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

Magali Delmas
University of California, Santa Barbara and Stanford Graduate School of Business[1]

And Yesim Tokat
University of California, Santa Barbara

ABSTRACT

This paper is an empirical assessment of the comparative efficiency of governance structures in an environment marked by high uncertainty. We analyze the short-term impact of retail deregulation on the productive efficiency of electric utilities in the United States. We argue that there are transitory costs linked to the process of deregulation. The business strategy literature suggests different governance structures to cope with uncertainty linked to changing regulatory environments. Transaction cost economics suggests that firms may reduce their exposure to the uncertainty created by the process of deregulation by adopting vertical integration strategies. Organizational scholars on the contrary argue that firms vertically disintegrate and adopt flexible governance structures to increase their adaptability to the new conditions. Our empirical analysis is based on 177 investor-owned electric utilities representing 83% of the total U.S. electricity production by utilities from 1998-2001. Our results show that the process of deregulation has a negative impact on firms' productive efficiency measured using Data Envelopment Analysis. However, 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.

Keywords (transaction costs, governance structures, uncertainty, deregulation, efficiency)

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[1] For correspondence Magali Delmas 518 Memorial Way, Stanford - CA - 94305-5015. Phone: (650) 724-3687. Email: Delmas_Magali@gsb.stanford.edu.This project was funded by the University of California Energy Institute.

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1. Introduction

The strategy literature proposes apparently conflicting options for firms to deal efficiently with environmental uncertainty and a changing regulatory environment. Transaction costs economics (TCE) analyzes the comparative efficiency of governance structures in response to the level of uncertainty and specificity of the transaction (Williamson, 1971, 1985). Vertical integration is the response to the inability of arms-length market relationships to govern exchange efficiently for frequent transactions, entailing a high level of specialized assets and uncertainty associated with the exchange. In a transaction cost framework, the firm can be insulated from the environment through hierarchy and, thereby protected from the cost of market transactions for specific investments.

However, other organizational scholars 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). The lack of direct competitive pressure on the cost of intermediate products may encourage an increasing level of organizational slack (Cyert and March, 1963). Moreover, environmental uncertainty increases the information processing needs of organizations (Thompson, 1967). For vertically integrated subunits, this task may be more difficult than for vertically disintegrated units as 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 (D'Aveni and Ravenscraft, 1994). Furthermore, highly integrated organizations may be slower to adapt to rapidly changing environments as compared to nonintegrated organizations. Nelson and Winter (1982) demonstrate how organizational routines can be an obstacle to change. The firm choosing an integrated governance structure in an uncertain environment may find it difficult to manage and relatively difficult to dissolve (Rumelt, 1995). Nonintegrated firms do not face such inertia and may focus all their resources on adopting the know-how and technologies tailored to the new environment (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 test whether vertical integration or market transaction is the most appropriate governance structure to deal with changes in the regulated environment of the electric utility sector. We analyze the governance structures of 177 major U.S. electric utilities from the start of retail deregulation in 1998 to 2001. We compare the efficiency of utilities on a continuum from vertical integration where firms generate 100% of their own electricity to market strategies where utilities buy 100% of their electricity on the wholesale market.

The institutional environment -- comprising the rules of the game -- can be an important source of uncertainty for organizations. The ability of the institutional environment to credibly commit and favor private investment is one component of regulatory uncertainty (Levy and Spiller, 1994; Bergara, Henisz and Spiller, 1998; Delmas and Heiman, 2001). The institutional environment can also create uncertainty by changing the regime of property rights that governs firms' ability to capture the profits of their operations (Teece, 1986).

In the context of an emerging regulatory or deregulatory scheme, regulators might operate by experimentation. This can create an important source of uncertainty for firms. Managers face uncertainty concerning the path that deregulation is taking when the deregulation process is not complete. In addition, a deregulated environment is marked by different features than a regulated environment. Specifically, 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. For example prices may become less stable and demand less predictable in the deregulated environment. Firms need to learn how to function in the new operating environment and to rearrange their organizational structure accordingly. Specifically, firms need to spend time and resources on adjusting to increased competition in input and output markets as well as to the new institutional environment. The question of which governance structure is best adapted to cope with uncertainty and adapt to change is therefore fundamental.

Retail deregulation initiatives in electricity markets were implemented by U.S. states starting in California in 1998.[2] As of 2001, 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.

Although 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. Joskow (1997) suggests that deregulation is unlikely to lead to significant short-run cost savings, but medium to long-term efficiency gains may be achieved by increasing the productivity of labor and improving the performance of existing facilities. Borenstein and Bushnell (2000) also point out that due to significant alterations to operational practices in the generation market and exercise of market power, operational efficiency may decrease during the restructuring process.

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). Our research compares the efficiency of competing governance structures. We use Data Envelopment Analysis (DEA) to measure efficiency (Banker, Charnes and Cooper, 1984). DEA is a technique that measures the relative efficiency of decision-making units, in our case network configurations, with multiple inputs and outputs but with no 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.

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

Our analysis shows that the process of deregulation has a short-term negative impact on firms' productive efficiency. However, we find a non linear 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. In the case of transaction costs economics, the firm is able to use hierarchy to mitigate the uncertainty of market exchanges. Organizational scholars, who argue that more flexible structures are better able to cope with uncertainty, refer to the ability of these structures to efficiently adapt to the new environment through organizational learning. Vertical integration allows firms to be insulated from uncertainty, while nonintegrated firms are more efficient in adapting to the conditions of the new environment. This research has important implications as it shows the coexistence of two different types of governance structures that are able to cope efficiently with regulatory uncertainty through different mechanisms.

2. Hypotheses

The traditional structure of a U.S. regulated firm in the electric utility industry is vertical integration where 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 held exclusive rights to serve retail customers within defined geographical areas. Utilities were required to serve all consumers within their territory. The early structure of the electric utility industry was predicated on 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 dispatched has increased greatly and the natural monopoly argument lost some of its credence.

