

**POWERING PROGRESS:
RESTRUCTURING, COMPETITION, AND R&D IN THE U.S. ELECTRIC
UTILITY INDUSTRY***

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Abstract:

This paper investigates the R&D behavior of regulated firms when they transition to a competitive environment. Using data from the US electricity market from 1990-2000, we analyze how competition, institutional changes, and political constraints have contributed to the precipitous decline in R&D expenditure by regulated utilities. We find that firms reduce their R&D significantly at the very early stages of restructuring or even when they expect restructuring to occur. Once the emerging institutional structure becomes clear, R&D spending recovers but is later offset by another decline when restructuring legislation is enacted. In addition, greater competition and the nearing of such competition adversely affects research spending. In aggregate, R&D declines by 78.6 percent after electricity markets are restructured. Firm and state characteristics matter, and a majority of the research is conducted by large generation companies located in pro-research states, especially if they are part of a larger holding company. Such characteristics have a different impact on research spending in the pre- and post-restructured periods.

Key Words: R&D, Regulation, Competition, Electricity Restructuring

JEL Codes: O30, O31, L50, L94, L97

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“Research and development is our nation’s investment in its own future. America’s science and technology base may well stand as our most important renewable resource. The overarching public goal of US R&D policy, of which energy R&D is a major component, must be to assure for future generations that our Nation’s capacity to shape the future through scientific research and technological innovation is continually being renewed” (US Department of Energy Report).¹

“In a nutshell, the government that had created this regulated industry was saying, ‘We don’t want to regulate you anymore. Here’s your business. Good luck.’ However, the restructuring process initially generated more questions than answers, as the various players in the market tried to understand how the configuration of this industry might need to change.” (CEO, TXU)²

Introduction

The two statements above, one by the Department of Energy taskforce and the other by an electric utility CEO, succinctly capture the central ideas on which this paper is based. First, investment in research and development (R&D) activities is fundamental for economic progress (Schmookler, 1966), and energy-related research is especially important. Second, the restructuring of the US power market has created uncertainties about the future business landscape, and electric utilities are trying to adapt as best as they can. This paper analyzes how R&D has fared in this environment. Data shows that, coincident with the movement towards restructuring the electricity industry in the early to mid-1990s, there was a dramatic decline in research activity in this sector in a relatively short period of time. This decline is worrying

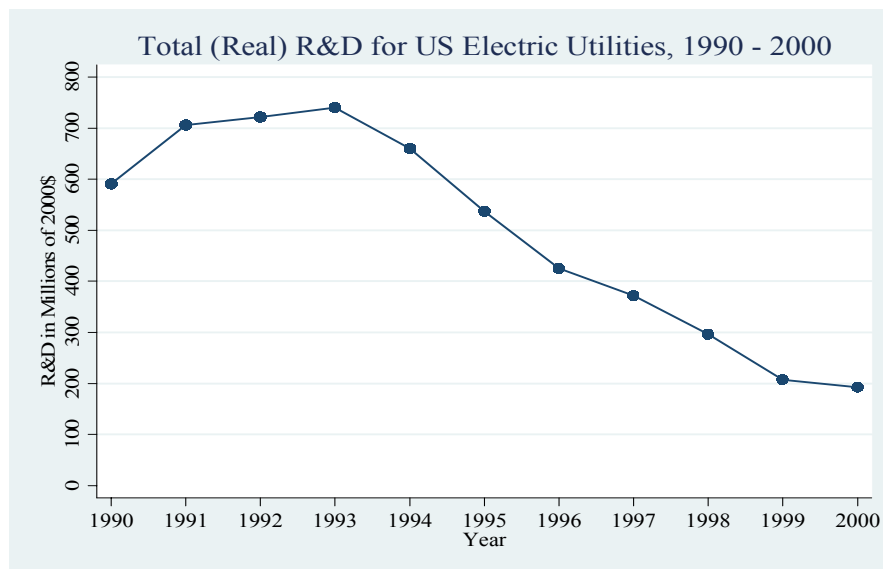
¹ Final Report of the Task Force on Strategic Energy Research and Development, Secretary of Energy Advisory Board, U.S. Department of Energy, June 1995.

² “Leading change: An interview with TXU's CEO (C. John Wilder)” by Warren L. Strickland. The McKinsey Quarterly, 29th March 2007.

because it may “result in slowing technology development, sacrificing future prosperity to meet short-term goals, and failing to meet national energy goals” (GAO Report, 1996) and may thus have implications for the future of U.S. energy security. This paper is a step towards understanding how the transition from a regulated to a market regime influences firm R&D behavior.

Four major entities performed R&D in the U.S. electricity sector – the electrical equipment manufacturers (EEMs), such as General Electric³; the investor owned utilities; the Department of Energy; and the Electric Power Research Institute (EPRI). This paper focuses on the utilities’ R&D expenditure, which fell precipitously between 1993 and 2000.⁴

Figure 1



From its highest level of \$741 million (in 2000 dollars) in 1993, R&D expenditure declined to \$193 million in 2000 - a drop of nearly 74% (Figure 1 above).⁵

³ For a detailed discussion on the structure and organization of research activities in the electric utility sector, please refer to Sanyal (2001).

⁴ To put this in context, the Energy Policy Act, which started the deregulation process, was passed in 1992. Utilities could probably see that market restructuring would follow in the near future, and since R&D spending is forward looking, they would have begun reducing their expenditures.

⁵ We use the data that was collected up to the year 2000 since this corresponds to our sample period. Due to the California electricity crisis in 2001, many states stopped the restructuring process and some reversed course. Thus,

R&D expenditures by the other players declined as well. Collaborative research by EPRI experienced a sharp drop (71 percent) as major utilities⁶ slashed contributions. State electricity R&D funding declined by 30 percent between 1993 and 1999, and the Department Of Energy's funding decreased by 3 percent during the same period.⁷ In addition, for EEMs, total R&D as a percent of sales declined as well. To provide a context, we can benchmark these numbers against other industries. In Appendix Figure 1, we provide graphs for the total (real) R&D trends from 1990-2000 for four industrial sectors: drugs, chemicals, machinery, and autos.⁸ We find that three out of the four sectors show a steady increase in R&D expenditures over the time period.⁹ This illustrates that the changes in the electric utility industry R&D during this period were not due to any general macroeconomic factor but were rather, peculiar to the industry itself. As such, the sharp drop in utilities' R&D expenditure requires further investigation.

The magnitude and timing of these changes raise questions about the forces behind this decline. Since this drop in R&D was coincident with market restructuring, the obvious factors appear to be the changing institutional and market structures in the power sector. At the outset, however, it is important to ask whether such a decrease is cause for concern. To answer this question, we need to briefly address two related issues. First, what are the technology improvements that have taken place in the electricity industry, and what is the contribution of electric utility research to such progress? Second, how has the composition of R&D spending by utilities changed during restructuring, and should we be concerned?

On the technology front, there have been some major breakthroughs. The first is the rise of distributed generation technologies, such as the combustion turbine, fuel cells, and

including data after 2000 would have confounding effects on our results. Fabrizio et. al (2007) limit their sample to 1999 when studying electric utility productivity due to similar concerns.

⁶ GAO (Appendix II, 1996), Moore (1995)

⁷ EPRI (1997), GAO (1998)

⁸ The graphs are based on Compustat data. R&D is in millions of dollars and has been deflated by the producer price index in 2000.

photovoltaics, which have eliminated the need for large scale power plants. The second is the development of the Integrated Gasification Combined Cycle (IGCC),^{10, 11} which is a part of the clean coal technology program and can confer significant environmental and efficiency benefits. The third type of technology relates to renewables, such as wind, geothermal, and biomass energy. The fourth innovation is in the creation of demand side management programs to reduce electricity use by consumers. Although a majority of these technologies are being developed by large electric equipment manufacturers, such as GE, utilities have been playing a large role in testing these technologies and improving them.

As an example, in 1994 Southern California Edison spent approximately \$1 million a piece on heat-rate improvement of fossil fuel generation and distributed generation; \$8 million on renewable technologies, such as photovoltaics; and another \$6 million on demand side management programs, for a total budget of approximately \$70 million.¹² In 2000, the company was not involved in any of the above projects, and total R&D expenditure fell to just \$1 million. Duke Energy Corporation spent 21 percent of its internal R&D budget on fossil-fuel generation research in 1994, and this declined to 9 percent in 2000. During the same period, their total R&D budget shrank from \$18 million to \$9 million. Yet another example is the Gulf Power Company, which spent about 40 percent of its internal R&D budget on clean coal technologies in 1994 and reduced this expenditure to zero in 2000. With the vast reduction in these budgets, the equipment manufacturers may have to look elsewhere for testing their technology, and this may adversely impact new technology development.

⁹ The chemical sector shows a slight decline after 1999.

¹⁰ This technology is being developed by two competing consortia: GE (Chevron Texaco)/Bechtel and Siemens (Conoco Phillips). (http://www.hewm.com/docs/en/regulatory_strategies_new_energy_tech.pdf)

¹¹ This technology converts coal into gas and then removes the impurities from that gas before it is used for electricity generation. This significantly reduces the emissions of sulfur dioxide, mercury, and particulate matter.

¹² All dollar figures here are 2000 dollars.

In addition, utilities spent a sizeable portion of their internal research budgets on public interest environmental R&D projects, such as research on global warming and the effects of electromagnetic fields on health. From the data, we find that for most utilities, the large projects with potential externalities, such as air and environmental quality research, have been replaced by smaller and more targeted research projects, such as hydro basic research projects.¹³ Again using Southern California Edison as an example, we find that such R&D expenditures have declined from \$11 million to 160,000 dollars, a drop of almost 98 percent. In general, we find that collaborative research and classic “public interest” R&D has led the charge in the overall decline in research spending (Hirsch, 1998; U.S. House of Representatives Testimony, 1998). Since such research does not confer any short-term monetary benefits, one would assume that the equipment manufacturers would not be willing to step in and pick up the slack. The combination of declining federal R&D support and the precipitous drop in utility research expenditures does not bode well for such research. These are important concerns, and analyzing how the restructuring policies have affected utility R&D behavior will help in understanding the relation between market structure and the conduct of R&D.

Considerable theoretical and empirical attention has been focused on the linkages between market structure, innovation, productivity, and R&D¹⁴ for manufacturing firms. However, relatively little attention has been devoted to the behavior of firm R&D when such firms are regulated and have to adapt to a competitive threat. The electricity industry restructuring provides a good opportunity to study this question. The restructuring of the U.S. electricity industry is likely to substantially alter innovation incentives and, consequently, affect the level and composition of R&D. We believe that this study has broader implications for the

¹³ For an extensive discussion, see Sanyal (2007).

¹⁴ For a complete discussion on this topic, please refer to Kamien & Schwartz (1975) - "Market Structure & Innovation: A Survey", JEL, 13:1.

conduct of R&D in restructured industries and may serve as a good benchmark for other regulated industries in transition. In addition, identifying the factors behind the decline may suggest ways in which such funding decreases can be mitigated.

