino, 1990; Royston, 1991).

[19] Unconditional fixed-effects Tobit models may be estimated but the estimates are biased (Stata 7, 2001: 474). We also ran a random-effects model. Unfortunately, the quadrature approximation underlying the estimation of the random-effects model is problematic in our data set and the parameter estimates of the random-effects model are not stable. Two aspects of random-effects models have the potential to make the quadrature approximation inaccurate: large group sizes and large correlations within groups (Stata 7, 2001: 476). These factors can also work in tandem, decreasing or increasing the reliability of the quadrature. Therefore, we do not report them in this paper.

[20] They also find some evidence that high stranded-cost burdens and the availability of nearby profitable export markets for power may have a positive influence on both legislative and regulatory decisions to consider or adopt retail competition.

[21] Since there could be some potential links between retail price, percentage of industrial sales, and efficiency, we also compute a variable instrument with only the presidential election variable. The sign and significance of this other variable instrument in our regressions are comparable to those we present in this paper. Results for this further variable are available upon request.

Table 1. Logistic regression of deregulation dummy on retail price of electricity, percentage of industrial market and presidential election results

	1998	1999	2000	2001
Election	−0.765	−1.341*	−1.843**	−1.400**
Industrial market	−1.475	−1.296	−6.400*	−5.763*
Price	0.568***	0.373*	0.78	0.121
Percentage predicted	78.4	76.5	70.6	70.6

* ≤0.10; ** ≤0.05; *** ≤0.01

observations. The variables are not highly correlated except for SIZE, which is significantly correlated with BIGPLAYER. We test the robustness of the results to the exclusion of these two variables.

Table 4 shows the regression results. Model 1 includes all the variables except the variables representing deregulation and PROP_GEN. Model 2 adds the quadratic term of PROP_GEN. Models 3–6 present the results using the variable DEREGULATION (coded from 0 to 4). By construction, all the deregulation variables are highly correlated. Because of this, we enter each of them in the regression independently. In Model 7, we use DEREG2 based on deregulation as a dummy variable. Models 7, 9, and 10 include respectively PCAP, DIVESTURE, and STCOST as measures of deregulation. In Model 11, we use the instrument variable (IV) instead of a deregulation variable.

Our regression analysis shows that the deregulation dummy is negative and significant. The coefficient of the deregulation variable is increased when using DEREG2 instead of deregulation. The results do not change with the exclusion of the variables SIZE and BIGPLAYER. Models 8–10 also show a negative and significant coefficient for the deregulation variables PCAP, DIVESTURE, and SCOST. The coefficients for PCAP and DIVESTURE are very similar. The variable SCOST shows a coefficient smaller than those of PCAP and DIVESTURE. We find that the instrument for deregulation also has a negative and statistically significant

Table 2. Descriptive statistics[a]

Variable		Obs.	Mean	S.D.	Min.	Max.
EFFICIENCY	Productive efficiency measured using DEA	707	0.860	0.178	0.151	1.000
DEREGULATION	Deregulation (0 to 4)	1378	1.880	1.722	0.000	4.000
DEREG2	Deregulation (0 to 1)	1378	0.421	0.487	0.000	1.000
PCAP	Deregulation and price cap on retail prices	960	0.613	0.494	0.000	2.000
DIVESTURE	Deregulation and divesture of assets required	960	0.715	0.639	0.000	2.000
STCOST	Deregulation and recovery of stranded costs allowed	960	1.154	0.940	0.000	2.000
IV	Instrument variable	960	0.096	0.402	−0.900	0.931
PROP_GEN	Proportion of electricity generated	1638	−0.112	0.395	−0.501	0.499
PROP_GEN2	$(Prop\_gen)^2$	1638	0.168	0.094	0.000	0.251
FRAGMENT	Fragmentation of market	909	1.344	1.728	0.150	14.720
BIGPLAYER	Firm is among 5 top sellers in one of more states	924	0.707	0.757	0.000	5.000
SIZE	Log total electricity sales MWh	1182	15.494	1.882	3.640	19.020
PROP_NUC	Proportion nuclear	1638	0.101	0.228	0.000	1.000
PROP_REN	Proportion renewable	1638	0.139	0.312	0.000	1.000
SUBSIDIARIES	Number of subsidiaries of holding company	1092	1.290	2.321	0.000	9.000
MERGER	Merger process with other utilities	1092	0.185	0.388	0.000	1.000
WESTERN	Western Interconnected System	1486	0.117	0.322	0.000	1.000
TEXAS	Texas Interconnected System	1486	0.057	0.231	0.000	1.000
CALIFORNIA	California dummy	1638	0.013	0.115	0.000	1.000
YEAR1999	Year 1999	1092	0.250	0.433	0.000	1.000
YEAR2000	Year 2000	1092	0.250	0.433	0.000	1.000
YEAR2001	Year 2001	1092	0.250	0.433	0.000	1.000

[a] Proportion generated in this table is in de-meaned form. Proportion generated square is the second-order term for this variable.