The Public Utility Regulatory Policies Act of 1978 required utilities to purchase power from independent power producers that are called Qualifying Facilities.[3] 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 regulations encouraged the entry of independent power producers into the market, they did not allow retail competition. In 1996, FERC issued Order 888 that required utilities to open their transmission lines to competitors. Starting in 1998, New Hampshire launched a pilot program allowing competition, as did California, Pennsylvania, New York and Rhode Island.[4]

Drawing upon the experience of other deregulated industries, Winston (1998) observes that it takes time for firms to adjust to the new competitive environment. Therefore, industries are slow to achieve maximum efficiency by adopting more efficient production and marketing practices. We argue that there are important transitory costs when changing from a regulated to a deregulated environment. First, during the deregulation process, managers face uncertainty concerning the path that deregulation is taking. Second, a regulated environment is marked by several unique conditions, which are no longer present in a deregulated environment, and firms need time to adapt to these new conditions.

Uncertainties appear during the transitory period from regulation to deregulation. Competition in the wholesale generation market may take time to increase because production is capital intensive and construction delays are long compared to variations in supply-and-demand conditions. Indeed, there are barriers to entry in the electricity industry since firms have to get permits to build generation plants. Hence, entry into the market may be slow and there is a potential risk of market power in the electricity trading market.

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[3] The implementation of the regulation beyond the minimum requirements was left to the discretion of states. Several states such as California, New York, and New Jersey embraced this regulation and exceeded the minimum requirements.

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

The conditions that mark regulated environments are stable prices and predictability of demand. Indeed, with rate of return regulation, prices are set based on the needs and costs of the electricity companies, so that they can recover their costs. In this way there is little financial risk for the company. In addition, information about existing capacities and demand is also fully available. The demand that needs to be forecasted in the case of a regulated monopoly is the total aggregated demand from a region or country. Due to low market uncertainty, and the availability of full information, the planning process for new capacity, retirement of capacity, capacity upgrade, etc. can be approached using standard operations research models aiming for optimal investment strategies (Watson and Ter-Gazarian, 1996).

As deregulation takes place, a large number of what were previously seen as parameters with low uncertainty gradually become parameters with high uncertainty. First, wholesale prices can fluctuate, not only during the day and week, but also depending on the season and weather conditions (e.g. summer/winter, the amount of rain, etc.). Second, in deregulated markets, it might still be possible to predict overall demand. However, the demand from a single company might have little connection with the growth or decline in the overall demand. The demand that each individual company faces will increasingly depend on the reliability and service provided and perceived, but primarily on the price and general marketing skills with which a company can deliver electricity.

The increasing uncertainty in most, if not all, major inputs to the planning process discussed above creates a need for changes in the way electricity companies think about planning and strategy. Dyner and Larsen demonstrate that planning methods used under regulation are no longer appropriate under deregulated environments (Dyner and Larsen, 2001). They argue that the deregulation of utilities requires that companies in these industries change from traditional planning to strategy development: "the conditions of regulated environments were stable and favored "hard modeling" approaches, such as those provided by short and mid-term forecasting and optimization, which often proved to be appropriate…The uncertainty in the environment was relatively small and the commitment of resources, e.g. financial resources, was unlikely to have an adverse impact on the firm, as prices could be increased if the wrong decisions were made" (Dyner and Larsen, 2001: 1146).

For example, concerning the wholesale market for electricity, electric utilities need time to learn how to manage market risks due to price fluctuations. New financial instruments such as weather derivatives have to be developed to hedge the risk of electricity price fluctuations because of weather conditions. [5]

Concerning the distribution of retail electricity, firms have to learn how to market their product. Before deregulation they had exclusive rights to serve regions and did not have to compete for customers. With the advent of deregulation, they have to learn how to compete for customers. In this new situation, firms will therefore increase their marketing expenses. However, sales may not increase in the short term because of inelastic demand and the time it takes to implement the institutions necessary for consumers to switch from one utility to another.

Firms will also have to use labor more efficiently in deregulated environments due to increased competition. During the reorganization within the utilities, firms may have to lay off some workers and train others for new tasks. This may cause inefficiency in the short term.

In addition, some firms that invested 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).

Technical efficiency is the ability of a firm to obtain maximum output with given inputs (Farrell, 1957). 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 output such as wholesale prices, capital, labor and distribution costs without much increase in the size of their market. We hypothesize that deregulation

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[5] 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 5,000 weather contracts with a total exposure of $7.5 billion were transacted between October 1997 and April 2001.
http://www.platts.com/features/weatherderivs/intro.shtml (accessed 03-01-03).

leads to lower technical efficiency in the short term. 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 not completed. [6] We are therefore analyzing the period which constitute the process of deregulation.

> *H1: In the short term, the greater the level of deregulation, the lower the level of the technical efficiency of the utility.*

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 or divest some of the activities of the value chain.

Several characteristics of the electric utility sector make vertical integration a favorable option for firms in this industry. The possibility of equipment failures and primary input price fluctuations makes the supply of electricity uncertain. In addition, variations of weather and fluctuations of consumer demand make the electricity demand uncertain. These uncertainties can make the design, negotiation, and enforcement of long-term contracts expensive or difficult (Kaserman and Mayo, 1991). 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. In addition, 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. 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.

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[6] For example, in the U.S. five years after the first state started deregulation, no proposal for widespread structural change has yet achieved a broad consensus and the process of deregulation is still ongoing.

Several empirical studies 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) investigate a sample of 74 privately owned electric utilities in 1981 and provide empirical evidence for the existence of economies of vertical integration in the generation and transmission/distribution of electric supply. Lee (1995) analyzes the technological efficiency benefits of vertical integration for 70 electric utilities in 1990 and concludes that separating the functions of generation, transmission, and distribution will result in loss of technical efficiency.