Our results indicate that restructuring, and consequent changes in market and institutional arrangements, are a significant determinant of the R&D response of utilities. In particular, the expectation of restructuring and the early stages of the restructuring process are associated with a decline in research spending. R&D suffers as the specter of competition draws closer and as the level of competition increases. A part of this decline is reversed when an actual restructuring order has been passed and utilities are fairly certain about the emerging institutional structure. However, this increase is offset by a further decline when states actually implement restructuring legislation. In aggregate, restructuring is responsible for a 78.6 percent decline in electric utility R&D expenditures. In addition, a majority of the research is conducted by large generation companies, especially if they are part of a larger holding company. State preferences also influence the amount of R&D conducted by the utilities, and firm and state characteristics have a different impact on R&D before and after restructuring. The derivation and the implication of these results are analyzed in subsequent sections of the paper.

This paper is organized into five sections. The first section briefly outlines the restructuring process and the nature and organization of R&D activities in the US power industry. The second section discusses earlier literature that investigates both the R&D model and the incentives to conduct R&D under a regulated versus a market framework. Methodological issues, data sources, and the specifics about the variables used are presented in the third section. The fourth section explains the empirical results, and the last section concludes.

Section 1: Background

The Energy Policy Act (EPAct) of 1992 gave impetus to wholesale power competition by creating a new class of power producers called the exempt wholesale generators and by creating open-access transmission grids for wholesale transactions. In 1996, FERC Orders 888 & 889¹⁵ encouraged retail competition for the first time while furthering wholesale competition.¹⁶ These were federal guidelines, and each state interpreted and implemented the Orders in different ways. This led to the emergence of a diverse set of state-specific institutional arrangements that governed utilities and this paved the way for altering the existing regulated monopolies into firms that could successfully navigate the new competitive environment¹⁷ (Blumstein, 1997; Borenstein, & Bushnell, 1997; Bushnell & Stoft, 1995; Hogan, 1997; Joskow, 1989, 1997, 1999; Moyer, 1993; Sloan, 1994; Taylor, 1998; Wolak, 1997).

Despite common federal guidelines, deregulation and restructuring of the industry did not occur as a one-time monolithic change. Instead, the processes involved a complex set of institutional changes that ranged from implementing pricing rules and setting up auction mechanisms for the power market to modifying the policies governing various operational facets of electric utilities. The pace and nature of restructuring differed considerably from state to state.

¹⁵ Order 888 – “Promoting Wholesale Competition Through Open Access Non-Discriminatory Transmission Service by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities” and Order 889 – “Open-Access Same-Time Information System.” For a detailed provision of the orders, please refer to DOE/EIA (1997).

¹⁶ The main provision of Order 888 is that utilities that own transmission networks must provide transmission services to other power generators at cost-based, non-discriminatory prices. Provisions were also laid out governing the recovery of stranded costs by utilities. Order 889 required each public utility to participate in an Open Access Same-Time Information System (OASIS) to facilitate wheeling by third parties that did not own transmission capacities. These orders taken together provided impetus to wholesale competition and initiated an effective groundwork to begin retail wheeling whereby retail consumers could shop around for the best rates while purchasing electricity.

¹⁷ Currently there are about 3200 electric utilities in the US, of which only about 700 generate power. In the generation sector there are two broad groups – the utilities and the non-utilities. The utilities consist of the five distinct groups: the investor owned utilities (IOUs), federally owned utilities, other public utilities (state, municipal, etc.), co-operatives, and power marketers. The non-utility group is comprised of qualified and non-qualified cogenerators, small power producers, exempt wholesale generators, and non-qualified non-cogenerators. The non-utilities are “privately owned entities that generate power for their own use and/or sale to utilities and others”

Most states, however, went through three common stages of restructuring, starting with the initiation of investigations into the deregulation process and ending with the passage of some form of retail competition order. In addition, several other policies, including those that affected the mandated date for retail competition, the percentage of market open to such competition, the guidelines governing the divestiture of assets, default provider rules, and stranded cost recovery, were important as well. All these policies changed not only the operating environment of the utility, but also the very nature of the firm, and hence have implications for the conduct of R&D.

We are interested in studying electric utilities because they were the entities most directly affected by the restructuring process. Historically, the EEMs have conducted most of the R&D and generated a majority of the innovations in this industry.¹⁸ Compared to these EEMs, the R&D levels for utilities were low since the latter could not internalize the benefits of such research. They allocated some of the research dollars to in-house projects, such as those focused on global warming, and the rest of the money was given to external collaborative research agencies, such as EPRI. Within the cohort of utilities, R&D was primarily conducted by big, vertically integrated firms that owned generation, transmission, and distribution. Companies that were solely distribution or transmission companies invested very little in research. In the regulated environment, R&D investment was essentially a risk-free venture for the utilities since such investments could be recouped. With restructuring, the incentives for R&D changed, and appropriability and cost concerns became important. The next section briefly discusses the motives for R&D in the regulated and restructured regimes and frames the observed decline in light of the changed incentives.

(DOE/EIA-X037, 2000). The investor owned utilities are the most important category, and they account for 75 percent of power generated in the US.

Section 2: Literature Review

Section 2.1: General Determinants of R&D

R&D is considered a critical engine of economic and productivity growth (Griliches, 1979, 1986; Griliches and Mairesse, 1984; Nadiri, 1979; Van Reenen, 1997), and there has been substantial research on the drivers of R&D (Cumming and Macintosh, 2000). Two broad hypotheses have emerged from such analysis. Pioneered by Schmookler (1966), the demand-pull hypothesis emphasizes demand side factors, such as consumers' demand for new products, and cost-reductions as primary drivers of R&D. The supply-push hypothesis, on the other hand, (Rosenberg, 1974) holds that supply-side factors, such as differences in the technological environment of the firm and industry concentration, lead to variations in R&D expenditures. Empirical evidence suggests that neither hypothesis alone can explain firm R&D behavior and that both demand and supply aspects are important (Scherer, 1982; Pakes and Schankerman, 1984; Jaffe, 1986, 1988). Combining the hypotheses, one can point to a common set of factors that are important drivers of R&D spending.

First, a firm's characteristics and organizational structure (Piga and Vivarelli, 2003) are important in explaining its R&D propensity. Firm size seems to be of critical importance, and large firms are more research intensive than small ones (Grabowski, 1968; Lee, 2003). Profitable firms, and those with excess cash, also conduct more R&D (Reynard, 1979; Connolly and Hirschey, 1984). Unionization is an important determinant of R&D, and greater unionization has adverse impact on such spending (Menezes-Filho et. al, 1998). Second, features of the industry within which the firm operates are equally important. Industry concentration, product market competition (Wahlroos and Backstrom, 1982), and exogenous technology accumulation by other

¹⁸ See Sanyal & Ghosh (2008) for a detailed analysis of the impact of restructuring on innovation by electric equipment manufacturers, such as GW and Westinghouse.

firms (Lee, 2003) also explain a firm's R&D behavior. Third, government policies and public R&D support influence a firm's R&D choice. Tax incentives and R&D subsidies can often boost research expenditures (Mansfield and Switzer, 1985; Hall and Van Reenen, 2000). In addition, most studies find that government support has a positive effect on private R&D expenditures (Levin and Reiss, 1984; Lichtenberg, 1984, 1987, 1988; David et. al, 1999). In this paper, we add to this literature by analyzing the R&D behavior of regulated private monopolies, which then undergo restructuring and have to respond to market competition and price-cost pressures.

Section 2.2: R&D under Regulation

The relation among market structure, R&D, and innovation has been the subject of extensive analysis in the industrial organization literature (Fellner, 1951; Scherer, 1967; Needham, 1975; Kamien and Schwartz, 1975; Levin, 1981; Culbertson, 1985; Cohen and Levin, 1989). Most studies, however, have focused on the incentives of profit-maximizing firms. While there are a few studies that analyze the behavior of regulated firms, their focus is on technology choice rather than R&D decisions. These studies have two main findings. First, regulation appears to have an adverse effect on technological progress and stifles innovation (Petersen, 1975; Magat, 1976; Riorden, 1992; Granderson, 1999). Second, rate of return regulation distorts firms' choice of technology (Smith, 1975; Okuguchi, 1975). In particular, regulated firms choose technology that enhances the non-capital input at the expense of capital inputs, and this input mix differs from that chosen by non-regulated firms (Granderson, 1999).

These papers give us some insight into the incentive structures of regulated firms and their technology choice behavior. However, they do not directly address the R&D decisions by these firms. The analysis of technology choice in these papers is based on Averch-Johnson types

of distortion,¹⁹ where the regulated firm goes off its path of equilibrium and chooses a technology that distorts the capital-labor ratio in a way that exacerbates the distortion. R&D decisions are different because such expenditures are expensed and not capitalized and therefore have to be analyzed separately from technology investment questions. To the best of our knowledge, the only works that investigate this question are a paper by Wilder and Stansell (1974) and a comment on their paper by Delaney and Honeycutt (1976). The former estimate a simple model based on 1968-1970 electric utility data and find that firm size and profitability are important determinants of R&D. Delaney and Honeycutt (1976) refute the claims made by the above authors and show that their conclusions are sensitive to sample and time-frame choice. Our paper adds a necessary piece to the existing literature by investigating the determinants of R&D expenditure choice by regulated utilities and the changes that occur with restructuring.

The incentive structure of regulated utilities are different from profit-maximizing firms since the former were subject to rate-based regulation, and most major expenditures had to be approved by regulators. For regulated utilities, R&D was done, for the most part, not to gain any competitive advantage but for other political economy reasons. One might argue that under “regulatory lag” conditions, a company might perform R&D in order to improve operating efficiencies, which is consistent with the notion that its incentives are aligned with those of private firms when not subject to rate reviews. But the incentive to perform R&D under these conditions is weak.²⁰ Electric utilities had franchise monopolies that not only protected their activities from interlopers (obviating the basic Schumpeterian reason for conducting research)

¹⁹ Rate of return regulation distorts investment incentives and leads to over-capitalization in a regulated industry.

²⁰ During the 20th century, electricity technology underwent enormous technological advance, and regulated utilities are credited with providing a stable, forgiving environment ideal for inducing innovation (of at least some types) from electric equipment manufacturers (EEM) and other manufacturing firms. Innovation by EEMs and other firms and the role of regulation in inducing such innovation is clearly an important topic, but an analysis of it is beyond the scope of this paper. See Ishii (2004), and Sanyal and Ghosh (2008) for a related analysis.

but also circumscribed their own business undertakings. Their ability to exploit research results was consequently limited.

Even when formal rate hearings lag company decisions, regulated utilities operate in a shadow of potential regulatory oversight that darkens prospects for R&D. Research is inherently risky, with the risk justified by infrequent but valuable inventions. But if a utility succeeded in producing, for example, a cost-reducing innovation, regulators would likely take notice and redistribute exceptional returns to rate-payers. Our data series does not include years during which utilities allegedly enjoyed regulatory lags, but anecdotal evidence suggests that they did not devote unsupervised surplus to the pursuit of research.²¹

The second reason a regulated utility would have a research program is by order, or anticipated order, of its regulatory commission. In this case, we would expect the program to reflect the preferences of the commissioners. For example, “green” states, such as California, may want their utilities to invest more in environmental projects and increase the overall R&D spending on the firms. The discussion above yields some suggestions about the variables that can be used to model R&D activity in a regulatory regime. In the econometric specification, we use regulator characteristics and state R&D preferences to capture the above influences.