Table 3. Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1 EFFICIENCY	1.000																					
2 DEREGULATION	−0.107	1.000																				
3 DEREG2	−0.146	0.953	1.000																			
4 PCAP	−0.147	0.948	0.994	1.000																		
5 DIVESTURE	−0.204	0.871	0.901	0.904	1.000																	
6 STCOST	−0.133	0.943	0.975	0.970	0.886	1.000																
7 IV	−0.094	0.324	0.310	0.308	0.255	0.285	1.000															
8 PROP_GEN	0.270	−0.307	−0.305	−0.303	−0.325	−0.307	−0.094	1.000														
9 PROP_GEN2	0.051	0.080	0.075	0.066	0.053	0.088	0.135	−0.277	1.000													
10 FRAGMENT	−0.187	−0.313	−0.328	−0.328	−0.301	−0.344	−0.058	0.055	0.016	1.000												
11 BIGPLAYER	0.055	−0.156	−0.153	−0.150	−0.105	−0.160	−0.112	0.176	−0.359	0.081	1.000											
12 SIZE	0.262	−0.019	−0.013	−0.005	−0.027	−0.016	−0.012	0.445	−0.532	−0.218	0.480	1.000										
13 PROP_NUC	−0.162	0.132	0.161	0.167	0.217	0.157	0.041	0.128	−0.212	−0.085	0.013	0.279	1.000									
14 PROP_REN	−0.173	−0.040	−0.051	−0.049	−0.057	−0.082	0.008	−0.114	0.154	0.176	−0.137	−0.342	−0.227	1.000								
15 SUBSIDIARIES	0.198	0.085	0.040	0.037	−0.002	0.048	0.030	0.030	−0.065	−0.143	0.013	0.224	0.054	−0.200	1.000							
16 MERGER	−0.016	0.158	0.139	0.134	0.084	0.144	0.051	−0.023	−0.111	−0.084	0.093	0.169	0.029	−0.132	0.337	1.000						
17 WESTERN	0.043	0.036	0.046	0.063	0.137	0.028	−0.058	−0.048	−0.142	−0.080	0.032	0.037	−0.052	0.104	−0.194	−0.044	1.000					
18 TEXAS	0.098	0.066	0.050	0.048	0.004	0.056	0.199	0.029	0.022	−0.111	0.087	0.098	−0.031	−0.071	−0.020	−0.037	−0.085	1.000				
19 CALIFORNIA	−0.095	0.126	0.117	0.162	0.274	0.128	0.043	−0.024	−0.159	−0.083	0.024	0.143	0.210	0.006	−0.059	−0.042	0.354	−0.030	1.000			
20 YEAR1999	0.062	0.065	0.072	0.082	0.034	0.056	0.032	0.056	−0.051	0.005	0.019	0.031	0.025	−0.059	0.011	0.117	−0.021	−0.005	−0.021	1.000		
21 YEAR2000	−0.015	0.048	0.031	0.027	0.054	0.047	0.029	−0.052	0.038	−0.003	−0.032	−0.030	0.010	0.014	0.006	0.037	0.016	−0.017	0.008	−0.333	1.000	
22 YEAR2001	−0.049	0.020	0.023	0.019	0.047	0.036	−0.090	−0.115	0.075	−0.011	−0.002	−0.015	0.006	0.048	−0.002	−0.056	0.017	−0.001	0.008	−0.332	−0.327	1.000