When dealing with the process of deregulation, firms face additional uncertainties as described above, which could make vertical integration even more attractive in a deregulated environment than in a regulated environment. In particular concerning the generation of electricity, firms that are vertically integrated are less exposed to price volatility. They can internally adjust supply and demand and operate more efficiently. Russo suggests that vertical integration might vary negatively with regulatory monitoring costs, as uncertainties about future regulatory policies would begin to overtake any gain from stabilizing supply (Russo, 1992).

However, as we discussed earlier, in the case of highly uncertain environments, nonintegrated governance structures may also be efficient to cope with uncertainty. Firms that are nonintegrated may, for example, be able to focus on new management procedures without facing the organizational inertia associated with vertical integration. By focusing mostly on buying power from wholesale markets and not on generating power, these organizations may be able to rapidly develop the managerial skills necessary to cope with the new environment.

Companies that have a medium level of integration may incur the costs of both governance structures without their advantages. Indeed, the combination of these different forms within an organization may increase internal costs of coordination. These hybrid forms can be viewed as a special balance between the incentives of the market, and the central coordinating properties of hierarchy. However, the organizational inertia associated with vertical integration can hamper the dynamism and adaptability associated with flexible forms.

In conclusion, it is difficult to hypothesize a simple linear relationship between vertical integration and efficiency in the short term. 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 and do not need to adapt to it as much. 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. The hypothesis can be formalized as follows:

> *H2: 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 vertical integration will be more efficient than those with a medium level of vertical integration.*

3. Methodology

The data used 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.[7] 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) (Banker, Charnes and Cooper, 1984; Seiford, 1996; Majumdar, 1998; Majumdar and Marcus 2001). This measure captures the efficiency of each firm in converting inputs into outputs as compared to all other firms in the set. A piecewise linear industry best practice frontier is constructed using the observations. If a firm is on this frontier, it is considered efficient. If it is not on the

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[7] Major electric utilities includes utilities with annual sales or transmission service that exceeds 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 (deliveries plus losses).

frontier, its radial distance from the best practice frontier is a measure of the firm's inefficiency. 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, Cooper and Rhodes (CCR), 1978).

The DEA technique converts multiple input and output measures into a single measure of relative performance for each observation. The ratio of the weighted outputs to weighted inputs for each observation is maximized. Charnes, Cooper and Rhodes (1978) developed this multiple output-input measure of efficiency and Banker, Charnes and Cooper (1984) refined it. The general DEA model can be formulated as follows:

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\begin{aligned}
&\max \quad e_{k,k} \qquad (1)\\
&s.t.\\
&e_{j,k} \quad \leq 1, \quad \forall j \quad (2)\\
&\mu_{r,k} \quad \geq \in, \quad \forall r \quad (3)\\
&\nu_{i,k} \quad \geq \in \quad \forall i \quad (4)
\end{aligned}
$$

where: $e_{k,k}$ is a ratio measure of performance, which is the efficiency score of firm k with regard to jointly and simultaneously converting a set of multiple inputs into a set of multiple outputs, $e_{j,k}$ is the relative efficiency of observation j, when observation k is evaluated, $\mu_{r,k}$ and $\nu_{i,k}$ are the output and input weights associated with the evaluation of observation k, j is the index for all the firm-year observations in the data set, r is the index for the outputs, i is the index for the resource inputs, and $\in$ is a very small positive nonzero quantity.

The optimization is repeated for each observation in the data set in order to calculate the efficiency of firm k with respect to all other firms in the data set. Each time the optimization is carried out, data for all j observations form part of the constraint set, so that the observation is compared against all others in the data set. Constraint (2) implies that the efficiency of any other observation in the constraint set cannot be greater than 1. Constraints (3) and (4) require that input and output weights cannot be negative. The efficiency values partition the data set into two parts: one part consisting of efficient observations, which determine the efficiency best practice frontier and the other part consisting of firms that are inefficient and for which $e_{k,k}$ <1.

The weights $\mu_{r,k}$ and $v_{i,k}$ are determined each time the optimization in (1) is carried out. The DEA procedure takes each observation's idiosyncrasies into account in evaluating efficiency, and the weights are computed based on determination of which inputs a particular observation is adept at utilizing or which outputs it is adept at generating. This approach maximizes the observed performance of each observation in light of its particular capabilities.

Consider a simple model of four utilities in Figure 1, where each firm uses two inputs X_1 and X_2 to produce one output, Y. Firms that use lower amounts of inputs for a given amount of output are more efficient. Therefore, firms that have lower amounts of X_1/Y and X_2/Y are more efficient. Firms C and D are the best performers in the industry and they define the efficient or best practice frontier of SS' for the industry. The technical efficiency scores of C and D are 1. The other firms, A and B, are less efficient because they would need to reduce their inputs per unit output to be on the corresponding best practice frontier points of A' and B', respectively. The technical efficiencies of A and B are the radial measures of OA'/OA and OB'/OB, respectively. Their technical efficiency measures are less than 1.

As we described, DEA considers multiple inputs and outputs. This is particularly important 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. An alternative way of calculating productive efficiency is the econometric method called stochastic frontier analysis (Aigner, Lovell and Schmidt, 1977). In DEA, the technical efficiency of individual observation reflects its radial distance from the directly estimated best practice frontier. In this method, production correspondences are estimated directly. The econometric approach, on the other hand, requires the prespecification of a functional form, whereas DEA requires only an assumption of convexity of the production possibility set. In DEA, different returns to scale behavior can be observed in different segments of the production possibility set (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. Furthermore, the extension of the stochastic frontier analysis method for estimations of multiple outputs raises computational problems as the number of parameters to be estimated would be very large (Banker, Conrad and Strauss, 1986).

The weak point 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% of the electric production

Computation of productive efficiency. DEA has been used by several researchers analyzing the electric utility industry (Roberts, 1986; Majundar and Marcus, 2001; Goto and Tsutsui, 1998; Sueyoshi and Goto, 2001). We build on this work to construct our measure of productive efficiency. 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.[8] We use an input oriented technical efficiency measure, which seeks to reduce the input quantities without changing the output quantities.[9] 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 technical efficiency measure is devoid of the scale effects (Coelli, 1996). The inputs and outputs of the variable EFF representing efficiency are described below.

