R&D Choice in Restructured Industries: In-house v/s Collaborative Research in the US Electricity Industry

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Abstract

This paper studies the impact of market restructuring on the character of research and development (R&D) expenditures. Using a political economy approach, we consider the likely differences in internal and collaborative R&D activities under regulatory and market regimes, and test the predictions on R&D investments by a panel of investor owned electric utilities between 1989 and 1997. We find that spending on internal projects declines with the uncertainty associated with restructuring, but recuperates for companies in states that transition to relative competitive market regimes. Alternatively, external R&D expenditures (outsourced or consortium activities) are initially higher for firms subject to the uncertainty of the policy transition but subsequently decline in restructuring states. Our analysis yields insights into the incentives for firms to perform research internally or to outsource it, and suggests some new guidelines for effective public technology programs.

Keywords: deregulation, electricity industry, research and development, technology policy

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Introduction

In the last quarter century, the deregulation of industries in the United States has brought significant cost savings and product improvements through the diffusion of new technology and business practices.[1] Proponents of restructuring the electricity industry claim that, in common with these other industries, markets for electricity will create radically different business opportunities, yield incentives for creation and diffusion of new technology and bring long-run productivity gains.[2] They point to the rapid deployment of advanced gas generating plants in the initial years of electricity restructuring to illustrate the dynamic benefits of deregulation.

A contrasting view of markets and innovation is suggested by the research and development (R&D) expenditure patterns in the electricity industry. The U.S. General Accounting Office and a variety of scholars have raised alarm over the sharp decline in spending on R&D in the wake of restructuring.[3] R&D programs have been curtailed in all of the research performing sectors of the electricity business: manufacturers, utilities, non-utility generators, and the federal government. Of particular concern is the claim that surviving research activities address only short-term goals rather than more fundamental questions that could lead to important technological advances.

We believe that both arguments are flawed. First, reaching conclusions about either the level or composition of R&D investments from recent expenditures is unwarranted. The confusion and uncertainty over the ultimate structure of the industry would, on its own, suggest a temporary reduction in R&D activities. Second, the incentives to perform R&D in regulated industries have not been examined in any detail. If the regulated sector was relatively intense in performing fundamental research, then the rapid rates of technological innovation in deregulated industries might be transitory as well.[4] Without understanding the motives to conduct research in the regulated regime, we may be jumping to conclusions about changes under restructuring.

Strategic interactions between companies -- the basis for analyses of R&D by Schumpeter and others working in his tradition -- are now relevant to decisions about investments in research and innovation in the electricity industry. But whereas the

[1] Winston, 1998
[2] Joskow, 2003
[3] GAO, 1996, 1998; Morgan & Tierney, 1998; Blumstein, Scheer & Wiel, 1998

Schumpeterian analyses are appropriate in the market regime, they are tangential to the regulatory regime. Regulated monopolies need not fear the loss of their monopoly and (to some degree) face legal profit constraints. They largely lack the motives for investing in R&D in the Schumpeterian world. Alternatively, regulated firms face regulatory oversight. R&D programs by regulated firms are molded to respond to incentives structured by political as well as economic imperatives. Thus, an analysis of changes in patterns of R&D given deregulation rests not the classic Schumpeterian distinction between competition and monopoly but requires instead a political economy foundation.

This paper draws from political economy models to hypothesize about research spending in a regulated regime and compares the predictions to the standard Schumpeterian results. We then formulate an empirical strategy to consider changes in R&D activities by electric utilities. Our data series starts in 1989 and ends in 1997, a year that roughly coincides with the start of the major divestitures of generating capacity by some utilities.[5] The federal government enhanced wholesale market opportunities following passage of the 1992 Energy Policy Act. In subsequent years, some states further restructured the industry in an attempt to promote greater wholesale and retail competition. While the industry structure was effectively transitioning throughout the period, the transitions moved at different rates in different states, allowing a certain amount of cross-sectional, as well as longitudinal variation in institutions and expectations.

All of the utilities in our sample reduced their level of R&D spending during the sample period. The decline is larger for the utilities in states that have undertaken retail restructuring. However, our results suggest that a portion of the drop is indeed transitory. Specifically, we find that the threat of restructuring dramatically reduced R&D spending, but that some of the losses were recouped when markets started operating. As restructuring had barely started by the close of our sample period (and its outcome is perhaps even murkier today), we suspect that the effect measured by our regressions reflects uncertainty about whether restructuring would actually be imposed rather than a response to market conditions versus regulation.