Table 4. Tobit regression results

	(1) Efficiency	(2) Efficiency	(3) Efficiency	(4) Efficiency	(5) Efficiency	(6) Efficiency	(7) Efficiency	(8) Efficiency	(9) Efficiency	(10) Efficiency	(11) Efficiency
DEREGULATION			−0.022	−0.021	−0.019	−0.025					
			(0.008)**	(0.008)**	(0.008)*	(0.008)**					
DEREG2							−0.093				
							(0.024)**				
PCAP								−0.092			
								(0.023)**			
DIVESTURE									−0.080		
									(0.018)**		
STCOST										−0.046	
										(0.012)**	
IV											−0.082
											(0.025)**
PROP_GEN		0.196	0.167	0.174	0.254	0.175	0.154	0.154	0.149	0.157	0.184
		(0.033)**	(0.034)**	(0.034)**	(0.032)**	(0.034)**	(0.034)**	(0.034)**	(0.034)**	(0.034)**	(0.032)**
PROP_GEN2		0.839	0.859	0.887	0.578	0.886	0.870	0.871	0.871	0.869	0.896
		(0.133)**	(0.133)**	(0.133)**	(0.128)**	(0.134)**	(0.133)**	(0.133)**	(0.132)**	(0.133)**	(0.134)**
FRAGMENT	−0.013	−0.015	−0.019	−0.021	−0.028	−0.019	−0.021	−0.021	−0.021	−0.021	−0.015
	(0.005)*	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.006)**	(0.005)**	(0.005)**	(0.005)**	(0.006)**	(0.005)**
BIGPLAYER	−0.043	−0.022	−0.026		0.011	−0.028	−0.027	−0.027	−0.022	−0.027	−0.028
	(0.016)**	(0.015)	(0.015)		(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
SIZE	0.052	0.049	0.051	0.045		0.049	0.052	0.052	0.050	0.051	0.052
	(0.007)**	(0.008)**	(0.008)**	(0.008)**		(0.008)**	(0.008)**	(0.008)**	(0.008)**	(0.008)**	(0.008)**
PROP_NUC	−0.240	−0.220	−0.203	−0.194	−0.165	−0.201	−0.190	−0.191	−0.178	−0.194	−0.210
	(0.041)**	(0.039)**	(0.039)**	(0.039)**	(0.040)**	(0.040)**	(0.039)**	(0.039)**	(0.040)**	(0.039)**	(0.039)**

PROP_REN	−0.065	−0.065	−0.063	−0.062	−0.087	−0.058	−0.064	−0.063	−0.068	−0.069	−0.060
	(0.033)*	(0.031)*	(0.031)*	(0.031)*	(0.032)**	(0.031)	(0.031)*	(0.031)*	(0.031)*	(0.031)*	(0.031)
SUBSIDIARIES	0.028	0.028	0.028	0.029	0.033	0.023	0.027	0.027	0.027	0.027	0.028
	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**	(0.005)**
MERGER	−0.121	−0.098	−0.092	−0.094	−0.081		−0.091	−0.092	−0.094	−0.091	−0.094
	(0.026)**	(0.025)**	(0.025)**	(0.025)**	(0.026)**		(0.025)**	(0.025)**	(0.025)**	(0.025)**	(0.025)**
WESTERN	0.097	0.119	0.121	0.122	0.130	0.119	0.124	0.124	0.131	0.120	0.116
	(0.037)**	(0.035)**	(0.034)**	(0.035)**	(0.036)**	(0.035)**	(0.034)**	(0.034)**	(0.034)**	(0.034)**	(0.034)**
TEXAS	0.108	0.088	0.096	0.089	0.123	0.108	0.094	0.094	0.084	0.094	0.118
	(0.052)*	(0.049)	(0.049)	(0.049)	(0.049)*	(0.049)*	(0.049)	(0.049)	(0.048)	(0.049)	(0.050)*
CALIFORNIA	−0.290	−0.205	−0.188	−0.184	−0.146	−0.168	−0.192	−0.175	−0.133	−0.184	−0.191
	(0.086)**	(0.081)*	(0.081)*	(0.081)*	(0.083)	(0.081)*	(0.080)*	(0.080)*	(0.081)	(0.080)*	(0.080)*
YEAR1999	0.055	0.059	0.066	0.066	0.067	0.055	0.069	0.070	0.068	0.068	0.060
	(0.029)	(0.028)*	(0.028)*	(0.028)*	(0.029)*	(0.028)*	(0.028)*	(0.028)*	(0.027)*	(0.028)*	(0.028)*
YEAR2000	0.020	0.024	0.028	0.028	0.033	0.022	0.026	0.026	0.030	0.029	0.022
	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
YEAR2001	−0.006	0.002	0.002	0.002	0.014	0.003	0.001	0.001	0.005	0.004	−0.006
	(0.029)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)	(0.028)
CONSTANT	0.199	0.097	0.127	0.189	0.916	0.155	0.108	0.105	0.136	0.114	0.060
	(0.111)	(0.134)	(0.134)	(0.129)	(0.040)**	(0.135)	(0.133)	(0.133)	(0.133)	(0.133)	(0.134)
OBSERVATIONS	696	696	696	696	699	696	696	696	696	696	696

Standard errors in parentheses; * significant at 5%; ** significant at 1%

coefficient in Model 11. These results confirm our first hypothesis, which states that deregulation had a negative effect on efficiency during the transitory period of 1998–2001.