[8] 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 and 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.

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

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.[10] 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.

Output. 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. Roberts (1986) points out that a firm's cost of supplying power to final consumers is affected by the type of customer it serves (see also Thompson, 1997), therefore high- and low-voltage sales should be considered as different outputs. Berry and Mixon (1999) further argue that there are cost differences in serving different types of buyers in the electric utility industry and one should treat industrial sales separately from wholesale sales. Therefore, we consider these three types of outputs as separate.

Independent Variables

The independent variables are divided into several categories related to the level of deregulation that utilities face, the nature of the competitive environment, the level of vertical integration of utilities, the size 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 DEREG represents the stages of deregulation of each state for each year from 1998 to 2001. These stages areas follows: 0) no activity, 1) commission or legislative investigation ongoing, 2) legislation orders pending, 3) comprehensive regulatory

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

order issued and 4) restructuring legislation enacted. This variable is coded from 0 to 4 with 0 representing no activity and 4 representing restructuring legislation enacted.[11] However, some firms are operating in several states and are therefore subject to different levels of deregulation. DEREG is therefore weighted based on the percentage of the electricity sold by each utility in each state.[12] For example, if in 2001 a utility is selling 80% of its electricity in state A with restructuring legislation enacted (4) and 20% in state B with legislation orders pending (2), then DEREG will take the value of $4\times(80/100)+2\times(20/100) = 3.6$. We create a second variable DEREG2, which represents whether or not restructuring has been enacted. We first create a variable that takes the value of 1 if restructuring regulation has been enacted or a regulatory order has been issued, and 0 otherwise. This variable is weighted based on the percentage of electricity sold by each utility within the state to create DEREG2.

Not only does the level of deregulation vary across states but so does the type of deregulation. 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 create three additional variables that represent whether i) divesture is of generating assets is required (DIVEST) ii) there is price cap at the retail level (PCAP) and iii) the recovery of stranded costs is allowed (SCOST). DIVEST 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 price cap, and 2 if there is deregulation without price cap. Second we weight this variable by the percentage of electricity sold by each utility within the state.

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

[12] This information was taken from the Energy Information Administration (EIA) publication “Sales and Electric Revenue”, Table A1: Electric Utilities Serving Ultimate Consumers in More Than One State.

Level of vertical integration of the firm. The variable PROP_GEN represents the proportion of electricity sold that is generated by the utility as a proxy for the degree of vertical integration of the firm. Because we hypothesized 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). It is interesting to note that in the period 1998 to 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 22 percent to 29 percent. In the analysis, we control for other important facets of electric utilities' activities that affect productivity.

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

Economies of scale. 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 LN_TOTAL captures 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. We 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

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

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

HOLDSUBS 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 HOLDSUBS 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] 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 BIGPLAYE has the value of 2, if it is a big player in three states it has the value of 3, etc.

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_U 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, i.e. 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 nuclear generation leads to efficiency gains compared to fossil fuel generation. Variable PROP_NUC represents the proportion of nuclear power generated by the utility. We also control for the proportion of renewable power generated by

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[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 e.g. 1999, 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 1998-1999. Since it is not available for year 2000-2001, we calculated it using the EIA publication, "Sales and Electric Revenue".

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

the utility (PROP_REN). Different levels of efficiency could also be attributed to the specific interconnected network (power grid) to which the electric utility belongs. The three networks 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.

Estimation method

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. Therefore, the distribution of this variable is censored at 1 (Figure 2). When the dependent variable is censored, conventional regression methods fail to account for the qualitative difference between limit observations, i.e. 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 tested whether the residuals of our regressions are normally distributed. We performed Skewness and Kurtosis, Shapiro-Wilk and Shapiro-Francia tests for normality which did 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 three-year period and as a sufficient statistic allowing the fixed effect to be conditioned out of the

[18] Shapiro-Wilk test is based on Shapiro and Wilk (1965) and Shapiro-Francia test is based on Shapiro and Francia (1972). Skewness and kurtosis tests test for normality are based on a combined measure of skewness and kurtosis of the data (D'Agostino et al., 1990; Royston, 1991).

likelihood does not exist (Greene, 2001). We include fixed-effect factors for years and geographical regions in the U.S.[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 analyze the factors that may influence the rate at which state legislators and regulators move towards putting retail competition in place (Ando and Palmer, 1998). 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 regulation 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 at the 1996 presidential election at the state level.[21] We regress the deregulation dummy on these three variables on a using binomial Logit for each year. Table 1 shows the regression results per

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[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 computed a variable instrument with only the presidential election variable. The sign and significance of this other variable instrument in our regressions is comparable to the one we present in this paper. Results available upon request.

year. The regressions correctly predict the deregulation dummy from 70.6% to 78.4% 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.

4. Results

Table 2 presents the descriptive statistics and Table 3 the correlations. Our pooled sample includes 696 observations. The variables are not highly correlated except for LN_TOTAL, which is significantly correlated with BIGPLAYE. We test the robustness of the results to the exclusion of these two variables.

Table 4 shows the regression results. Model 1 includes all 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 DEREG (coded from 0 to 4). In Model 7, we use DEREG2 based on deregulation as a dummy variable. Models 7, 9 and10 include respectively PCAP, DIVEST 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 LN_TOTAL and BIGPLAYE. Models 8 to10 also show a negative and significant coefficient for the deregulation variables PCAP, DIVEST and SCOST. The coefficients for PCAP and DIVEST are very similar. The variable SCOST shows a coefficient smaller than those of PCAP and DIVEST. We find that the instrument for deregulation also has a negative and statistically significant 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 non-linear 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 3 depicts the nonlinear structure of the relationship. We include both proportion generated and proportion generated squared 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 significant and negative. This indicates that firms which operate in more fragmented markets are less efficient. We capture economies of scale by using various variables. The variable LN_TOTAL representing the size of utilities, measured in the amount of megawatt hours sold, is positive and significant. Similarly, the variable HOLDSUBS 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 BIGPLAYE 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-U is negative and significant). This may capture the cost that the firm faces during the merger process for both electricity and gas companies. 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 zero 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]

The dummy variable WESTERN representing whether firms belong to the Western States is positive and significant. We also test if our findings are driven by the negative deregulation experience in California. We

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[22] Results available upon request.

control for the “California effect” by including a dummy variable (CA_DUMMY) representing electric utilities that operate in California. This variable is negative in all regressions and statistically significant all models except model 9, when we use DIVEST as a measure of deregulation.