Section 2.3: R&D under Restructuring

Under restructuring, the incentives will be mostly similar to that of other private profit-maximizing firms. The restructuring process involves significant uncertainties about market structure and conduct, and will thus have a large impact on a firm’s research investment decisions, although a priori, its direction is ambiguous. For example, uncertainty over demand

²¹ In contrast, AT&T, while holding down a regulated monopoly on phone service, conducted an extraordinarily successful research program and was among the world’s top annual patent recipients. Neither the electric utilities nor, prior to 1990, their research consortium, the Electric Power Research Institute (EPRI), obtained patents on inventions. See Hirsh (1989); Corey (1997).

conditions may affect the timing of an investment or the choice of technology. If the actual nature of the market is unknown, the real options literature and efficient investment principles dictate a delay in investment (McDonald and Siegel, 1986; Dixit and Pindyck, 1994; Ishii and Yan, 2003; Goorbergh et. al, 2003; Macauley, 2003). This spills over to R&D to the extent that research is conducted in response to demand for technology, or "induced demand" R&D (Newell, Jaffe and Stavins, 1999). Thus, we expect uncertainty to dampen R&D expenditures. In addition, policies that adversely impact firm finances, such as the ability of a firm to recoup its stranded costs, will decrease R&D.

However, there are forces that work in the opposite direction (Kort, 1998). Research activities in a firm increase the firm's ability to absorb the research results of others or to innovate in areas related to, but distinct from, the firm's own research project (Dosi, 1988). Second, R&D can be a hedge. A firm may choose to conduct research on several technology options and thus increase the research budget during the investment delay. The importance of this effect depends on the timing of the resolution of uncertainty and on the research production function. If there are high fixed costs to research (Hall, 2002),²² the hedging characteristic may dominate the incentive to delay. Third, if a firm delays ordinary investment, it may face fewer budget constraints for other activities. R&D can substitute for investment if it places the firm in a position to invest more rapidly in new technology once the optimal investment strategy is revealed. Last, Schumpeterian analysis predicts that when firms face a relatively elastic demand curve (as in the restructured phase), they may perform more R&D (Reinganum, 1989).²³

²² R&D activities tend to be very stable over time, an effect believed to be due to the high fixed costs of assembling a research staff and the very low value of the staff in any alternate use.

²³ The intuition is that a small success – and small price decrease – will secure for the firm a large number of new customers.

Drawing from the above discussion, the next section formulates the empirical model that analyzes the effect of restructuring policies on R&D expenditures by IOUs, conditional on state and firm characteristics.

Section 3: Data and Variable Construction

Section 3.1: Data on R&D Expenditures

The key source of data for this paper is Form 1, which regulated utilities file with the Federal Energy Regulatory Commission (FERC). The Form contains all financial data, such as revenue and sales; generation data, such as the amount of electricity produced from steam, nuclear, and hydro; customer data about the share of sales, the revenue of residential, commercial and industrial customers; and other expense data, such as R&D, wages, and salaries. The primary data on restructuring policies is collected from EIA's (Energy Information Administration) "Status of State Electric Industry Restructuring Activity as of February 2004."²⁴ Data on the percentage of customers eligible for retail access is obtained from the "Retail Energy Deregulation Index 2000," published by the Center for Advancement of Electricity Markets.

Our main focus is to study how the transition from regulation to competition changes the R&D behavior of firms. To implement this we use data for the period 1990-2000²⁵ for all major utilities (195 of them). The panel is unbalanced due to missing data, which occur primarily in the early 1990s. Merger of companies also contributes to the unbalanced nature of the panel, although this accounts for less than 1 percent of the missing numbers. In total, there are 1663 observations for the period, and 1291 are associated with positive R&D numbers. These numbers

²⁴ This publication outlines the regulatory orders, legislations, and investigative studies that have been undertaken by each state up to the present.

²⁵ Although available, we do not use data after 2000 as there are confounding issues after that year. The California electricity crisis happened in the summer of 2001, and many states, including California, halted the restructuring

imply that approximately a quarter of the utilities do not conduct any research. From the pre- and post-deregulation statistics presented in Table 1, we observe that the R&D expenditures are significantly different in the two periods. Appendix Figure 2 shows a dramatic decline in R&D for the top 15 R&D performing firms, further supporting the trends in Table 1. The next sections discuss the explanatory variables used in the empirical analysis.

Section 3.2: Regulatory Variables

Restructuring Variables

Over the last decade, the electric utility industry has been in a state of flux. Deregulation, mergers, acquisitions, and divestitures have dramatically changed the landscape of the industry. The sharp decline in electric utility R&D expenditure (by approximately 74 percent) that has accompanied the electricity market restructuring puts the responsibility of this decrease squarely on the regulatory policies. We use several variables to capture these policy changes. First, the major federal law change (FERC Order 888 & 889) that began the restructuring process and market competition is captured by a dummy variable $FERC_{1996}$ that takes the value 1 starting in 1996. However, restructuring was not embodied in any single law change, and each state pursued restructuring in a different way and at a different pace. Thus, any one variable is not adequate to capture the dynamic nature of this change, and we use six variables to characterize these state-level institutional changes.

First, we construct three dummy variables based on the status of restructuring in states.²⁶ EIA classifies the status of deregulation into four categories: “No Activity,” “Investigations Ongoing or Orders and Legislation Pending,” “Order Issued for Retail Competition,” and “Legislation Enacted to Implement Retail Access.” The *deregulation investigation dummy* is 1 if

process. Adding the post-crisis years would make our results difficult to interpret because of the reversals, and no general conclusions about the effect of competition on regulated firm R&D behavior can be drawn.

the state has, at the very least, started investigations into the restructuring process or has legislation pending and is 0 otherwise. The *restructuring order dummy* is 1 if a state has issued an order for retail competition and is 0 otherwise. The *legislation enactment dummy* is 1 if the state has passed a legislation to implement retail competition and is 0 otherwise. Table 2a shows the status of restructuring for each state from 1994-2000.²⁷ From Appendix Figure 3, we observe that states at different levels of restructuring display very different R&D expenditure levels. The states with the lowest levels of restructuring, i.e., ones where investigations are ongoing or orders are pending, suffer the most. High deregulation states where restructuring laws have been passed by the legislature, have low but stable levels of R&D. This foreshadows the fact that it may not be restructuring policies per se, but, rather, the uncertainties associated with the process that adversely affect R&D spending.

In addition to the above dummies, other important restructuring policies that may affect a firm's R&D behavior are those that are concerned with divestiture and stranded cost recovery. In the selection model (Table 5A), we use a *divestiture dummy* that equals 1 if a state encourages or mandates divestiture of generation assets and equals 0 otherwise, and turns on when legislation outlining the divestiture policies adopted by a state, is passed. We hypothesize that if a state encourages divestiture of generation assets, then utilities in those states will stop R&D activity since a majority of R&D resources were invested in generation-related projects.

Last, we use two dummies to capture stranded cost recovery policies. In the selection model we use a *stranded cost mechanism dummy* that takes the value 1 if a state has a stranded cost recovery policy in place. If such a policy exists, then utilities will be confident that they can recover at least a portion of their stranded costs and will not take a financial hit. This should

²⁶ This is based on EIA's publication "Status of State Electric Industry Restructuring Activity as of February 2004."

mitigate the R&D expenditure decrease to some extent. To explain the impact of this policy on the level of R&D, we construct a different variable (*stranded cost recovery type*) that captures the permitted level of stranded cost recovery. It is conceivable that a utility located in a state that allows one hundred percent recovery through a wire charge, for example, will decrease its R&D budget by less than a utility located in a state where full recovery is not allowed, or where there is uncertainty about the recovery mechanism. During our sample period, 14 states had taken steps to mandate the level of permitted stranded cost recovery and its composition. We generate an indicator variable that takes the value 0 if there is no recovery mechanism in place, 1 if there is discussion about stranded cost recovery but no concrete step has been taken, 2 if a mechanism is in place but full recovery is not guaranteed and is conditional on certain factors being fulfilled,²⁸ and 3 if there is opportunity for full recovery of all stranded costs. Both variables are turned on when stranded cost recovery legislation is enacted (Table 2b)

Competition Variables

To characterize the nature of competition in a state, we use the number of months until retail competition begins and the percentage of customers eligible for retail competition. First, the *number of months until retail competition begins* should affect a firm's R&D spending. Two states may have passed a retail access order in the same year, but one may mandate that retail competition should begin ten years from the order date, while the other may mandate that retail competition begin immediately. Presumably, firms will behave differently in the two situations. Apriori, the effect on research spending is not clear and will depend on a firm's perception of uncertainty, and thus we are agnostic about the direction of this variable. One may argue that as

²⁷ There are two states that had reversal in their deregulation status in 2000. Iowa had started investigations about restructuring in 1996 but stopped the process in 2000. By 1999, Mississippi had restructuring legislation that was pending, but it stopped all activity in 2000

²⁸ The recovery may vary by individual utility and depends on its mitigation efforts, divestiture of generation assets, whether just and reasonable stranded costs can be recoverable if appropriate consumer safeguards related to stranded costs are implemented, or if there is an opportunity to recover prudently incurred stranded costs.

retail access moves closer, the firms will cut back on research because the pressure to reduce prices will adversely affect discretionary spending such as R&D. On the other hand, if such research increases efficiency or decreases cost, then such R&D spending should increase as the threat of competition draws closer.

So far, 23 states have set concrete dates for the phasing in of full retail competition. For states that have not set a date, we assume that they have 180 months (or 15 years) until retail competition begins (i.e., at any point in time, their expected start date is 180 months in the future, unless an act regarding retail access is passed). For the states with a specific start date, this variable is constructed as a difference between the mandated start-date (month and year) of retail competition and the current month and year, i.e., it counts the number of months until the actual start of retail access, and becomes zero once retail access is implemented. Thus, it is bounded below at zero, and bounded above at 180.²⁹ For a summary of the mandated dates, please refer to Table 2c.

Passing a restructuring order, or even mandating the date for the start of retail competition, may not be sufficient to engender effective competition in the market. For example, a state may be deregulated but may lack firms that will compete in the retail market, or only some customers may be eligible to switch to other power providers (at least at the beginning of the restructuring phase). These conditions would lead to low levels of actual competition. To measure this we use the *percent of customers eligible for retail competition*, i.e., the percentage a utility's of customers who are eligible to choose an alternate provider (Malloy and Mohammad, 2000). This is essential to the development of retail energy competition and its maturation because the greater the percentage of eligible customers, the greater the potential competitive threat to the incumbent utility. This is particularly important as research expenditures are

²⁹ Sensitivity analysis shows that the choice of 20 years does not affect the results.

essentially forward looking, and a firm that knows that its entire market will be open to competition a few years down the line may behave very differently from another whose market is fairly protected despite restructuring. Theoretically, the effect of competition on R&D is ambiguous. On one hand, firms may increase their research spending, especially on those projects that directly related to gaining market share or increasing profits. On the other, firms may cut back on R&D if it does not help them gain a competitive advantage. Since R&D was not the core mission of these regulated utilities, we expect the latter effect to dominate, i.e., we expect competition to adversely affect research spending.