This conclusion is supported by the changes in the composition of R&D performed by companies in states that restructured. The reduction in expenditures was initially far more

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[4] This argument - speculative in any event - applies at most to product innovations in deregulated industries, rather than the productivity gains associated with changes in management and business models.

pronounced for R&D conducted internally by firms than for their consortia activities. Indeed, restructuring firms initially conducted more external R&D than their neighbors in states subject to traditional regulation. By the end of our sample period the tables had turned. Internal R&D expenditures in part recovered for those utilities in states that had restructured. Alternatively, in these same utilities external R&D spending decreased as restructuring plans progressed and the electricity markets started operating.

The different trends for internal and external R&D expenditures suggest that they fulfill different functions. The pattern for internal R&D is consistent with what we expect (and limited empirical evidence supports) about the depressing effect of uncertainty on ordinary private investment[6] and the induced innovation model of research.[7] If uncertainty delays investment and investment induces innovation, then research leading to the innovation would plausibly decline as well. The relative increase in external R&D is also consistent with uncertainty driving the change in expenditure patterns. A stated advantage of research consortia is that they can consider a wider portfolio of projects than can individual firms. Uncertainty about the nature of future desirable technologies increases the value of portfolio strategies today.

The paper is organized as follows. The next section presents a political economy perspective on R&D in a regulated environment and compares the outcome with that expected in a market-mediated Schumpeterian world. Section 2 reviews aspects of electricity industry, (very briefly) discusses changes in its structure, and summarizes the structure of R&D in the industry. In section 3 we present an empirical model, and discuss our econometric strategy and data. Results are contained in section 4. Section 5 considers the implications of these results for government technology policy.

Section 1: R&D in a Regulated Environment

This section proposes hypotheses about the conduct of R&D in a regulated regime and in a market regime, focusing on incentives to conduct research internally or externally. We first

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[5] The data used here are not available after 1997 as the divested generation companies are not subject to the reporting requirements of regulated firms and, like other private firms, do not divulge details of their R&D programs.

[6] See Ishii and Yan (2003). The uncertainty analyzed in both this paper and in Ishii and Yan is about policy decisions -- whether the restructuring plans would in fact be followed through to a market-based industry -- rather than increased price variability anticipated in market regimes. See Macauley (2003) and the discussion in section 1 (D), *infra.*

[7] Binswanger and Ruttan (1978); Newell, Jaffe and Stavins (1999).

sketch out the principal market failures ascribed to the conduct of R&D. We then review conclusions from the political economy literature that provide guidance about utility investments under traditional regulation. Next we apply these principles to derive hypotheses about how investment in R&D in a regulated regime is likely to differ from that of an industry subject to greater market forces. The section concludes with a discussion of the impact of policy uncertainty on R&D investment during a transitional restructuring period.

Section 1.1: Market Failures and the Conduct of R&D

Two characteristics that distinguish R&D from other investment activities of firms are incomplete property rights and asymmetric information. Because successful research produces knowledge, and because knowledge is difficult to fully protect, an inventor may not appropriate the full social benefits of his invention. As a result, less R&D is performed than is socially efficient. Alternatively, if intellectual property can be appropriated, an invention confers an exclusive advantage to the inventor, who can use it not only to increase profits through cost-reductions, but also to preempt the inventions of his competitors. As firms race to patent, more R&D may be performed than is socially optimal.

These apparently divergent conclusions follow from different assumptions about the legal or technological treatment of intellectual property. Most R&D activities suffer from insecure property rights. Unfortunately, establishing security through patents creates other problems. The patent system incorporates a principle of balancing, both for these and other reasons, so that the "rights" established by a patent are intentionally incomplete.[8] Incomplete intellectual property rights exacerbate the market failure caused by asymmetric information. Firms have an incentive to keep information private and avoid resolving asymmetric information even though the privacy strategy complicates transactions in intellectual property and confers a cost on financing.

Both market failures create problems for external or outsourced R&D. The benefits of external research derive primarily from the potential for different scale economies in research and production. The portfolio of research projects suitable for the risks and opportunities in a

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[8] See Reinganum (1989) for a review of this literature. Perhaps the most important balancing attempted by the patent regime is between current and future innovators. Strong patents discourage the conduct of research by competitors in innovations that build on a current patent, and perhaps replace the current innovator's product.

given technical area may be larger than the capabilities of a single firm. The portfolio of applications that result from the research projects may be wider than the interests of a single firm. In both cases, difficulties with licensing technology reduce the benefits of an internal research shop versus some external arrangement.