5. 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) showed that productivity declined in large U.S. commercial banks in the following year of deregulation. Grabashi et al. (1994) consider the effect of deregulation on bank efficiency in the U.S. 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. Similarities as well as important differences exist among electric power utilities. Even though the structure of the electricity industries 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 important 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.

Transaction costs economics and organizational scholars propose different governance structures to cope with uncertainty linked to changing regulatory environments and we tested the comparative efficiency of various levels of vertical integration. We find a non-linear 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" (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" (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.

Our study has limitations. Although our sample represents 83% of the electric production, our analysis did not take into account public power utilities, smaller utilities or independent (or non-utility) power production. Russo 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 (Russo, 2001).

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 nonintegrated governance structures are also efficient to adapt to new environmental conditions. Our study has important theoretical implications as it shows that vertical integrated and nonintegrated 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. 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.

References

Aigner, D., Lovell, C., and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production models. Journal of Econometrics, 6: 21– 37.

Ando, A. W. and Palmer K. L. 1998. Getting on the Map: The Political Economy of State-Level Electricity Restructuring, *Resources for the Future* Discussion paper 98-19-REV.

Banker, R., Charnes A. and Cooper, W. W. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science,*, 30(9): 1078–1092.

Banker, R.D., Conrad, R.F., and Strauss, R.P. 1986. A comparative application of data envelopment analysis and translog methods: an illustrative study of hospital production. *Management Science*. 32(1): 30-44.

Baumol, W.J. and Sidak, J.G. 1995. Transmission Pricing and Stranded Costs in the Electric Power Industry, Washington: AEI Press.

Bergara, Mario E., Henisz, W.T., and Spiller, S.T. 1998. Political institutions and electric utility investment: A cross-nation analysis. *California Management Review*, 40(2): 18-35.

Berry, D. M. and Mixon, F.G. Jr. 1999. Multiproduct outputs and scale economies in electric power production: some new estimates. *Review of Industrial Organization.* 15: 65-76.

Boerner C.S. and Macher, J.T. 2001. Transaction Cost Economics: An Assessment of Empirical Research in the Social Sciences. Working Paper. Georgetown University.

Borenstein, S. and Bushnell, B. J. 2000. Electricity Restructuring: Deregulation or Reregulation? *Regulation*. 23(2): 46-52.

Charnes, A., W.W. Cooper, WW and Rhodes. E. 1978. Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, 2(6): 429-444.

Coelli, T. 1996. A guide to DEAP version 2.1: a data envelopment analysis computer program. Department of Econometrics. University of New England, Australia.

Cubbin, J. and G. Tzanidakis, G.1998. “Regression versus Data Envelopment Analysis for Efficiency Measurement: An Application to the England and Wales Regulated Water Industry.” *Utilities Policy*(7): 75–85.

Cyert, R. M. and March, J.G. 1963. A Behavioral Theory of the Firm. Englewood Cliffs, NJ: Prentice-Hall.

D’Agostino, R.B., Balanger, A., and D’Agostino, R.B., Jr. 1990. A suggestion for using powerful and informative tests of normality. *The American Statistician*. 44(4):316-321.

D'Aveni, R. A. and Ravenscraft, D. J. 1994. Economies of integration versus bureaucracy costs: does vertical integration improve performance? *Academy of Management Journal*. 37(5): 1167-206.

Delmas, M. 1999. Exposing strategic assets to create new competencies: the case of technological acquisition in the waste management industry in Europe and North America. *Industrial and Corporate Change*. 8(4): 635-72.

Delmas, M. and Heiman, B. 2001. Government Credible Commitment in the French and American Nuclear Industry. *Journal of Policy Analysis and Management*. 20(3): 433-456.

Dyner, I. and Larsen, E.R. 2001. From planning to strategy in the electricity industry. *Energy Policy*. 29(13): 1145-54.

Farrell, M.J. 1957. The measurement of productive efficiency. *Journal of The Royal Statistical Society Series A-General*. 120 (3): 253-290.

Goto, M. and. Tsutsui. M. 1998. Comparison of productive and cost efficiencies among Japanese and US electric utilities. *Omega*, 6(2): 177-94.

Greene, W.H. 2001 Estimating Econometric Models with Fixed Effects. Working paper. Department of Economics, Stern School of Business, New York University,

Greene, W.H. 1997. Econometric Analysis. Prentice Hall, New Jersey.

Hill, C.W. L. and Hoskisson, R.E. 1987. Strategy and Structure in the Multiproduct Firm. *Academy of Management Review*. 12(2): 331-41.

Hollas, D R., Macleod; K R., and Stanley R. Stansell. 2002. A data envelopment analysis of gas utilities' efficiency. *Journal of Economics and Finance,* 26(2): 123-38.

Joskow, P.L. 1997. Restructuring, competition and regulatory reform in the U.S. electricity sector. *Journal of Economic Perspectives*. 11(3): 119-138.

Joskow, P. L. 2000 Deregulation and Regulatory Reform in the U.S. Electric Power Sector. Discussion Paper. MIT Prepared for the Brookings-AEI Conference on Deregulation in Network Industries, December 9-10, 1999.

Kamerschen, D.R. and Thompson, H.G.. 1993. Nuclear and fossil steam generation of electricity: differences and similarities. *Southern Economic Journal*. 60 (July): 14-27.