Our second hypothesis predicts a nonlinear relationship between vertical integration and efficiency. We observe a nonlinear structure for PROP_GEN, which represents the level of vertical integration of the firm. Figure 2 depicts the nonlinear structure of the relationship. We include both the proportion of electricity sold that is generated and the square of the proportion of electricity sold in the regressions. We find that both PROP_GEN and PROP_GEN2 are positive and significant. This result shows that utilities which are mostly vertically integrated and utilities which are mostly vertically disintegrated are more efficient than utilities that are partially vertically integrated.

The variable FRAGMENT is also negative and significant. This indicates that firms which operate in more fragmented markets are less efficient. We capture economies of scale by using various variables. The variable SIZE, which represents the size of utilities, measured in the amount of megawatt hours sold, is positive and significant. Similarly, the variable SUBSIDIARIES, representing whether a firm belongs to a holding company and hence is associated with other utilities, is positive and significant in all models. The variable BIGPLAYER signifies whether a firm is among the big players in the market, and is only significant when PROP_GEN is not included. Overall, the results show that economies of scale play an important role in predicting efficiency and are consistent with previous findings (Roberts, 1986; Joskow, 2000; Kleit and Terrell, 2001).

Our analysis shows that electric utilities which are in the process of merging with other utilities or independent power producers are less efficient than electric utilities that are not in the process of merging (variable MERGER is negative and significant). This may capture the cost that the firm faces during the merger process of two electricity-based entities. The regression analysis reveals that the proportion of nuclear generation (PROP_NUC) and proportion of renewable generation (PROP_REN) both have a negative impact on efficiency. We interpret these variables with caution since we do not have information about which method of electricity generation was used for purchased electricity on the wholesale market. These variables are coded 0 for utilities that purchase all their electricity from outside sources. The exclusion of these two variables from the regression does not change the results for the other variables of interest.[22]

[22] Results are available upon request.

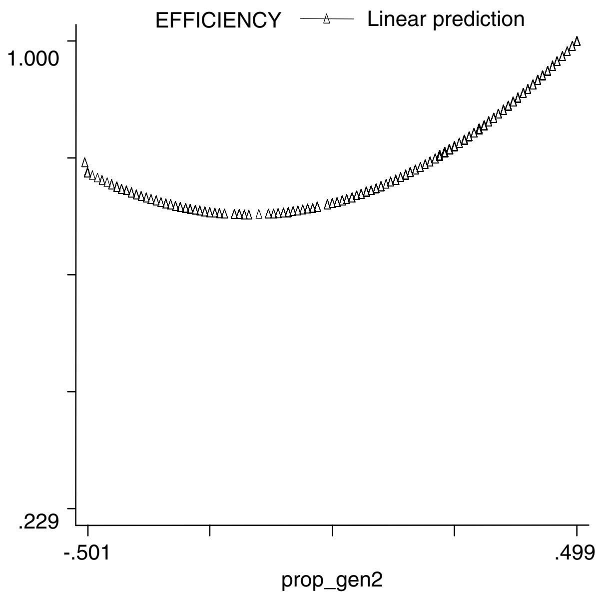

Figure 2. Relationship between efficiency and governance structure. The efficiency measure is de-meaned, so −0.5 represents 100 percent retail and 0.5 represents 100 percent generation

The geographical location of utilities also impacts efficiency. The dummy variable representing whether firms belong to the Western States is positive and significant. In addition, we also test if our findings are driven by the negative deregulation experience in California. We control for the 'California effect' by including a dummy variable representing electric utilities that operate in California. This variable is negative in all regressions and statistically significant on all models except Model 9, when we use DIVESTURE as a measure of deregulation.