Section 3.3: State Characteristics

The move towards restructuring the energy markets was a fairly gradual process. Thus, utilities may have formed a fairly good expectation about the emerging status of restructuring in their home states. Since R&D is a forward looking variable, expectations about future changes in the institutional structure should affect the decision to conduct R&D. We capture this by using a *high electricity price state dummy* that takes the value 1 if the average electricity price per megawatt-hour in the state was greater than the average US price between 1990 and 1996 and takes the value 0 otherwise.³⁰ The state electricity price is a good predictor of the varied status of electricity reform in different states (Ando Palmer, 1998; Sanyal, 2001). Utilities could have made a fairly good prediction about the possibility of restructuring in their states by looking at these prices since higher-priced states had a greater chance of embarking on a restructuring program in an attempt to decrease these rates. We expect this variable to have a negative impact due to the reasons cited above for the deregulation investigation dummy.

³⁰ We choose 1996 as the cutoff date because this variable loses its information content after that year. States such as California began their restructuring in 1996, and this dummy is no longer a good predictor of restructuring due to endogeneity between electricity prices and restructuring policies.

Implicit regulatory pressure and other state characteristics also influence R&D investment decisions by utilities. We use the voting records of state legislators on green issues as a proxy for *regulator nature*. The League of Conservation Voters (LCV) publishes detailed voting records of state senators and legislators on all environmental legislations brought forward in the Senate and Congress. If legislators reflect the preferences of their constituents, then their voting pattern should convey information about the state. Typically, green states have also been pro-active in areas such as R&D and innovation. Thus, we assume that regulators in green states will be pro-R&D and thus may exert pressure on utilities to increase their research spending. We use a three-year moving average for the LCV score (for legislators) of each state.

The *share of coal generation in the state* also captures state preferences, and is constructed as the ratio of electricity generated from coal divided by the total electricity generated in the state. The effect of this variable on R&D can go in either direction. States that generate most of their electricity from coal are big polluters, and therefore regulators may not have much incentive to push utilities to do more research. On the other hand, since these firms pollute much more than others, regulators may choose to placate environmental action groups by having them conduct more research.³¹

Last, we include a *dummy for high R&D states*. Traditionally, six US states, California, Massachusetts, Michigan, New Jersey, New York, and Pennsylvania, have been considered high R&D states (NSF Science & Technology Report, 1993). These states have a high level of private and state funding for R&D, and it stands to reason that this reflects some preference pattern for investing in research. We hypothesize that utilities in such states will, on average, be more likely to invest more in R&D because of both regulator preferences and a greater availability of monetary and non-monetary R&D support.

Section 3.4: Firm Characteristics

The nature and type of firm also affects both the decision to conduct R&D and the magnitude of the research spending. The yearly operating revenue (2000 dollars) of each company is used as a proxy for *firm size*. We expect size to have a positive impact on both the decision to engage in R&D and its magnitude. Firms need a critical minimum scale to reap benefits from research; therefore, small firms will not conduct R&D. Among the firms that choose to invest in R&D, larger firms have more resources at their disposal than their smaller counterparts and will thus invest more.

Utility Type

We use several variables to characterize the nature of the utility. First, we use two variables that show whether electricity generation is an important part of the utility. In the selection model, we use a *distribution firm dummy* to capture the fact that distribution companies rarely perform any R&D. Only firms that are involved in generation conduct research. This dummy is 1 if the share of generated electricity is less than 75 percent of the total electricity sold by the company³² and 0 otherwise. When explaining what determines R&D levels, we use the *share of generation in total electricity sales* to capture the fact that a company that generates more power may invest more in R&D since a large portion of such research expenditure was generation related.

Second, we use a fuel based variable to capture generation technology. The *share of fossil fuel* in the generation mix is used to investigate whether dirtier fossil fuel-based plants conduct more research. If it is true that these utilities conduct more research, it may be the case that they perform the research in order to keep regulators happy, or they are particularly interested in

³¹ In other specifications not reported here, we also included state GSP and the share of electric utilities in the state GSP to capture the wealth of a state and the importance of the electricity sector in the state. Neither were significant.

developing cleaner technologies. A hydro-electric utility rarely does any research as these are traditionally low-technology operations and are less likely to invest in research than are nuclear or fossil fuel companies. Nuclear utilities also conduct little research.

Third, we use the *share of industrial customers* to characterize a firm's exposure to competition. Utilities serve three distinct types of customers – industrial, commercial, and residential. Even before deregulation, new co-generation technology had made it possible for some large industrial customers to supply their own power. The existence of such bypass opportunities pressured some utilities to offer better rates to these customers. In addition, with retail access, this customer segment would be the first to look for alternative suppliers that could give them cheaper rates. Thus, utilities that serve a greater amount of industrial customers would have greater exposure to competition and may be under pressure to lower their rates. Apriori, the effect on R&D is unclear. Firms may invest more in R&D projects that enhance generation efficiency and decrease costs. However, the opposite may happen as well: utilities may decide to cut back on R&D to save money, thereby reducing costs.

Last, we use a *wholesale market participation* variable to capture whether a utility has been participating in the competitive wholesale market. After the introduction of the 1992 EPA Act, utilities could buy and sell power for resale, and rates were usually set by the transacting parties.³³ Customers such as municipalities could shop for power, and this greatly increased the risk for utilities, who found themselves in danger of losing these customers to competitors. This may have put downward pressure on prices, and concern about the bottom line may decrease R&D participation. Hence, we expect a negative coefficient on this variable.

³² For robustness, we have varied the cutoff from 75 to 80, 85, and 90 percent, and this does not make a difference to the results.

Organizational Structure

We also control for the organizational structure of the utility. Some utilities belong to large holding companies, and the budget constraints driving their R&D spending will be different from stand-alone utilities. We use two variables to capture this: *holding company dummy* and the *size of the holding company*. In the selection equation, we use the holding company dummy to control for the fact that a utility within a holding company may have access to greater internal resources, and externalities from its research may be better internalized. Thus, such a firm may be more likely to invest in research. In the level regression, we include the size of the holding company, i.e., the number of firms within the holding company structure. We expect utilities belonging to larger holding companies to invest more resources in R&D for the same reasons stated above.

Last, in the selection equation we use a dummy to control for *pending mergers*. This dummy is 1 from the time mergers are announced until the date they are consummated. Utilities with a merger in the horizon face substantial uncertainty about the nature of the emerging firm. The real options literature suggests that in such a scenario, firms will hold back on investment until the dust settles. Therefore, we expect such firms to put a hold on their research activities, at least temporarily. The next section presents the empirical results, and summary statistics for the estimation sample (with and without zero research expenditures) are presented in Table 3.

³³ The rates were nominally required to be set by the Federal Energy Regulatory Commission (FERC), but, in

Section 4: Empirical Specification and Results

Section 4.1: Did Restructuring Really Affect R&D Spending?

We begin by estimating a simple difference-in-difference model (Bertrand et. al, 2002) to analyze whether restructuring was, indeed, responsible for the significant R&D decline. The equation given below is estimated using the random effects panel data methodology.³⁴

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \lambda Treated_{jt} + \theta(FERC_{1996} * Treated_{jt}) + \sum_{p=1}^p \gamma_p F_{ijt} + \sum_{j=1}^{47} \delta_j S + \sum_{t=1}^9 \gamma_t T + v_i + \varepsilon_{it-1} \quad (1)$$

where: i denotes the firm; j , the state; and t , the year. $\ln RD_{ijt}$ is the log of the firm's real R&D expenditure in a given year, F_{ijt} denotes firm characteristics, S and T denote state and year fixed effects, and $FERC_t$ is the FERC order dummy. The $Treated_{jt}$ dummy takes the value 1 for those states that had a higher than average electricity price before restructuring, i.e., the *high electricity price state dummy* equals 1. We choose this as the treatment group since the primary reason for restructuring was to bring down high electricity prices, and states that had prices higher than the national average were the first targets of restructuring. θ is the difference-in-difference coefficient. Results are presented in Table 4.

We find that after controlling for basic firm and state characteristics, the estimate for θ (the difference-in-difference parameter) is negative (-0.283) and significant at the 5 % level – indicating that restructuring has indeed resulted in a significant decline in R&D spending for these utilities. However, this simple specification fails to capture the various facets of restructuring. After 1996, states differed not only in their pace of deregulation and restructuring but also in terms of effective competition and other market institution variables. Hence, we

practice, FERC allowed the parties involved to choose the rate.

³⁴ The error can be disaggregated into two components: v_i - the random disturbance that varies by firm but not over time ($v_i \sim N(0, \sigma_v^2)$) and ε_{it} - is the idiosyncratic error component ($\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$).

estimate a richer model in Table 5a and 5b to investigate the impact of these variables. The next section presents the detailed two-step model used to analyze R&D spending by utilities.

Section 4.2: Modeling Research Spending by Utilities

R&D data has some peculiar characteristics that are different from other types of data. Typically, small firms do very little R&D, and this results in a high occurrence of zeros in the R&D data. For the econometrician observing the data from the outside, this presents a unique challenge. One is always faced with the question: What do these zeros represent? Do they represent the decision not to conduct any R&D, or are these just zero dollars spent on R&D? Econometrically, these two situations call for different estimation techniques. Although we can use econometric tests to select one over the other, one should also draw from qualitative evidence about firm conduct. For R&D, we believe that the zeros represent decisions not to conduct any R&D. This assertion is based primarily on the qualitative study of how these firms made R&D decisions. We will test this assumption when estimating the empirical models.

We hypothesize that research expenditure decisions are a two-step process. In the first stage, the firm decides whether it should engage in R&D at all, which depends on its expected future benefits from R&D. Benefits in this case do not imply monetary profits alone, but they may include intangible benefits a firm enjoys by keeping regulators happy. The second-level decision involves determining the optimal amount of R&D expenditure that would maximize the present discounted value of the firm's benefit function, subject to various institutional and revenue constraints. In this context, both unobserved heterogeneity and selection issues are a problem. A number of studies have addressed selection issues and unobserved heterogeneity under conditions of strict exogeneity of explanatory variables (Kyriazidou, 1997; Verbeek and Nijman, 1992) and with endogenous regressors (Vella and Verbeek, 1999; Wooldridge, 2002; Fernandez-Val and Vella, 2007). Using methodology developed in the above studies, we first test

whether selection is a concern for our specification.³⁵ We then use the selection correction outlined in Wooldridge (2002) to estimate our two stage model.