Kaserman, D.L. and Mayo, J.W. 1991. The measurement of vertical economies and the efficient structure of the electric utility industry. *Journal of Industrial Economics*. 39 (September): 483-502.

Kleit, A. N. and Terrell, D. 2001. Measuring Potential Efficiency Gains from Deregulation of Electric Generation: A Bayesian Approach. *The Review of Economics and Statistics.* 83(3): 523-530.

Landon, J.H. 1983. Theories of vertical integration and their application to the electric utility industry. *Antitrust Bulletin*. Spring: 101-130.

Lawrence, P.R. and Lorsch, J.W. 1967. Organization and Environment: Managing Differentiation and Integration. Boston: Boston, Division of Research, Graduate School of Business Administration, Harvard University.

Lee, B. 1995. Separability Test for the Electric Supply Industry. *Journal of Applied Econometrics*. 10(1): 49-60.

Leibenstein, H. and. Maital, S. 1992. Empirical Estimation and Partitioning of X-Inefficiency. *The American Economic Review*, 82(2): 428-33.

Levy, B. and Spiller, P. 1994. The Institutional Foundations of Regulatory Commitment: A Comparative Analysis of Telecommunications Regulation. *Journal of Law Economics and Organization*. 10(2): 201-46.

Mahoney, J.T. 1992. The Choice of Organizational Form: Vertical Financial Ownership Versus Other Methods of Vertical Integration. *Strategic Management Journal*. 13(8): 559-84.

Majumdar, S. 1998. “On the Utilization of Resources: Perspectives from the U.S. Telecommunications Industry.” *Strategic Management Journal* **19**(9): 809-831.

Majumdar, S.K., Marcus, A.A. 2001. Rules versus Discretion: The productivity consequences of flexible regulations. *Academy of Management Journal.* 44(1): 170-179.

Mukherjee, K., Subhash C. Ray, and. Miller, S.M. 2001. Productivity growth in large US commercial banks: The initial post-deregulation experience. *Journal of Banking & Finance*, 25(5): 913-.

Murillo-Zamorano, L R. and Vego-Cervera, J.A.. 2001. The use of parametric and non-parametric frontier methods to measure the productive efficiency in the industrial sector: A comparative study. *International Journal of Production Economics*, 69(3): 265-75.

Nelson, R.R. and Winter, S.G. 1982. An Evolutionary Theory of Economic Change. Cambridge: Belknap Press.

Pfeffer, J. and Salancik, G.R. 1978. The External Control of Organizations: A Resource Dependence Perspective. New York: Harper and Row.

Roberts, M. J. 1986. Economies of Density and Size in the Production and Delivery of Electric Power. *Land Economics*. 62(4): 378-387.

Royston, B. 1991. sg3.5: Comment on sg3.4 and an improved D'Agostino test. *Stata Technical Bulletin.* 3: 23-24.

Rumelt, R. P. 1995. Inertia and Transformation. In Montgomery, C.A., editor, *Resource–Based and Evolutionary Theories of the Firm.* Boston: Kluwer Academic Publishers.

Russo, M. V. 1992. Power Plays: Regulation, Diversification, and Backward Integration in the Electric Utility Industry. *Strategic Management Journal* 13(1): 13-27.

Russo, M. V. 2001. Institutions, exchange relations, and the emergence of new fields: Regulatory policies and independent power producing in America, 1978-1922. *Administrative Science Quarterly* 46(1): 57-86.

Seiford, L. H. 1996. Data Envelopment Analysis: The evolution of the state of the art (1978-1995). *The Journal of Productivity Analysis*, 7: 99-137.

Shapiro, S.S. and Wilk, M.B. 1965. An analysis of variance test for normality (complete samples). *Biometrika*. 55: 591-611.

Shapiro, S.S., Francia, R.S. 1972. An approximate analysis of variance test for normality. *Journal of American Statistical Association.* 67 : 215-216.

Stata 2001 Stata Reference Manual vol 4 Su_Z. Stata Press, College Station, Texas.

Sueyoshi, T. and. Goto. M. 2001. Slack-adjusted DEA for time series analysis: Performance measurement of Japanese electric power generation industry in 1984-1993. *European Journal of Operational Research*, 133(2): 232-59.

Teece, D. J. 1986. Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy*. 15(6): 285-305.

Thompson, H. G. Jr. 1997. Cost efficiency in power procurement and delivery service in the electric utility industry. *Land Economics*. 73(3): 287-296.

Thompson, J. D. 1967. Organizations in Action: Social Science Bases of Administrative Theory. New York: McGraw-Hill.

U.S. Department of Agriculture- Office of the Chief Economist. 1999. Electric Utility Deregulation: Rural Effects, Briefing to Senior USDA Policy Officials.

U.S. Department of Energy - Energy Information Administration. 2000 The Changing Structure of the Electric Power Industry 2000: An Update. DOE/EIA-0562 (00).Washington, DC.

U.S. Department of Energy - Office of Policy. 1999. Supporting Analysis for the Administration's Comprehensive Electricity Competition Act. Washington, D.C.

Uri, N. D. 2001. The effect of incentive regulation on productive efficiency in telecommunications. *Journal of Policy Modeling*. 23(8): 825-846.

Watson S. J. and Ter-Gazarian, A.G. 1996. The Optimisation of Renewable Energy Sources in an Electrical Power System by Use of Simulation and Deterministic Planning Models**,** *International Transactions in Operational Research.* 3(3-4): 255-269.

Wheelock, D. C. and Wilson, P.W. 1999. Technical progress, inefficiency, and productivity change in U.S. banking, 1984-1993. *Journal of Money, Credit, and Banking*, 31(2): David C.

Williamson, O. E. 1985. Economic Institutions of Capitalism. New York: The Free Press.

Williamson, O. E. 1991. Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. *Administrative Science Quarterly*, 36(2): 269-96.