DISCUSSION AND CONCLUSION

Our results show that deregulation has a negative impact on efficiency in the short term. This is an interesting result as it illustrates the short-term costs of going from a regulated environment to a deregulated environment. Our results are in agreement with some studies that analyzed the impact of deregulation on efficiency in the banking and gas industries. Hollas, Macleod, and Stansell (2002) do not find a positive effect following the alteration of the regulatory environment in which natural gas distribution utilities operated. Mukherjee, Ray, and Miller (2001) show that productivity declined in large U.S. commercial banks in the year following deregulation. Grabowski, Rangan, and Rezvanian (1994) consider the effect of deregulation on bank efficiency in the United States between 1979 and 1987 and do not find a positive effect. Wheelock and Wilson (1999) find negative productivity growth for large U.S. commercial banks just after deregulation.[23]

Even though the structure of the electricity industry may differ technically, economically, and institutionally from the natural gas, telecommunication and banking industries, the process of deregulation negatively affects the efficiency of firms. These findings have significant policy implications. It is important to acknowledge the transitory costs of deregulation, as they may otherwise endanger the long-term success of deregulation. Policy-makers may not anticipate these costs when they start the deregulation process. This becomes particularly important as the transitory period of the deregulation process may last longer than originally expected. Dyner and Larsen explain that because of the long investment horizon and the political and legal environment in which the industry exists, it is likely that what may be labeled as the 'transitory period', or the period between fully regulated and deregulated states, might be more than 10 years (Dyner and Larsen, 2001: 1153).

Transaction costs economics and organizational scholars propose different governance structures to cope with uncertainty linked to changing regulatory environments and we test the comparative efficiency of various levels of vertical integration. We find a nonlinear relationship between vertical integration and efficiency. Firms that are mostly vertically integrated as well as firms that are mostly vertically disintegrated are more efficient than firms that are both generating and buying their power on the market. According to Williamson, transaction costs economics 'is concerned with the organization of transactions for mature goods and services and introduces parameter shifts one at a time' (Williamson, 1991: 292). Williamson also states that 'added apparatus is needed to deal with the full set of issues that arise when responsiveness in real time, rather than equilibrium contracting is the central concern' (Williamson, 1991: 293). Indeed, transaction costs economics does not sufficiently explain why many firms engage in more flexible organizational forms, especially for transactions involving specialized assets in competitive environments marked by rapid change. On the other hand, theories of organizational adaptation to environmental uncertainty argue that flexible and specialized organizational structures are more efficient than vertically integrated organizations to adapt to environments marked by high uncertainty. Our findings show that both governance structures are efficient, albeit through different mechanisms. Transaction costs economics and the theories of flexible adaptation refer to different types of adaptation. The first is adaptation through hierarchy. That is to say, the firm 'insulates' itself from market transactions and therefore uncertainty. The second is adaptation through market mechanisms where firms specialize in dealing with complex transactions and avoid the costs of organizational slack. Our findings are important because they suggest that both structures can be efficient in the same environment; they just represent different strategies.

[23] Most of the studies on the impact of deregulation on efficiency in the banking sector also find that the dispersion of the distribution of profitability increases in the years following deregulation and decreases subsequently (Hao, Hunter, and Yang, 2001; Mukherjee *et al*., 2001; Tortosa-Ausina, 2002).

Our research also provides important insights on hybrid structures (a combination of vertical integration and non-vertical integration). We suggest that hybrid structures are associated with the lowest efficiency during the deregulation process. In the case of the electric utility sector, they represent a type of diversification strategy that requires higher coordination costs than single use of either vertical integration or contracting. It is still unclear, however, whether these hybrid structures represent transitory governances that firms use when going through the process of vertically disintegrating, or whether these hybrid structures could provide benefits that can make them attractive over time. Previous studies have shown that hybrid structures allow firms to learn about new techniques and diversify their risks (Delmas, 1999; Nicholls-Nixon and Woo, 2003). For example, Delmas (1999) shows that hybrid forms involving specific assets deployed in emerging industries are exposed to higher transaction costs than vertical integration or contracts due to the potential of high *ex post* opportunism. Nevertheless, managers still prefer to use alliances because they facilitate the creation and diffusion of strategic competencies when the sources of knowledge are dispersed among several partners. Further research could investigate the long-term efficiency of these hybrid structures as well as the other benefits they may provide.

In conclusion, our research shows that, in the short term, deregulation in the electric utility sector has a negative impact on the efficiency of electric utilities. Our results indicate that vertical integration is an efficient governance structure to reduce the costs associated with the process of deregulation, and that non-integrated governance structures are also efficient to adapt to new environmental conditions. Our study has important theoretical implications as it shows that vertically integrated and non-integrated governance structures can both be efficient strategies in the short term to cope with uncertainty created by the regulatory environment. Our study focuses on the period 1998–2001 and on the short-term impact of deregulation on efficiency. It will be interesting to empirically assess the long-term impact of deregulation on efficiency in this sector when more data become available. It will be particularly interesting to see which of these governance structures remain efficient over time.

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