On the other side of the ledger are at least two disadvantages of outsourcing or consortium research. First, other firms, including non-participants in joint ventures or consortia, are likely to profit from external R&D, and the free-rider problem can be severe in certain forms of R&D. Second, the technology developed in an external program needs to be transferred to the sponsor. Technology transfer is difficult and expensive. Firms that rely on external R&D usually have significant internal research programs as well in order to exploit the external results.[9]

This discussion suggests that in a competitive industry, external and internal R&D programs are not substitutes, but rather address different technological or market challenges. In brief, external programs benefit when the value of portfolio work is high, when technical applications are broad (e.g., generic technology), and when licensing intellectual property is difficult. Internal projects are advantaged when projects are subject to asymmetric information and when formal property rights are inadequate to protect investments. Absent compelling reasons to the contrary, we expect firms to favor an internal solution. Historically, private firms have outsourced very little research in the United States.

Section 1.2: Regulatory Principles

The above "Schumpeterian" analyses are not immediately relevant to a regulated industry. Schumpeter’s monopoly was inherently dynamic, scheming to conquer new worlds while suspiciously guarding its turf. Traditional utilities had no markets to penetrate nor were they threatened by an innovating neighbor. This picture is, of course, too stark, (for a start, some regulated monopolies did conquer new worlds even during the heyday of regulation[10]) but it underscores the need for a different approach to analyze R&D investments of regulated utilities.

Inefficiencies associated with strong property rights depend on the existence of transaction costs, for frictionless licensing obviates the externalities. As usual, Coase was here first.

[9] Dosi (1988)

[10] ATT's activities to forestall competition in microwave technology and the TV industry's delay of cable are examples of dynamic monopolistic activities by regulated firms. In electricity, the utilities' were proactive in their

Regulatory outcomes have been fruitfully analyzed as resulting from public and private interest groups interacting in an electoral and institutional context.[11] Some of the conclusions of that literature are relevant to R&D investments.[12] First, regulators have a core consumer constituency that is satisfied by steady or declining prices. As long as costs are declining, companies can accumulate surpluses. Indeed, in periods of falling costs, regulated firms may largely avoid regulatory reviews, so that they achieve an apparently large degree of independence from regulators. In theory, such firms can act like unregulated monopolists and acquire an incentive to achieve operating efficiency. Rising costs, alternatively, occasion regulatory oversight and reforms[13]. Notwithstanding the absence of formal rate-reviews, evidence exists that the preferences of regulators are important during the years of plenty. Regulated firms strategically distribute surpluses to favor politically important constituents[14]. In addition, regulated firms apparently distribute some of their surpluses towards internal non-profit oriented goals.[15]

The interaction of the market failures discussed above and regulatory oversight suggests that regulated firms will conduct more external to internal R&D relative to market firms. First, the regulated firms care less about appropriating returns from R&D projects. Thus, the competitive bias against out-sourcing and any third-party work in R&D will be weak or absent. Furthermore, information asymmetry will lead regulators both to eschew internal programs and to prefer external work relative to the choices of an unregulated firm.[16] All the potential sources of financing for a regulated firm -- company cash, debt and equity -- are subject to regulatory

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development of nuclear power in order to avoid the threat of a TVA-style federal power authority that would have provided electricity generated from nuclear power plants.

[11] E.g., Stigler (1971); Becker (1983). This literature is reviewed in Joskow and Noll (1994); and Noll (1989).

[12] Joskow, (1974); see Noll (1989), and citations there-in.

[13] Efforts by regulators to maintain price levels has resulted in short-sighted cuts in maintenance as well as other policies that predictably imposed large costs in subsequent years. Troesken (1996); Sweeney (2002).

[14] Labor unions, for example, were a beneficiary of abnormal profits in transportation industries; indeed, much of the cost savings from deregulating transportation industries arose from reduced labor costs. Winston (1998).

[15] In a study of non-profit research universities (analogous in their non-profit status to regulated utilities), Noll (2000) argues that the surplus at a university is distributed according to various academic principles; it supports, among other things, research activities with little value outside the academic institution itself.

[16] Note, however, that informational asymmetry may be less of a problem for regulated firms than for market firms, because the presence of insecure intellectual property does not provide an additional incentive to keep information private. The dislike arises because retained earnings do not provide a solution to the information asymmetry problem. For this reason, we do not expect that the relationship between R&D and current profits would be as strong for regulated forms as for market firms. However, other factors -- in particular the regulators' preference for constant or declining prices -- confuse any empirical test of the point. Our current data do not contain sufficiently detailed financial information to discriminate between a profit or cost relationship.

review. The regulated firm has no fully discretionary funds, and projects need to be equally justified to regulators whatever the source of finance. *Ceteris paribus*, internal conduct of R&D on projects characterized by information asymmetry will be lower than at market-regime firms.[17]

Alternatively, consortia projects and external R&D allow regulators to obtain external verification of project value. Without other means to deal with information asymmetry, the value of transparency is higher in the regulated environment than the market regime, and hence the value of external activities. Thus, in contrast to the market regime, absent compelling reasons to the contrary, we expect regulated firms to favor external research.