Williamson, O.E. 1971. The vertical integration of production: market failure considerations. *American Economic Review.* 61: 112-123.

Winston, C. 1998. U.S. industry adjustment to economic deregulation. *The Journal of Economic Perspectives.* 12(3): 89-110.

Figure 1. DEA illustration

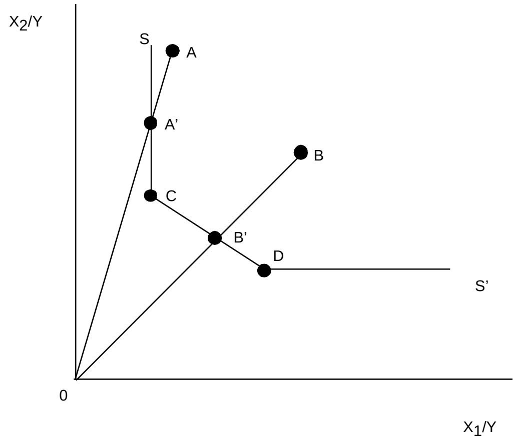


Figure 2. Distribution of efficiency the efficiency variable (pooled sample)

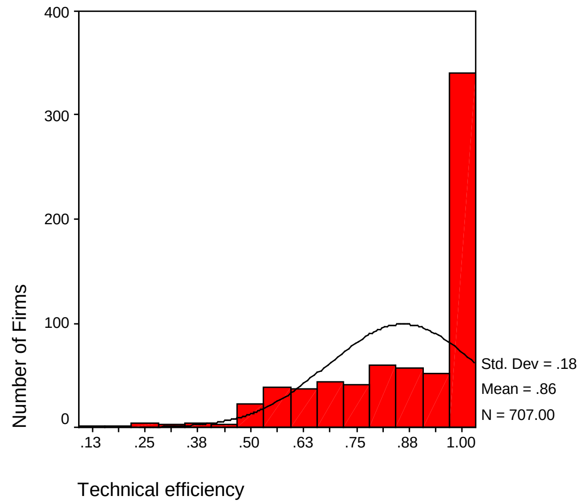
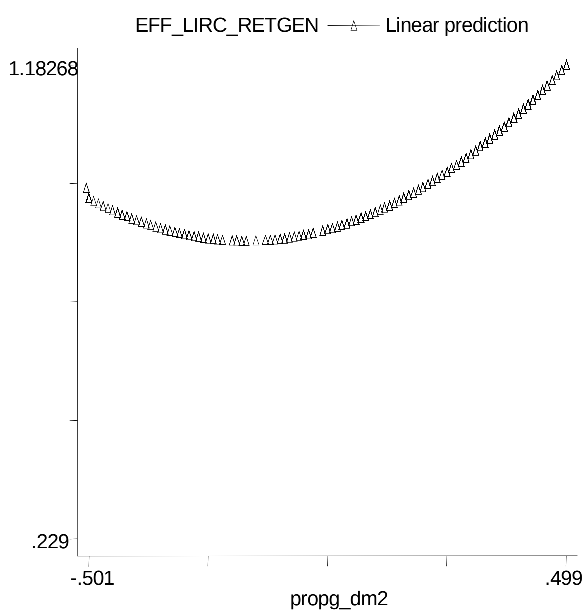


Figure 3. Relationship between efficiency and governance structure.



The efficiency measure is de-meaned so -0.5 represents 100% retail and 0.5 represents 100% generation.

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***	.373*	0.78	.121
Percentage predicted	78.4	76.5	70.6	70.6

$* \leq 0.10$, $** \leq 0.05$, $*** \leq 0.01$

Table 2. Descriptive statistics[23]

Variable		**Obs**	**Mean**	**Std.Dev.**	**Min**	**Max**
EFF	Productive efficiency measured using DEA	707	0.860	0.178	0.151	1.000
DEREG	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
DIVEST	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	$(\text{Prop\_gen})^2$	1638	0.168	0.094	0.000	0.251
FRAGMENT	Fragmentation of market	909	1.344	1.728	0.150	14.720
BIGPLAYE	Firm is among 5 top sellers in one of more states	924	0.707	0.757	0.000	5.000
LN_TOTAL	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
HOLDSUBS	Number of subsidiaries of holding comp	1092	1.290	2.321	0.000	9.000
MERGER_U	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
CA_DUMMY	California Dummy	1638	0.013	0.115	0.000	1.000
YEAR1999	year1999	1092	0.250	0.433	0.000	1.000
YEAR2000	year2000	1092	0.250	0.433	0.000	1.000
YEAR2001	year2001	1092	0.250	0.433	0.000	1.000

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

Table 3. Correlations

	eff	dereg	Dereg2	pcap	divest	stcost	IV	Prop_gen	Prop_gen2	fragment	bigplaye	ln_total	prop_nuc	prop_ren	holdsubs	merger_u	western	texas	ca_dummy	year1999	year2000	year2001
EFF	1.000																					
DEREG	-0.107	1.000																				
DEREG2	-0.146	0.953	1.000																			
PCAP	-0.147	0.948	0.994	1.000																		
DIVEST	-0.204	0.871	0.901	0.904	1.000																	
STCOST	-0.133	0.943	0.975	0.970	0.886	1.000																
IV	-0.094	0.324	0.310	0.308	0.255	0.285	1.000															
PROP_GEN	0.270	-0.307	-0.305	-0.303	-0.325	-0.307	-0.094	1.000														
PROP_GEN2	0.051	0.080	0.075	0.066	0.053	0.088	0.135	-0.277	1.000													
FRAGMENT	-0.187	-0.313	-0.328	-0.328	-0.301	-0.344	-0.058	0.055	0.016	1.000												
BIGPLAYE	0.055	-0.156	-0.153	-0.150	-0.105	-0.160	-0.112	0.176	-0.359	0.081	1.000											
LN_TOTAL	0.262	-0.019	-0.013	-0.005	-0.027	-0.016	-0.012	0.445	-0.532	-0.218	0.480	1.000										
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									
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								
HOLDSUBS	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							
MERGER_U	-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						
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					
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				
CA_DUMMY	-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			
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		
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	
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 (standard errors in parentheses * significant at 5%; ** significant at 1%)