Stage 1: Selection Equation

Each year the firm decides to invest in research (y_{it}) if such investment is associated with positive net benefits. The latent unobserved variable is net benefit stream from such research (y_{it}^*). Thus the decision is modeled as:

$$\begin{aligned} y_{it}^* &= x_{it}'\varphi + u_{it}, \quad \text{where } i = 1, \dots, n \text{ and } t = 1, \dots, T_i \\ y_{it} &= 1 \quad \text{if } y_{it}^* > 0, \text{ and } 0 \text{ otherwise} \end{aligned} \quad (2)$$

where: u_{it} is the error term independent of x_{it} , which represents the vector of covariates and comprises state restructuring characteristics, firm attributes, and regulator characteristics.

Although this is a panel specification,³⁶ both, testing for sample selection and consistent estimation of the two-stage model require that we estimate a cross-section probit equation for each year t (Wooldridge, 1995, 2002). We derive the inverse Mills ratio³⁷ (IMR) for each firm i for t years and use it to test and correct for sample selection in the second stage.

In Table 5a we show the combined results derived from a pooled probit regression.³⁸ First, we find that the decision to conduct research depends crucially on the regulatory environment of the state and the nature of the firm. The expectation of deregulation (as proxied by the high electricity price state dummy) has a significant negative impact on the decision to engage in research. This variable may be picking up the effects of uncertainty generated by the expectation of restructuring, and utilities are more likely to disengage themselves from research in such an environment. The legislation enactment dummy is negative and significant as well,

³⁵ The tobit model would be an appropriate model if there was no selection present

³⁶ Following Chamberlain's approach (1980, 1982), we could have used the panel specification, but it would require certain linearity assumptions that may not be warranted for our specification.

³⁷ The inverse Mill's ratio captures the non-selection hazard and is given by $\phi(x_{it}'\beta)/\Phi(x_{it}'\beta)$, where $\phi(\cdot)$ and $\Phi(\cdot)$ denote the PDF and CDF of the standard normal distribution respectively.

implying that as states take the final step towards restructuring, utilities are even less likely to do research (all else constant). Since restructuring is inherently uncertain, utilities may tend to conserve their resources and delay non-essential spending, such as R&D, until the market reaches a stable outcome. Second, stranded cost recovery policies have a significant impact as well. If states have a stranded cost recovery mechanism in place, utilities are more likely to engage in R&D since they are assured of a stable income stream in the future. However, contrary to expectation, having a mandatory divestiture policy does not adversely affect the R&D decision. Third, firms in states that have greener and more pro-active regulators (for example California) are more likely to invest in R&D.

In addition, we find that the size of the firm matters in the R&D decision. Bigger firms with higher operating revenues are more likely to engage in research than smaller firms, supporting the “deep pocket” theory of R&D. Contrary to expectation, a distribution company is as likely to invest in research, all else equal, as a generation company, and a fossil fuel-based utility is not any more likely to engage in research than is a hydro or nuclear firm. Wholesale market participation or pending mergers are not significant determinants of the R&D decision. To summarize, a large utility located in a low-price state with low deregulatory activity, a stranded cost recovery policy, and pro-active regulators has a higher probability of investing in R&D.

Stage 2: Determinants of Positive Total R&D

The second stage is observed, conditional on participation in research activities.³⁹ Here we investigate the factors that influence the magnitude of R&D spending, given that the utility

³⁸ Instead of presenting a table for each year, we run a pooled probit model on the data and present the results for ease of interpretation. The coefficients presented are marginal effects.

³⁹ The exclusion restrictions are satisfied because there are 3 variables in the selection model that are excluded from the levels equation and because we believe that these affect only the decision to conduct R&D and the level of expenditure.

has decided to engage in research. The dependent variable is log of positive R&D spending (in 2000 dollars) and the estimation equation is given by:

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \sum_{k=1}^6 \chi_k M_{jt} + \sum_{l=1}^L \gamma_l F_{ijt} + \sum_{r=1}^R \delta_r S_{jt} + \rho \tilde{\lambda}_{it} + \varepsilon_{jit-1} \quad (3)$$

where: $FERC_{1996}$ is the federal FERC Order dummy; M_{jt} is a vector of institutional variables; F_{ijt} denotes firm specific characteristics, such as size; and S_{jt} are state characteristics (that may vary by year), such as the nature of the regulators.⁴⁰ To account for selection effect, we include IMR ($\tilde{\lambda}_{it}$), which is calculated based on the probit equation of the first stage.^{41,42} Following Wooldridge (2002), we estimate the above equation using a pooled OLS model and correct the errors for heteroscedasticity and for the inclusion of the estimated IMR. We find that the coefficient on the IMR is negative and significant (-0.564), indicating the presence of selection.⁴³ Hence, instead of a tobit specification, a two-stage model is warranted.

Next, we investigate how various restructuring policies have influenced firm R&D behavior. First, we find that the 1996 FERC Order has a significant negative influence on research spending levels, which drop by almost 46.8 percent.⁴⁴ When individual states start investigating how they should proceed with restructuring, it has little impact on R&D. As a state proceeds further along the restructuring path, and passes an order for retail competition, utilities

⁴⁰ 'k', 'L' and 'R' denote the number of institutional variables, firm characteristics, and state characteristics included in the regression respectively.

⁴¹ For calculation of the inverse Mills ratio, see Wooldridge (2002) and Fernandez-Val and Vella (2007).

⁴² We first test whether selection issues are a problem in our specification. We estimate equation 3 using a fixed effects panel data model that accounts for time-invariant heterogeneity and has robust S.E. We find a significant coefficient on the inverse Mills ratio, indicating the presence of selection. This test was first proposed by Nijman and Verbeek (1992) and later modified by Wooldridge (1995). However, the estimates for the other coefficients are inconsistent, as shown in Wooldridge (2002), and thus results are not presented.

⁴³ To capture the time-varying nature of selection, we included the interaction between the IMR and year dummies – however, in all specifications the interactions were insignificant, showing that the selection effect does not vary with time. Thus, the interactions have been dropped from the final model.

⁴⁴ See Halvorsen, R. and Palmquist, P. (1980), and Kennedy, P. (1981) for interpretation of the dummy variable when the dependent variable is in logarithms. The result developed in these papers show that if b is the estimated

increase their research spending 57.8 percent. However, once legislation for retail access is enacted, there is a further decline in R&D by 30.5 percent. We believe that these results can be interpreted in the light of how uncertainties are resolved at each stage. When the federal FERC orders are announced, firms do not have enough information about which way the issue of restructuring will be resolved in their state or about the emerging market landscape. This makes them cut back on research. Once a restructuring order is passed, however, utilities can be fairly confident that the state will eventually move towards full retail access, and this has a positive effect on R&D and may be a correction to the earlier sharp decline. But this increase is temporary, and once legislation is enacted and utilities realize that competition is going to require cost-cutting measures, research spending drops by another 30.5 percent. In aggregate, we find that, even with the increase in R&D after the restructuring order, R&D spending is far below that of the pre-restructuring level.

To study the overall effect of all the restructuring policies, we compute the marginal effect in Table 7. We find that for the mean firm, research spending decreases by 1.9 million dollars when the FERC Orders are enacted, then increases by 1.5 million dollars when an actual retail access order is passed, and declines by 1.1 million dollars when legislation is enacted. So an average utility decreases spending by 1.5 dollars net, or 48 percent, by the time a state finally enacts restructuring legislation.

In line with earlier predictions, increased competition adversely affects R&D spending, and a 1 percent increase in this variable decreases R&D spending by 0.4 percent. In addition, the coefficient on the months till retail competition is positive and significant, implying that R&D declines as the threat of competition draws near. As the retail competition draws one month closer, R&D spending declines by \$7,635, which translates to an annual decline of \$94,455, or 3

coefficient on a dummy variable and $V(b)$ is the estimated variance of b , then an estimate of the percentage impact

percent. Contrary to expectation, the level of stranded cost recovery is not a significant factor in explaining the R&D decline. This may be because simply having a recovery policy in place is enough to guarantee utilities some safety net, and the type and nature of the recovery level becomes unimportant. To summarize, we find that the impact of the main federal and state restructuring policies is an order of magnitude greater than the subsequent policies, such as ones that affect stranded cost recovery.

The next set of variables relate to the financial health of the company and firm characteristics. The effect of size on R&D is positive and both statistically and economically significant. The elasticity of R&D expenditure with respect to size is 1.04, implying constant returns to scale. Also, as holding company size increases by 1 unit, R&D increases by 0.3 percent. R&D spending also increases as generation becomes a primary activity of the utility because a large portion of the R&D budget was spent on generation-related projects. In addition, firms increase their R&D spending when their share of industrial sales increases. Utilities with a larger share of such customers are at a higher risk of losing them after restructuring and may spend more on cost-reducing and efficiency-enhancing types of R&D to gain an edge over competitors. The nature of fuel used by the utility has little influence on R&D.

Last, we find that state characteristics matter, although regulator nature does not. A utility located in a pro-active state does not conduct more research than one located in a more passive state, conditional on the utility having decided to conduct R&D. An important factor that does influence research spending is whether the state had a higher than average electricity price before it actually undertook any formal restructuring activity. As explained earlier, this variable may be thought of as a proxy for the probability of restructuring in a state, and we find that, on average, utilities located in high electricity price states invest 27 percent less in R&D. Finally, we include

of the dummy variable on the variable being explained is given by $100 (\exp(b - V(b)/2) - 1)$.

a dummy for high R&D states, which is positive and significant. On average, electric utilities spend almost 57 percent more on R&D in these pro-research states. Our model predicts that the combined effect of the expectation of restructuring and the formal policies will decrease R&D expenditures by 78.6 percent (Table 7). This result, in conjunction with the difference-in-difference model, shows that there was, indeed, a regime shift when states began restructuring their electricity markets. Thus, firm and state characteristics may have a differential influence on R&D behavior depending on the regime (pre- or post-restructuring). The next section investigates this in greater detail.