While we expect the ratio of external to internal work to be higher in a regulated environment, the work performed externally will not be equivalent in the two regimes. Regulated firms will perform some projects externally that market-regime firms would have done on their own. Projects exist for which the portfolio advantages are not enough to outweigh the appropriability penalty to market firms, while regulated firms, caring less about protecting intellectual property, will favor the portfolio approach. Indeed, regulated firms may choose the external approach for projects that have no portfolio advantages, as long as the cost of transferring technology is small. Thus, a higher level of consortium work in a regulated environment does not necessarily imply that regulated firms are investing in more generic, portfolio, or "precompetitive" work than are the market firms that maintain some consortium activities.

Section 1.3: Uncertainty and the Transition to Deregulation

Modeling uncertainty is beyond the scope of this paper. However, we will summarize here several reasons why uncertainty may have different implications for internal and external R&D investments and for capital, or ordinary investment. Uncertainty over demand or market conditions results in uncertainty over the appropriateness of either the timing of an investment or the choice of technology.[18] [19] As a first approximation, we expect uncertainty to depress R&D

[17] We assume either that the utility is supervised (not in a period of regulatory lag) or the R&D program is a creature of regulators rather than utilities. See the discussion above and also in Part (C)..
[18] See Ishii and Yan (2003), Macauley (2003), Dixit and Pindyck,(1994), Kort (2003?).
[19] If the actual nature of the market is unknown, efficient investment principles dictate a delay in investment. 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).

expenditures. But three considerations work in the opposite direction[20] and suggest different patterns for internal and external R&D. First, research activities in a firm's in-house R&D increase its ability to absorb the research results of others, or its ability to innovate in areas related to, but distinct from, the firm's own research project.[21] Second, R&D can also be a hedge. If research is in part generic (potentially applying to both options), or if there are high fixed costs to research,[22] the hedging characteristic may dominate the incentive to delay. This would increase consortia-type work. 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.

The last two characteristics favor consortium work over internal projects. Just as uncertainty increases the value of a stock portfolio, so it advantages portfolio research. Consortium work is generally not considered adequate to provide absorptive benefits (on the contrary, internal programs may be necessary for firms to take advantage of consortium results); nevertheless, it at least provides information to the firm about available options. Consequently, we expect the ratio of external to internal R&D to increase during periods of uncertainty. We test these hypotheses in the subsequent sections.

Section 2: Regulation and Research in the US Power Industry

For the purposes of this paper we need to provide some background about the factors that contributed to changing the electricity industry, and their implications for the conduct of R&D. This section provides a brief overview in order to explain our modeling choices in the next sections. The history of the restructuring movement has been described in detail elsewhere.[23]

Section 2.1: The Backdrop

The electric utility industry in the United States evolved during the first half of the 20th century to an industry dominated by large, investor-owned utilities that were subject to complex regulatory requirements and that had monopoly franchises. State and federal agencies coexisted,

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[20] A theoretical treatment of some of these issues is presented in Kort (2003?).
[21] Dosi (1988) and references cited therein.
[22] R&D activities tend to be very stable over time, an effect believed due to the high fixed costs of assembling a research staff and the very low value of the staff in any alternate use. See Hall (2002).

with responsibilities defined by two depression-era federal laws[24]. State agencies dominated the day-to-day activities of utilities, subjecting them to rate-of-return regulation, and providing them with growth and investment opportunities and relatively stable profits through the 1960s. During this period the utilities conducted essentially no research. Manufacturers such as General Electric and Westinghouse maintained large R&D organizations and produced a stream of steady improvements in steam-electric generation plants. The high growth rate in demand for electricity accommodated large construction programs and rapid diffusion of new technology.[25]

The outlook for the industry changed in the late 1960s. A combination of interrelated factors[26] caused prices to increase, dissatisfaction on the part of everyone -- politicians, consumer groups and the utilities themselves -- to skyrocket. States and consumer groups demanded that the utilities consider innovations related not exclusively to generation units but rather to the integrated business including electricity use ("demand side programs"), transmission and "green" power sources. The utilities established a consortium, the Electric Power Research Institute (EPRI) to conduct and coordinate research on their behalf. The federal government also established an electricity R&D program that addressed environmental issues, energy conservation, and energy efficiency.[27] Utilities participated in these programs individually, through their consortia efforts and as hosts of joint projects.[28]

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[23] See e.g., Hirsh (1998), Brennan et al (1996; 2002); Joskow (2003).