	(1) Efficiency	(2) Efficiency	(3) Efficiency	(4) Efficiency	(5) Efficiency	(6) Efficiency	(7) Efficiency	(8) Efficiency	(9) Efficiency	(10) Efficiency	(11) Efficiency
DEREG			-0.022 (0.008)**	-0.021 (0.008)**	-0.019 (0.008)*	-0.025 (0.008)**					
DEREG2							-0.093 (0.024)**				
PCAP								-0.092 (0.023)**			
DIVEST									-0.080 (0.018)**		
STCOST										-0.046 (0.012)**	
IV											-0.082 (0.025)**
PROP_GEN	0.196 (0.033)**		0.167 (0.034)**	0.174 (0.034)**	0.254 (0.032)**	0.175 (0.034)**	0.154 (0.034)**	0.154 (0.034)**	0.149 (0.034)**	0.157 (0.034)**	0.184 (0.032)**
PROP_GEN2	0.839 (0.133)**		0.859 (0.133)**	0.887 (0.133)**	0.578 (0.128)**	0.886 (0.134)**	0.870 (0.133)**	0.871 (0.133)**	0.871 (0.132)**	0.869 (0.133)**	0.896 (0.134)**
FRAGMENT	-0.015 (0.005)**	-0.013 (0.005)*	-0.019 (0.005)**	-0.021 (0.005)**	-0.028 (0.005)**	-0.019 (0.006)**	-0.021 (0.005)**	-0.021 (0.005)**	-0.021 (0.005)**	-0.021 (0.006)**	-0.015 (0.005)**
BIGPLAYE	-0.022 (0.015)	-0.043 (0.016)**	-0.026 (0.015)		0.011 (0.014)	-0.028 (0.015)	-0.027 (0.015)	-0.027 (0.015)	-0.022 (0.015)	-0.027 (0.015)	-0.028 (0.015)
LN_TOTAL	0.049 (0.008)**	0.052 (0.007)**	0.051 (0.008)**	0.045 (0.008)**		0.049 (0.008)**	0.052 (0.008)**	0.052 (0.008)**	0.050 (0.008)**	0.051 (0.008)**	0.052 (0.008)**
PROP_NUC	-0.220 (0.039)**	-0.240 (0.041)**	-0.203 (0.039)**	-0.194 (0.039)**	-0.165 (0.040)**	-0.201 (0.040)**	-0.190 (0.039)**	-0.191 (0.039)**	-0.178 (0.040)**	-0.194 (0.039)**	-0.210 (0.039)**
PROP_REN	-0.065 (0.031)*	-0.065 (0.033)*	-0.063 (0.031)*	-0.062 (0.031)*	-0.087 (0.032)**	-0.058 (0.031)	-0.064 (0.031)*	-0.063 (0.031)*	-0.068 (0.031)*	-0.069 (0.031)*	-0.060 (0.031)
HOLDSUBS	0.028 (0.005)**	0.028 (0.005)**	0.028 (0.005)**	0.029 (0.005)**	0.033 (0.005)**	0.023 (0.005)**	0.027 (0.005)**	0.027 (0.005)**	0.027 (0.005)**	0.027 (0.005)**	0.028 (0.005)**
MERGER_U	-0.098 (0.025)**	-0.121 (0.026)**	-0.092 (0.025)**	-0.094 (0.025)**	-0.081 (0.026)**		-0.091 (0.025)**	-0.092 (0.025)**	-0.094 (0.025)**	-0.091 (0.025)**	-0.094 (0.025)**
WESTERN	0.119 (0.035)**	0.097 (0.037)**	0.121 (0.034)**	0.122 (0.035)**	0.130 (0.036)**	0.119 (0.035)**	0.124 (0.034)**	0.124 (0.034)**	0.131 (0.034)**	0.120 (0.034)**	0.116 (0.034)**
TEXAS	0.088 (0.049)	0.108 (0.052)*	0.096 (0.049)	0.089 (0.049)	0.123 (0.049)*	0.108 (0.049)*	0.094 (0.049)	0.094 (0.049)	0.084 (0.048)	0.094 (0.049)	0.118 (0.050)*
CA_DUMMY	-0.205 (0.081)*	-0.290 (0.086)**	-0.188 (0.081)*	-0.184 (0.081)*	-0.146 (0.083)	-0.168 (0.081)*	-0.192 (0.080)*	-0.175 (0.080)*	-0.133 (0.081)	-0.184 (0.080)*	-0.191 (0.080)*
YEAR1999	0.059 (0.028)*	0.055 (0.029)	0.066 (0.028)*	0.066 (0.028)*	0.067 (0.029)*	0.055 (0.028)*	0.069 (0.028)*	0.070 (0.028)*	0.068 (0.027)*	0.068 (0.028)*	0.060 (0.028)*
YEAR2000	0.024 (0.028)	0.020 (0.029)	0.028 (0.028)	0.028 (0.028)	0.033 (0.028)	0.022 (0.028)	0.026 (0.027)	0.026 (0.027)	0.030 (0.027)	0.029 (0.027)	0.022 (0.027)
YEAR2001	0.002 (0.028)	-0.006 (0.029)	0.002 (0.028)	0.002 (0.028)	0.014 (0.028)	0.003 (0.028)	0.001 (0.027)	0.001 (0.027)	0.005 (0.027)	0.004 (0.027)	-0.006 (0.028)
CONSTANT	0.097 (0.134)	0.199 (0.111)	0.127 (0.134)	0.189 (0.129)	0.916 (0.040)**	0.155 (0.135)	0.108 (0.133)	0.105 (0.133)	0.136 (0.133)	0.114 (0.133)	0.060 (0.134)
OBSERVATIONS	696	696	696	696	699	696	696	696	696	696	696