Section 4.3: Post-Restructuring Effect

In addition to the average effects described above, we study whether firms and state characteristics affect R&D differently in the pre- and post-restructuring periods since the rules of the game changed once restructuring legislation was enacted. For example, the importance of being within a large holding company structure may become even more important in the post-restructured period when utilities will face greater uncertainty. Being within a large holding company may mitigate some of this uncertainty and may counter the adverse effect of uncertainty on R&D spending. This analysis will add to our understanding of the factors determining R&D under different institutional assumptions. To the best of our knowledge, there are no papers that have analyzed this, and the current analysis will add a missing piece to the literature. To investigate this, we interact the firm and state characteristics with the restructuring legislation enactment dummy in (4) below ($Dum_legis * F_{ijt}$ and $Dum_legis * S_{jt}$). These interactions illustrate whether the firm and state variables behave the same way before and after restructuring.⁴⁵

⁴⁵ The interpretation of the coefficients is as follows: For the pre-restructuring phase, the marginal effects are denoted by the coefficients of the explanatory variables. For the post-restructuring phase, the marginal effects are

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \sum_{k=1}^6 \chi_k M_{jt} + \sum_{l=1}^L \gamma_l F_{ijt} + \sum_{r=1}^R \delta_r S_{jt} + \sum_{l=1}^L \mu_l (Dum_legis * F_{ijt}) + \sum_{r=1}^R \pi_r (Dum_legis * S_{jt}) + \rho \tilde{\lambda}_{it} + \varepsilon_{jit-1} \quad (4)$$

In Table 6 we present the results. In this specification, while there are differences in the firm and state characteristics, all market institution variables remain unchanged in sign and significance.⁴⁶ First, we find that the size of the holding company matters more in the post-restructured regime. This suggests that the holding company structure may provide a safety net in the restructured regime, allowing firms to take risks and invest in more R&D. In addition, after restructuring, a fossil fuel-based utility conducts more R&D than other types of utilities – a result opposite that of the regulated regime. In addition, the fuel composition of a state matters in the deregulated regime, and utilities located in states with a higher share of coal generation perform more R&D. These latter two findings may reflect the same phenomenon. Traditionally, fossil fuel-based utilities are of an older vintage. They are less efficient and face a greater competitive threat from newer plants when a state restructures. The increase in R&D spending may reflect an increase in cost-reducing and efficiency-enhancing types of R&D in an effort to retain their customers and gain an edge over competitors.

Section 5: Conclusion

When an industry transitions from a regulated to a market regime, there is concern about how firms adapt to the changes. Industry structure, firm financial decisions, product offerings, investment, research, and innovation conduct parameters may undergo significant changes. We

denoted by coefficient of variable + coefficient of interaction term if the interaction term is significant. Otherwise, the explanatory variable has the same marginal effects in both periods.

⁴⁶ The combined coefficient for the legislation enactment dummy is - 0.263 (significant at 5 percent), when all the significant interactions are taken into account.

focus on the R&D behavior of regulated utilities transitioning to a competitive market. Earlier literature has focused primarily on the R&D response of competitive industries. However, focusing on how R&D incentives change when competition is introduced to a hitherto regulated industry can provide valuable insights about the drivers of R&D. This paper does just that. We use the deregulation of the US power industry to analyze how the transition from regulation to competition affects the R&D behavior of firms.

The sharp decline in R&D that coincided with the start of the restructuring process has caused some apprehension amongst industry observers and policymakers. Our research concludes that the concern is justified. We find a dramatic decline in R&D at early stages of the restructuring process. The announcement of the FERC Order about retail wheeling alone leads to a 46.8 percent decline in R&D. In addition, the expectation of deregulation leads to a 27 percent drop in R&D, and greater actual competition and the nearing of such competition adversely affect research spending as well. Once the emerging institutional structure becomes clear, however, and an actual restructuring order is passed, R&D spending increases by 57.8 percent, almost reversing the earlier decline. However, we observe further cutbacks in R&D, by 30.5 percent, once restructuring legislation is enacted and the realities of the competitive environment set in. The fact that research expenditures show a large drop in the early stages of restructuring may be due to the uncertainty associated with the emerging institutional and market processes. The upturn in expenditures when an actual policy is passed may signal that the companies are more confident about the nature of the emerging market structure and are willing to begin investing more resources in their research projects. However, this increase is then offset by a further decline in research expenditures once firms are faced with the reality of a competitive market structure. In total, these policies lead to a 78.6 percent drop in R&D. We also find that

there was a regime change when states passed restructuring legislations. Some firm and state characteristics have differential effects in the pre- and post-restructured periods.

In aggregate, our model predicts a permanent drop in R&D expenditures for the electric utility industry due to the restructuring process. From Appendix Figure 4, we observe that the prediction from our model explains the reality quite well. Total R&D expenditures by electric utilities from 2001-2006 show no signs of recovering, and they seem to have stabilized at a much lower level than during the pre-restructuring phase. This paper is a step towards understanding the dynamics of R&D spending when firms transition from a regulated to a market environment. These findings suggest that when the uncertainty is resolved and all the institutional and market mechanisms are in place, R&D spending may recover slightly from its current low level but will not recover to pre-restructuring levels. Overall, the prognosis for research spending by the electric utilities in the restructured era is not optimistic and thus has important implications for the role of the government.

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APPENDIX TABLES

TABLE 1: R&D STATISTICS (ESTIMATION SAMPLE)

Real Total R&D (2000 \$)		
	Entire Sample	Positive R&D Only
Obs.	1663	1291
Mean	3,125,240	4,058,789
Median	787,782	1,510,386
Standard Deviation	7,213,986	7,939,385
Minimum	-306,125	368
Maximum	87,000,000	87,000,000
Entire Sample	Pre-1996	Post-1996
Obs.	935	728
Mean	4,022,568	1,972,766
Median	1,014,766	508,396
Standard Deviation	8,831,271	4,050,817
Minimum	0	-708,550
Maximum	87,000,000	38,300,000

Note: Kruskal-Wallis equality-of-populations rank test rejects null hypothesis of equality for the pre- and post-restructuring R&D statistics.

TABLE 2(A): DEREGULATION /RESTRUCTURING ORDERS

Year	Investigations Ongoing or Order Pending	Order Issued for Retail Access	Legislation Enacted to Implement Retail Access
1994	California		
1995	Connecticut, Louisiana, Vermont, Washington	California	
1996	Alabama, Colorado, Connecticut, Hawaii, Iowa, Kansas, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Virginia, Washington	New York, Vermont	California, New Hampshire, Pennsylvania, Rhode Island, Texas
1997	Alabama, Arizona, Arkansas, Colorado, Connecticut, Dc, Georgia, Hawaii, Idaho, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New Mexico, North Carolina, North Dakota, Oregon, South Carolina, Tennessee, Virginia, Washington, West Virginia, Wisconsin	Illinois, Maryland, New York, Vermont	California, Maine, Massachusetts, Montana, Nevada, New Hampshire, Oklahoma, Pennsylvania, Rhode Island, Texas

TABLE 2(A) CONTINUED

Year	Investigations Ongoing or Order Pending	Order Issued for Retail Access	Legislation Enacted to Implement Retail Access
1998	Alabama, Alaska, Arkansas, Colorado, Delaware, Hawaii, Idaho, Indiana, Iowa, Kansas, Louisiana, Minnesota, Missouri, New Mexico, North Carolina, North Dakota, Oregon, South Carolina, South Dakota, Tennessee, West Virginia	Arizona, DC, Georgia, Illinois, Maryland, Michigan, Mississippi, New Jersey, Vermont, Washington	California, Connecticut, Maine, Massachusetts, Montana, Nevada, New Hampshire, New York, Oklahoma, Pennsylvania, Rhode Island, Texas, Virginia, Wisconsin
1999	Alabama, Alaska, Colorado, Hawaii, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Missouri, North Carolina, North Dakota, South Carolina, South Dakota, Tennessee	Arkansas, DC, Georgia, Michigan, Minnesota, Mississippi, Vermont, Washington	Arizona, California, Connecticut, Delaware, Illinois, Maine, Maryland, Massachusetts, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, West Virginia, Wisconsin
2000	Alabama, Alaska, Colorado, Florida, Hawaii, Idaho, Indiana, Kansas, Kentucky, Louisiana, Missouri, North Carolina, North Dakota, South Dakota, Tennessee	Arkansas, Georgia, South Carolina, Vermont, Washington	Arizona, California, Connecticut, Delaware, DC, Illinois, Maine, Maryland, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, West Virginia, Wisconsin

TABLE 2(B): DATES FOR STRANDED COST RECOVERY ACTS

States with No Date (i.e. No Policy)	Alaska, Colorado, DC, Florida, Hawaii, Indiana, Iowa, Kansas, Kentucky, Louisiana, Minnesota, Missouri, North Carolina, North Dakota, Oregon, South Dakota, Tennessee, Vermont, Washington, West Virginia, Wisconsin
Year	
1996	Alabama, New Hampshire, New York
1997	Arkansas, California, Idaho, Illinois, Maine, Maryland, Massachusetts, Mississippi, Montana, Nevada, New Jersey, Ohio, Oklahoma, Pennsylvania
1998	Arizona, Connecticut, Delaware, Georgia, Rhode Island, South Carolina, Texas
1999	New Mexico, Virginia
2000	Michigan

TABLE 2(C): DATES OF EFFECTIVE RETAIL COMPETITION

State	Restructuring Legislation that introduced competition	Date when the Act was enacted	Date when large customers would get retail access	Date when all customers would get retail access
Arizona	HB 2663	5/1998	1/1/1999	1/2001
Arkansas	-	5/1999	1/1/2002	6/30/2003
California	AB 1890	9/1996	3/1998	3/1998
Connecticut	RB 5005	4/1998	1/2000	7/2000
Delaware	-	8/1999	10/1/1999	10/1/2000
Illinois	HB 362	12/1997	10/1999	5/2002
Maine	LD 1804	5/1997	3/2000	3/2000
Maryland	-	4/1999	7/2000	7/2000
Massachusetts	-	11/1997	3/1/1998	3/1/1998
Michigan	-	3/1999	9/1999	1/1/2002
Montana	SB 390	4/1997	7/1998	7/2002
Nevada	AB 366	7/1997	12/31/1999	12/31/1999
New Hampshire	HB 1392	5/1996	1/1/1998	7/1/1998
New Jersey	-	3/1999	6/1/1999	6/1/1999
New Mexico*	-	9/1997	1/2001	1/2001
New York	-	5/1996	1/1998	1/1998
Ohio	-	6/1999	1/1/2001	1/1/2001
Oklahoma	SB 500	4/1997	7/2002	7/2002
Oregon	-	7/1999	10/1/2001	10/1/2001
Pennsylvania	HB 1509	3/1998	7/1998	1/2000
Rhode Island	-	1/1996	1/1998	1/1998
Texas	-	6/1999	1/2002	1/2002
Virginia	SB 1269	3/1999	1/2002	1/2004

TABLE 3: SUMMARY STATISTICS FOR REGRESSIONS

First Stage: Sample: All Firms, 1990 – 2000 (1663 obs.)				
	Percentage of Ones			
Dependent Variable: Decision to conduct R&D	77.81			
Regressors (Dummies):				
Legislation Enactment Dummy	18.40			
Dummy for High Electricity Price States	42.99			
Stranded Cost Recovery Mechanism Dummy	19.96			
Divestiture Policy Dummy	16.60			
Distribution Company Dummy	19.06			
Pending Merger	11.12			
Regressors (Continuous Variables):	Mean	SD	Min	Max
Log (Real Operating Revenues)	20.110	1.555	14.561	23.235
Share of Fossil Fuel in Total Generation	0.708	0.338	0	1
Wholesale Market Participation	0.270	0/357	0	1
Regulator Nature	51.560	28.794	0	99
Second Stage: Sample: Firms with Positive R&D only, 1990 – 2000 (1288 obs.)				
	Mean	SD	Min	Max
Dependent Variable:				
Log (Real Total R&D Expenditure – 2000 dollars)	13.745	2.283	2.426	18.281
Real Total R&D Expenditure (2000 dollars)	4,58,789	7,939,385	11.314	87,000,000
Regressors (Dummies):				
Percentage of Ones				
FERC Order Dummy	44.00			
Deregulation Investigation Dummy	37.78			
Restructuring Order Dummy	21.88			
Legislation Enactment Dummy	17.53			
Dummy for High Electricity Price States	39.35			
Dummy for High R&D States	23.17			
Regressors (Continuous Variables):	Mean	SD	Min	Max
% Customers Eligible for Retail Comp.	9.622	28.910	0	100
Months Till Start of Retail Competition	153.235	62.891	0	180
Stranded Cost Recovery Type	0.436	0882	0	3
Log(Real Operating Revenues)	20.554	1.192	17.080	23.235
Holding Company Size	3.431	3.509	0	15
Share of Generation in Total Sales	0.684	0.317	0	1
Share of Fossil Fuel in Total Generation	0.746	0.288	0	1
Share of Ind. Sales in Total Elec. Gen.	0.210	0.117	0	0.925
Regulator Nature	50.542	28.338	0	99
Share of Coal Generation in State	0.501	0.298	0	0.985