[24] First, the Federal Power Act reserved to the federal government, through the Federal Power Administration (later, the Federal Regulatory Energy Commission, or FERC), the authority to regulate interstate sales of power. This became defined, through court cases, to encompass any wholesale transaction. Second, the Public Utility Holding Company Act (PUHCA) subjected utilities to a staggering array of reporting requirements, effectively limiting the sale of electricity to a small set of companies that operated entirely within single states and eschewed any operations not directly related to the sale of electricity. More precisely, no company would willingly submit to the PUHCA rules, so that electricity sales became a highly specialized business

[25] Joskow and Rose (1985).

[26] The most important factors were (i) the rise of the environmental movement, with its emphasis on conservation, non-nuclear activities, expensive abatement equipment and legal enforcement procedures; (ii) rapid inflation in construction costs, fuel costs and financing costs; and (iii) cessation of productivity gains from expanding and improving traditional steam-electric boilers.

[27] Nearly all of these goals were investigated in the context of use of fossil and nuclear fuels; that is, nearly all of the dollars went to coal and nuclear projects.

[28] These trends accelerated during the 1980s as more and more generation was produced by independent generators. In California, where the environmental movement was perhaps strongest, the utilities themselves constructed no new generating plants during the 1980s, and by the end of the decade over a quarter of the electricity sold in the state was produced by independent producers and another quarter by generators in other states who sold at wholesale to the states' utilities. The first group are usually called "qualifying facilities" as they qualify for an exemption to the PUHCA regulations. Prominent among the exporters to California was (and is) the Bonneville Power Administration.

The changes provided neither lower costs to consumers, satisfaction to environmental groups, profits to utilities nor peace to regulators. At the end of the 1980s, the federal government, commenced an overhaul of its regulatory structure. Key changes were a revision of PUHCA, allowing widespread entry by non-utilities into electricity generation, and changes in the FERC regulations intended to give the independent producers access to transmission lines. The key date for our analysis is 1992, when the Energy Policy Act became law, and wholesale markets were formally subject to a tariff of market-based prices. Simultaneous with changes in the formal regulatory structure, restructuring the market also commenced. This involved four main components: divestiture[29], merger[30], retail markets and wholesale markets.

Section 2.2: A Summary of Changes in R&D Expenditures in the Power Industry

Real expenditures on R&D by the electric utility industry fell by over forty percent between 1991 and 1996. During the same period, real R&D expenditures by the federal government were flat, while industry as a whole increased spending by 20%. Chart 1 shows these trends, and also shows the divergence between spending on internal and external spending by the utilities. For our entire 1989-1997 sample, external R&D accounts for 63% of all utility R&D, rising from 60% in 1989-1991 to 67% by 1996.[31] Between 1991 and 1996, utility real spending on internal R&D projects fell by half, and on external R&D projects by about a third.

During this period, the Electric Power Research Institute (EPRI) underwent major changes. It has attempted to fill the role of a contract researcher that does individual projects as well as consortia work. It now is supported from three primary activities: its traditional consortia work, the "tailored collaborations" which involve subsets of members, and other sources like license fees and royalties. Following an initial increase between 1991 and 1994, tailored

[29] Divestiture plans required utilities to sell off some of their generating capacity within the state where they planned to continue to offer transmission and retail services. Some companies invested the cash they received from divestiture in a subsidiary that engaged in generation activities in other states or in international markets. This popular arrangement allowed the companies to maintain and continue to profit from their expertise in generation activities and in generation R&D.

[30] Mergers have taken place as companies strived to achieve “critical mass” and expand their operations in order to survive or perhaps become dominant in a competitive environment. Besides the merger of power companies, electric utilities also merged with gas transmission and distribution utilities (convergence mergers). In line with the federal regulatory changes, wholesale markets are now operating in most states. The importance of the markets depends on the extent of both divestitures and mergers, which vary by state. Finally, arrangements for retail competition (still a goal rather than reality) are different both in timing and substance among states.

[31] FERC Form 1 data, assorted years. This data includes all private utilities, which account for 98% of all non-federal R&D in the power sector.

collaboration projects declined through 1997. Between 1994 and 1996, membership contributions to EPRI declined by nearly 30 percent.[32]

For the utilities in our sample, EPRI support represents 78% of their expenditures on external R&D and about 50% of their total R&D expenditures. The share of external R&D accounted for by EPRI rose from 75% to 81% over our sample period. Thus, EPRI fared well relative to other external R&D activities. EPRI's fee policies changed along with its programs. Prior to 1990, membership in EPRI involved, at least in principle, a non-negotiable fee based on the size and sales of the member utility. Contributions increased in flexibility in the 1990s depending on which activities a utility chose to join.[33]

Charts 2 and 3 give more detail about these trends, and illustrate the main phenomena that we investigate in the following sections[34]. We divide the utilities into those whose states still had traditional regulatory structures in 1997 and those that had either restructured or were expected to do so in the near future. Chart 2 illustrates changes in mean R&D intensity (the ratio of R&D expenditures to sales). R&D intensity declines for both internal and external projects, and for utilities subject to traditional regulation and those either anticipating or experiencing restructuring, over the five year period between the passage of EPAct and 1997. By 1997 the reduction in mean R&D intensity was virtually identical for the two sets of utilities. But they had reallocated their expenditures: utilities subject to traditional regulation shifted slightly from external to internal spending, while the utilities undergoing restructuring moved in the opposite direction with a fairly substantial shift from internal to external R&D projects.

Chart 3 presents data only for the utilities in states had either passed restructuring plans or were seriously considering such plans by 1997. We calculate the number of years remaining until the introduction of retail competition based on the year identified in each of the state's

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[32] Funding Summary -EPRI (1997), GAO (1996)

[33] We assume in the econometric model that utilities can adjust their expenditures at the margin. Very few utilities put all their external funding into EPRI prior to 1992, nor participate subsequently at the minimal, non-negotiable level, so our assumption about potential adjustments is reasonable.

[34] These charts are based on all utilities for which the R&D expenditure and other financial information is available from the "Form-1" annual reports that regulated utilities file with the FERC. Although filings are mandatory, data are missing for many of the utilities for some of the years. We present information for the 132 utilities for which we were able to acquire at least some data, and for a subset of 57 utilities for which complete data exist for the 1989-1997 time period. Our intensity statistics are identical to the statistics published by NSF for "Electric gas and sanitary services": 0.3% and 0.2% for 1995 and 1996 respectively, which are the only two years that NSF published RD intensity in this category. National Science Foundation/Division of Science Resources Studies, *Survey of Industrial Research and Development: 1998*, Table A-21.

restructuring plan.[35] The charts show that internal R&D intensity is higher on average for utilities with fewer years until the anticipated start of retail competition, whereas the opposite pattern holds for external R&D intensity.

These trends challenge some presumptions about the conduct of R&D. First, much of the concern about the impact of restructuring on R&D has focused on the reduction in consortia work. This work in general, and EPRI's activities in particular are thought to address "public interest" issues like environmental protection and energy conservation, and to have existed largely because of the demands of regulators. Restructuring, it was thought, would decimate public interest research, deter collaborative efforts and induce utilities to focus on internal, proprietary research. Our analysis in the previous section suggests two competing factors are at work: first, that collaborative, consortium work would in fact be favored in a regulated regime over a market regime, but second, that the collaborative work might have a relative advantage during periods of uncertainty. The trends in Chart 3, alternatively, comport with Schumpeterian analyses, as they suggest a relative increase or at least leveling off in internal (proprietary) R&D activities as the market regime becomes better established.

Chart 4 illustrates the changes in mean real R&D expenditures by year and status. The patterns are in part as described above, but introduce cautionary notes. Overall, the utilities in restructured states do far more R&D than those in states still subject to traditional regulation in the late 1990s. In addition, the discrepancy between these charts and the intensity charts show that the relative sizes of the utilities changed over the five year period. Finally, the distinction between the patterns of expenditures in 1992, especially in the internal R&D category, suggests that differences in the utilities existed prior to the institutional changes that we concentrate on here. In the following sections we attempt to sort out these influences and estimate the importance of the alternative institutions in determining the level and mix of R&D.

Section 3: Layout of the R&D Model & Data & Empirics

Section 3.1: Modeling R&D

[35] Each utility in the balanced panel appears in Chart 3 five times, once for each year from 1993 to 1997. For the unbalanced panel, utilities appear as often as we have data. Thus a company anticipating retail competition in 1999 would appear as a "6" with its 1993 R&D intensity, as a "5" with its 1994 intensity and so on. The chart thus combines data for different years. It is meant merely to be suggestive; the regressions in the subsequent section sort out the year and status effects using fixed effects and other models.

Standard models of R&D investment allow a firm's expenditure decision to depend on firm characteristics, markets conditions and technological opportunities. Our interest is primarily on the impact of political institutions, which enter the standard R&D model in three ways. First, an R&D project yields technology (with uncertainty) in the future. The value of the technology depends on market conditions at the time it is commercialized. Current R&D investment decisions are based on expectations about future market conditions, which depend in part on proposed legal and political institutions. Second, legislative and regulatory actions affect uncertainty over future market conditions. Most importantly, future market rules specified in current legislation or in a legislative proposal may be modified by subsequent state action before the changes are put into practice. Third, legal and political institutions change the relationship between other variables and R&D decisions. In a deregulated market we look to how an R&D project enhances a firm's profit opportunities, which may depend on the demand elasticity of its customers. As is discussed above, the impact of financial factors on R&D levels and portfolios also varies with the extent and nature of regulatory oversight.