TABLE 4: DIFFERENCE-IN-DIFFERENCE MODEL
Dependent Variable is Log (Positive Total R&D Expenditure)

Variable	Coefficient (S.E.)
Difference-in-Difference Specification	
FERC Order Dummy (1996)	-1.150 (0.177) ***
Treatment Group	-0.203 (0.236)
FERC Order Dummy* Treatment Group	-0.283 (0.138) **
Firm & State Characteristics	
Log(Real Operating Rev.)	1.233 (0.093) ***
Share of Generation in Total Sales	1.090 (0.272) ***
Share of Fossil Fuel in Total Generation	0.712 (0.325) **
Regression Diagnostics	
σ_u	1.086
σ_e	1.028
Fraction of Variance Due to U_i	0.528
Chi-Square(58)	1112.166
R-Square	0.662
No. of Firms	144
No. of Observations	1294

Note: The estimation equation is given by:

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \lambda Treated_{jt} + \theta(FERC_{1996} * Treated_{jt}) + \sum_{p=1}^p \gamma_p F_{ijt} + \sum_{j=1}^{47} \delta_j S + \sum_{t=1}^9 \gamma_t T + v_i + \varepsilon_{it-1}$$

The estimation technique is a random effects panel data model with year and state fixed effects, and a constant term. Errors are corrected for serial correlation and heteroscedasticity. The panel is unbalanced due to missing observations. Range: 1990-2000. The FERC order dummy takes the value 1 for year ≥ 1996 . The treatment group comprises states with electricity prices that were higher than the national average before 1996. ‘***’, ‘**’ & ‘*’ denote significance at the 1 percent, 5 percent and 10 percent level respectively. All regressors are jointly significant.

TABLE 5A: STAGE 1 - SELECTION EQUATION
 Dependent Variable is a Binary Index Function for Total R&D Expenditure

Variable	Coefficient (S.E.)
Regulatory Variables	
Dummy for High Electricity Price States	-0.132 (0.072) *
Legislation Enactment Dummy	-0.145 (0.063) **
Stranded Cost Recovery Mechanism Dummy	0.084 (0.048) *
Divestiture Policy Dummy	0.017 (0.072)
Regulator Nature	0.002 (0.001) *
Firm Characteristics	
Log (Real Operating Revenues)	0.135 (0.022) ***
Distribution Company Dummy	0.037 (0.054)
Share of Fossil Fuel in Total Generation	0.090 (0.059)
Wholesale Market Participation	-0.053 (0.055)
Pending Merger	-0.104 (0.074)
Constant	-10.750 (1.650) ***
Regression Diagnostics	
Pseudo R-Square	0.320
Wald (Chi-Square, 10)	137.36
Number of Observations	1663

Note: The underlying model is given by:

$$y_{it}^* = x_{it}'\beta + u_{it}, \quad \text{where } i = 1, \dots, n \text{ and } t = 1, \dots, T_i$$

$$y_{it} = 1 \quad \text{if } y_{it}^* > 0, \text{ and } 0 \text{ otherwise}$$

The unobserved latent variable y_{it}^* is the net benefit stream from investing in R&D. y_{it} is the binary indicator showing that R&D is observed only when the latent variable is positive. The results shown are from a pooled probit estimation of the above specification, and explains a firm's decision to conduct R&D ($y_{it}=1$) or refrain from it ($y_{it}=0$). The coefficients presented are marginal effects (except for the constant term). S.E. are robust and clustered by state. '***', '**' & '*' denote significance at the 1 percent, 5 percent and 10 percent level respectively. All regressors are jointly significant. For deriving the actual inverse Mill's ratio used in the second step estimation, the selection equation is estimated separately for each year in our sample using a probit model following Wooldridge (2002). Range: 1990-2000.

TABLE 5B: STAGE 2 - LEVELS EQUATION
 Dependent Variable is Log (Positive Total R&D Expenditure)

Variable	Coefficient (S.E.)	Semi-Elasticity/ Elasticity
Regulatory Variables		
FERC Order Dummy	-0.619 (0.151) ***	-46.76
Deregulation Investigation Dummy	0.045 (0.167)	
Restructuring Order Dummy	0.482 (0.228) **	57.78
Legislation Enactment Dummy	-0.343 (0.207) *	-30.50
% Customers Eligible for Retail Comp.	-0.004 (0.002) *	0.402
Months Till Start of Retail Competition	0.003 (0.001) *	0.384
Stranded Cost Recovery Type	0.106 (0.089)	
Firm Characteristics		
Log(Real Operating Revenues)	1.039 (0.072) ***	1.035
Holding Company Size	0.087 (0.013) ***	0.277
Share of Generation in Total Sales	1.177 (0.221) ***	0.764
Share of Fossil Fuel Generation	-0.027 (0.193)	
Share of Ind. Sales in Total Elec. Gen.	2.099 (0.484) ***	0.451
State Characteristics		
Dummy for High Electricity Price States	-0.303 (0.167) *	-27.19
Regulator Nature	-0.0004 (0.002)	
Share of Coal Generation in State	-0.328 (0.199)	
Dummy for High R&D States	0.848 (0.152) ***	57.66
Selection Correction		
Inverse Mills Ratio (IMR)	-0.564 (0.344) *	
Regression Diagnostics		
R-Square	0.573	
No. of Firms	144	
No. of Observations	1291	

Note: The estimation equation is given by (eqn. 3): $\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \sum_{k=1}^6 \chi_k M_{ijt} + \sum_{l=1}^L \gamma_l F_{ijt} + \sum_{r=1}^R \delta_r S_{ijt} + \rho \tilde{\lambda}_{it} + \varepsilon_{ijt}$

We estimate the selection corrected second stage equation using a pooled OLS model as suggested by Wooldridge (2002). S.E.s are robust and clustered by state, and bootstrapped to correct for the inclusion of first stage estimates of the Mills ratio. The panel is unbalanced with minimum observations per group=2 and max=11. Range: 1990-2000. Column 1 reports the coefficients and column 2 reports the semi-elasticities for the significant dummy variables and elasticities for the significant continuous variables. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 6: POST RESTRUCTURING EFFECT
Dependent Variable is Log (Positive Total R&D Expenditure)

Variable		Variable	
Regulatory Variables		Regulatory Variables	
FERC Order Dummy	-0.576 (0.151) ***	% Customers Eligible for Retail Comp.	0.002 (0.001) *
Deregulation Investigation Dummy	0.021 (0.170)	Months Till Start of Retail Competition	0.003 (0.001) **
Restructuring Order Dummy	0.362 (0.216) *	Stranded Cost Recovery Type	0.052 (0.089)
Legislation Enactment Dummy	-4.217 (2.565) *		
Firm Characteristics		Post-Restructuring Interactions	
Log(Real Operating Revenues)	1.013 (0.076) ***	Log(Real Oper. Rev.) * Legis. Enact. Dum.	0.103 (0.130)
Holding Company Size	0.098 (0.014) ***	Hold. Comp. Size * Legis. Enact. Dum.	0.062 (0.034) *
Share of Generation in Total Sales	1.089 (0.243) ***	Sh. of Gen. in Tot. Sales * Legis. Enact. Dum.	0.239 (0.511)
Share of Fossil Fuel Generation	-0.390 (0.211) *	Sh. of Fossil Fuel Gen. * Legis. Enact. Dum.	1.625 (0.516) ***
Share of Ind. Sales in Total Elec. Gen.	2.270 (0.492) ***	Sh. of Ind. Sales in Tot. Elec. Gen. * Legis. Enact. Dum.	-1.802 (1.507)
State Characteristics		Regulator Nature * Legis. Enact. Dum.	0.001 (0.004)
Regulator Nature	-0.0004 (0.002)	Sh. of Coal Gen. in State* Legis. Enact. Dum.	1.226 (0.494) **
Share of Coal Generation in State	-0.355 (0.222)		
Dummy for High Electricity Price States	-0.294 (0.162) *	Selection Correction	
Dummy for High R&D States	0.769 (0.156) ***	Inverse Mills Ratio (IMR)	-0.729 (0.364) **
Regression Diagnostics			
No. of Observations	1291	Adjusted R-Square	0.584

Note: The estimation equation is given by (eqn. 4 in text). The interaction terms with *Dum_legis* are added to test whether firms behave differently post

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \sum_{k=1}^6 \lambda_k M_{jt} + \sum_{l=1}^L \gamma_l F_{ijt} + \sum_{r=1}^R \delta_r S_{jt} + \sum_{s=1}^S \mu_s (Dum_legis * F_{ijt}) + \sum_{t=1}^T \pi_t (Dum_legis * S_{jt}) + \rho \tilde{\lambda}_a + \varepsilon_{ijt-1}$$

restructuring. Pre-restructuring - marginal effects are the coefficients of the explanatory variables. Post-restructuring: the marginal effects are: coefficient of variable + coefficient of interaction term if the interaction term is significant. Otherwise the explanatory variable has the same marginal effect pre and post restructuring. The estimation methodology is identical to Column 2 Table 5(B). S.E.s are robust and clustered by state, and bootstrapped to correct for the inclusion of first stage estimates of the Mills ratio. The panel is unbalanced with minimum observations per group=2 and max=11. Range: 1990-2000. ‘***’, ‘**’ & ‘*’ denotes significance at 1, 5 and 10 percent respectively.