Holding market conditions and technological opportunities constant, the key factor that explains differences in investment levels between firms is their size. Larger firms have larger R&D programs. Indeed, R&D intensity -- the ratio of R&D expenditures to sales -- is usually considered a more interesting and relevant indicator of R&D than the level of investment. The relationship of intensity to firm size, however, is itself not constant. R&D can exhibit economies of both scale and scope[36]. We use a flexible functional given below, form to capture the above mentioned effects.

$$RD_{it} = X_{it}^{\delta_1} e^{\delta_2 M_{it} + \delta_3 N_{it} + \delta_4 Z_i + \delta_5 t}$$

X_{it} is the size, in revenues, of firm i in year t. M_{it} is a vector of institutional variables, N_{it} denotes firm specific characteristics (interacted with institutional variables where appropriate) and Z_i comprises individual firm characteristics that vary between individual firms but not by year. 't' is

[36] The former arises when an innovation applies to each unit of output, hence the larger the output of a single firm, the more valuable the innovation. Scope economies follow from the uncertain nature of research. A particular R&D project may result in some innovation, but not necessarily that foreseen at the start of the project. A large firm may nevertheless to take advantage of the innovation in some part of its operation, while a smaller, more specialized firm would have to license the technology (if possible) to a different company. Similarly, a firm large enough to afford a portfolio of projects would have a qualitative, as well as quantitative advantage in using R&D results over a firm with fewer distinct R&D activities. These factors suggest that R&D intensity would increase with firm size. Arguments exist for the reverse as well, and in some industries -- not electric utilities, as is shown below -- the small “agile” firms are more research-intensive.

a time trend. Note that when δ_1 equals 1, R&D intensity is constant across firm size. The exponential relationship between the other independent variables and intensity is appropriate as R&D intensity must be non-negative.[37]

The firms in our sample make two R&D decisions: investments in internal R&D programs and in external R&D programs. The independent variables are expected to have a different impact for the two kinds of investments, although there are common attributes due to oversight by a single utility. For the basic model, we treat these as two independent decision and in subsequent specifications, test the complementarity hypothesis. The following section describes the important explanatory variables used to characterize the empirical model.

Section 3.2: Explanatory Variables

Institutional Variables

During the 1990s, the electric utility industry was in a state of flux. We use three variables that characterize the change within the constraints imposed by the data. First, we use a deregulation index to measure the level of deregulation that a firm faces. During our sample period none of the states had moved to a full retail competition model, but a number initiated restructuring reviews, passed legislation, oversaw utility divestiture and instituted extensive wholesale markets. We include a variable that measures the actual status of deregulation by year.

This index takes the value 0 for “No Activity”, 1 for “Investigations Ongoing or Orders and Legislation Pending”, 2 for “Order Issued For Retail Competition” and 3 for “Legislation Enacted to Implement Retail Access”. This index is zero before 1994. It also takes the value zero for those states that have not taken any action about deregulation. The supplementary data Appendix tables provides data on the status of restructuring in different states in 1998.

The policy changes, of course, were not instantaneous. Any rational player in the market could form an expectation about the status of deregulation in a particular state and tailor its R&D investment accordingly. To capture this forward-looking behavior, we assume that utilities were clued in to possible market changes by 1993, when the passage of EPAct made such plans

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[37] The time trend controls for a range of external factors likely to affect the R&D intensity for all firms: changes in macroeconomic conditions and changes in federal support for R&D. It also controls for synergistic effects in R&D performance between restructured and traditional utilities. This is likely to be more important in the consortia work, but holds for internal research as well: if restructured firms pull out of consortia projects, the projects become less attractive to traditional firms too, who may reduce their participation. In this case we underestimate the direct effect of restructuring on R&D performance.

plausible. We go further and assume that these utilities have perfect expectations over the extent to which the restructured market will have competitive characteristics.[38] We thus include a competition index to capture such behavior.

To measure competition, we use the Retail Energy Deregulation Index 2000, developed by the Center for Advancement of Energy Markets (Malloy, 2000). This is a weighted index of 18 different attributes that the center identifies as the most important characteristics that would enable states to make a transition to a competitive market.[39] The index is not intended as a measure of how competitive the current conditions are, but rather "it is a measure of the progress that the states have made in putting policies in place that are essential to the development of retail energy competition and its maturation."[40] Thus it properly corresponds to forward-looking research expenditures.