TABLE 7: MARGINAL EFFECTS

	FERC Order Dummy	Restructuring Order Dummy	Legislation Enactment Dummy	% of Customers Eligible for Retail Comp.	Months Till Start of Retail Comp.*	High Electricity Price State Dummy	Change in R&D (2000 \$)	Change in R&D (%)
Coeff. (dlnRD/dx)	-0.619	0.482	-0.343	-0.004	0.003	-0.303		
Effect on R&D when Continuous Variables Change by 1 unit & Dummies go from 0 to 1								
Mean R&D	(dRD/dx)	-1,935,721	1,507,519	-1,070,634	-1,336	7,871	-948,312	-
Median R&D	(dRD/dx)	-487,938	380,001	-269,876	-337	1,984	-239,042	-619,176

Note: Estimates based on the significant regulatory coefficients from Table 5(B). The estimation equation is given by (eqn. 3 in text):

$$\ln RD_{ijt} = \alpha + \beta FERC_{1996} + \sum_{k=1}^6 \chi_k M_{jt} + \sum_{l=1}^L \gamma_l F_{ijt} + \sum_{r=1}^R \delta_r S_{jt} + \rho \tilde{\lambda}_{it} + \varepsilon_{ijt}$$

All quantities are in 2000 dollars. The mean and median R&D expenditures are for the entire sample.

Thus these are unconditional effects and take into account both, the decision to conduct R&D and the amount. Mean R&D = \$3,125,240 and Median R&D=787,782.

* The dollar figures on this variable are added on as negative numbers in the total since as the retail competition date gets one year closer, R&D declines by that amount.

APPENDIX FIGURES

FIGURE 1: TOTAL R&D (REAL) FOR FOUR INDUSTRIAL SECTORS (1990 – 2000)

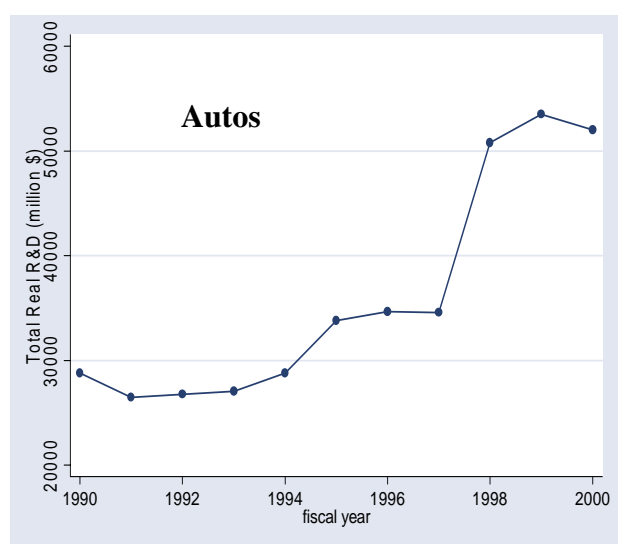
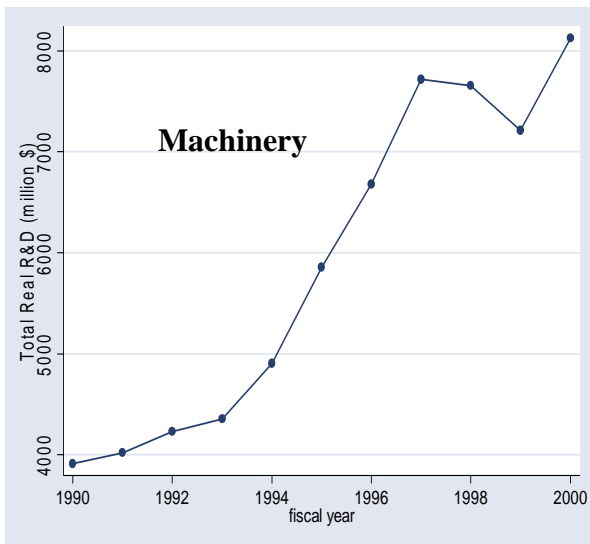
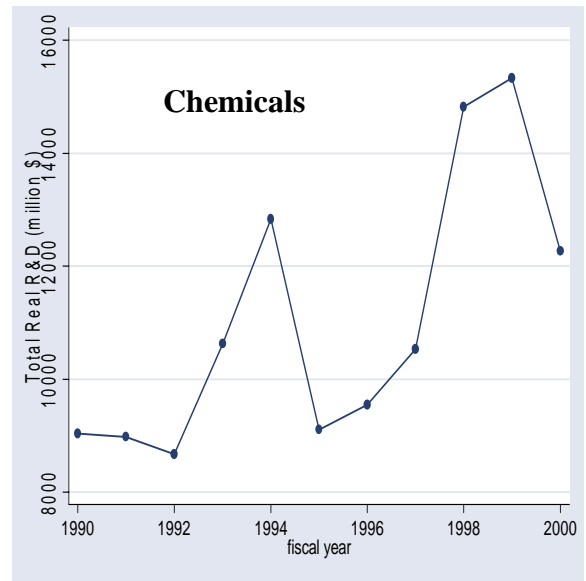
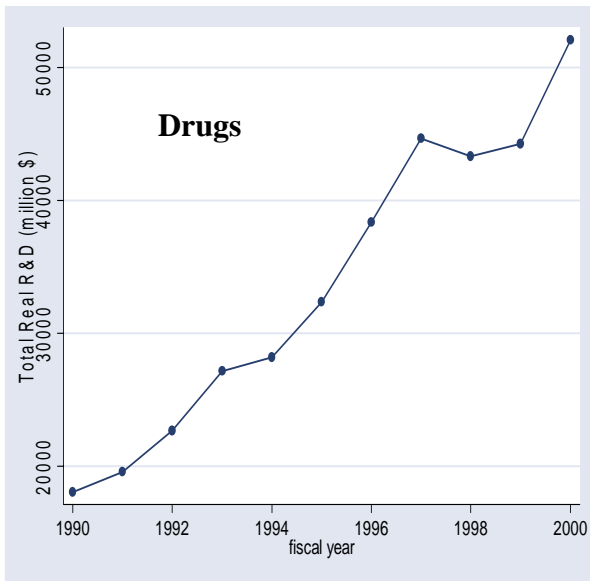


FIGURE 2: CHANGING IOU R&D IN FIFTEEN HIGH R&D STATES

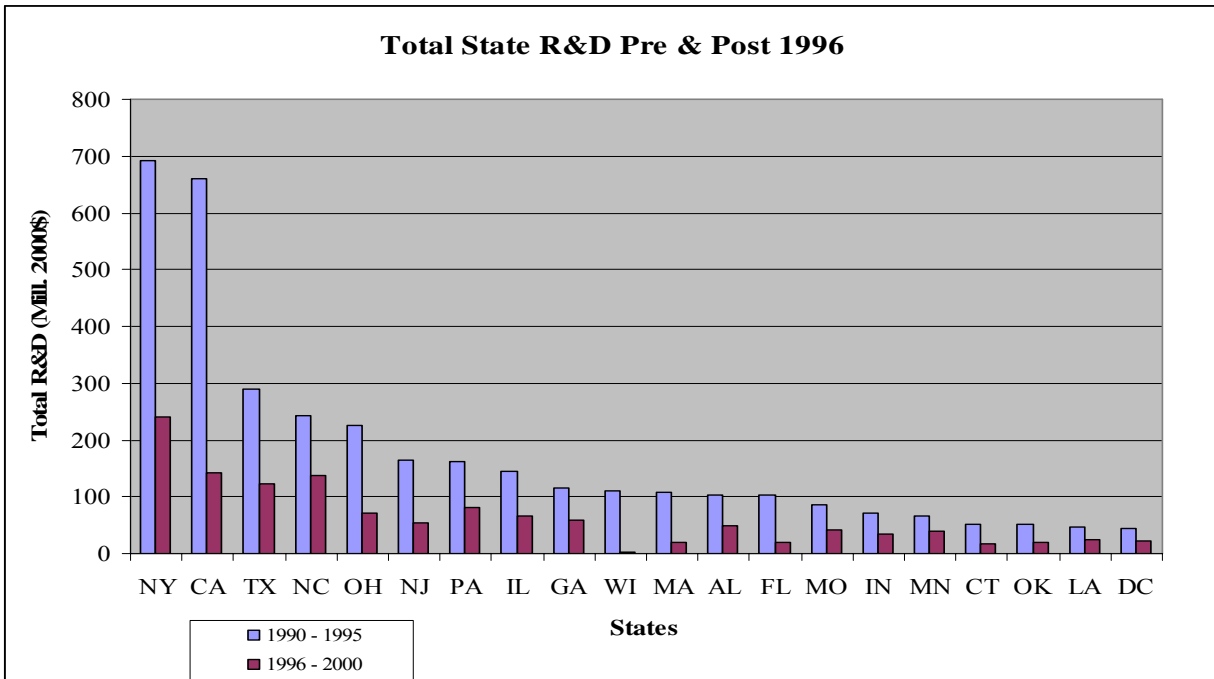


FIGURE 3: TOTAL (REAL) R&D FOR US ELECTRIC UTILITIES IN HIGH MEDIUM & LOW DEREGULATION STATES, 1990 - 2000

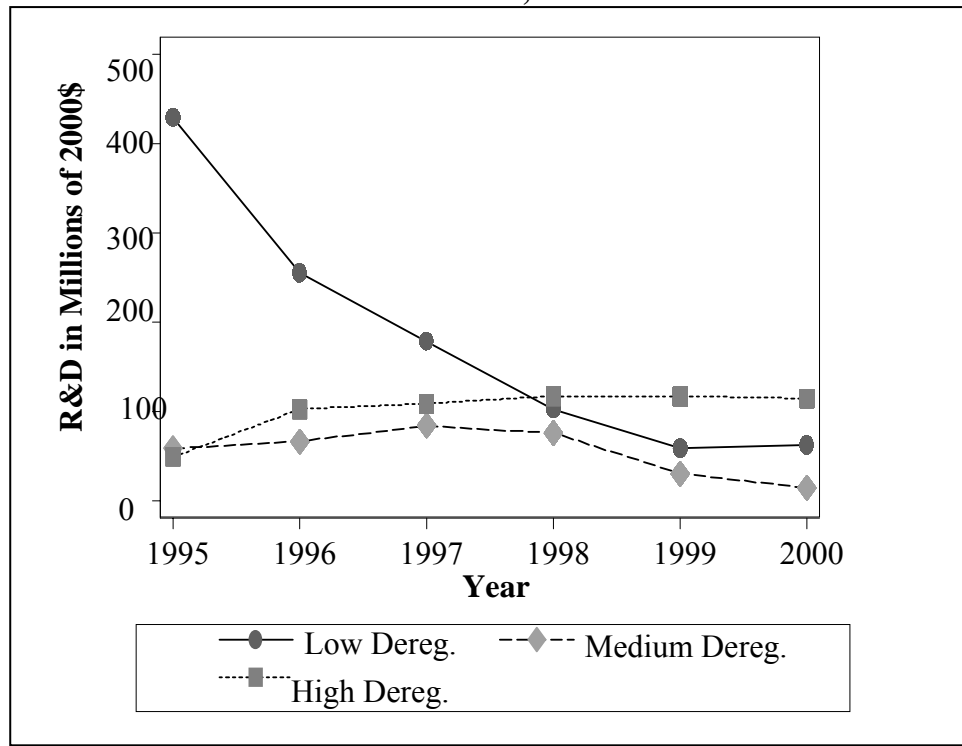


FIGURE 4: ACTUAL & PREDICTED R&D, US ELECTRIC UTILITIES 1990-2006