Third, we include the number of remaining years that the restructuring plan specifies (or will specify) until some degree of retail competition exists. Like the competition index, this variable allows firms to make investments on the basis of expected future competitive conditions. But to the extent that the equations otherwise control for both restructuring and competition, the variable incorporates two separate dynamic considerations. First, it should correspond to the imminence of competition. In addition, as retail competition is usually one of the final parts of a restructuring plan, if it is about to take place, other parts of restructuring are probably underway.[41]

The second phenomenon correlated to the variable is uncertainty about the credibility and durability of the restructuring plan. States can, and have modified their restructuring regulations

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[38] In initial regressions we also added a dummy term in years after 1992 for utilities in states that were either a 2 or 3 on the deregulatory index in 1997, as well as interacting the dummy with the competition index. This added nothing to the regression, so it was dropped in the specifications reported here.

[39] These attributes are: a deregulation plan; the percent of customers who are eligible to choose a provider; the percent of customers who have already switched by 2000; nature of divestiture of generation; the nature of the default provider; the default provider risk and rates; whether there are competitive standards and a uniform business rule; how stranded cost are calculated and how they are recovered; the billing and metering attributes; the nature of the wholesale market model; the distribution of interconnection resources; regulatory convergence; the existence of performance based pricing for network facilities and commission reengineering. The Supplementary Appendix A provides more details.

[40] Malloy (2000).

[41] For ordinary investments, this might be the more important consideration, as firms schedule their investments to be available when market conditions dictate. The straight timing (given the number of years under consideration) is less critical for R&D, as investments in any event pay off in the future. Thus, we expect that changes in an R&D program based on market conditions that materialize 2, 3, or 4 years hence are muted relative to similar considerations for investments in capacity.

and legislation. We posit that if fewer years remain until the introduction of retail competition, the state is more likely to persist in its restructuring plans; moreover the actual shape of that plan is more apparent. The deregulation index also measures this affect to some degree, although more crudely: as a state moves from considering restructuring (1) to an order (2) and finally legislation (3), the likelihood that the policy proposal will come to fruition increases.

Studies of institutional change need to consider the possibility that the pattern observed in the variables of interest and the institutional change both resulted from other phenomena. One story might be that proactive regulators responded to utilities or utility customers by approving large R&D programs and the same proactive nature led to the restructuring movement. Thus restructured states differed from the states that didn't restructure throughout the time period, and treating them all as equivalent and "traditional" prior to 1993 would be in error and not correcting for this would raise endogeneity concerns. We use two strategies to address the issue.

First, we calculate for each state the likelihood that the state will restructure by 1999. The politics of restructuring have been analyzed by several scholars, and following Ando Palmer (1998), White (1996), Stigler (1971), Noll (1989) and Peltzman (1976), we model the rate of deregulation in the different states and calculate the probability of deregulation, based on state politics, regulatory characteristics and utility characteristics prior to or at the start of the sample period (see Supplementary Appendix B).   This probability is identical for all years and for all utilities within each state[42]. Second, we use regulator characteristics that capture the proactive nature of the state. A couple of variables are used in this regard. The League of Conservation Voter's (LCV) rating of the house and the senate is used to measure the "greenness" of the state[43]. Traditionally, greener states like California have also been at the forefront of both research and regulatory changes. Alternatively, we use an index that measures regulator "pro-activeness" as indicated by state response to 1977 experimental electricity price reforms[44].

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[42]There may be concerns that the same factors that drove states to deregulate and restructure are the ones correlated with R&D spending. Including the predicted probability of deregulation attempts to control such endogeneity problems.

[43] The rating about legislators in a state is from the League of Conservation Voters "national Environmental Scorecard" for 1993. We use both the senate and the house rating and there is no significant difference in the empirical result.

[44] A higher score for PUC nature implies that the regulators are pro-active about the 1977 reforms. The regulatory history of the state is from Anderson (1981, pp. 82-83). It traces out the status of electric rate structure reform in the fifty states and DC in 1977. This reform is characterized by four indicators – generic rate hearings, FEA funded experiments, lifeline or inverted rates and time-of-day rates. We create an indicator variable using this information. A state is given 1 point for implementing each of the above reform mechanisms. So the highest point on the scale is

Firm Variables

In addition to firm size, determinants of R&D include technological opportunities and the characteristics of a firm's customers. We consider variables that correspond to a firm's production and consumer base. The former includes the share of a firm's electricity sales that it generates from steam, nuclear or hydroelectric sources and the share that it purchases from other companies for resale. A majority of these factors do not have a systematic effect on R&D decisions in our sample, and we ultimately dropped them from the regression. As is discussed above, these companies developed R&D to address local issues, integrated electricity concerns, and demand-side factors, while generation R&D has historically been the responsibility of electricity equipment firms.[45]

The utilities in our sample dispose of their electricity among four groups of customers: retail, commercial, industrial, and sales for resale. We included variables indicating the share of total company sales (in megawatts) that each group purchased. In addition to customer shares, we include, for the post-EPAct period, variables that interact the customer share with the restructuring status. For these and other interactions we use the bivariate classification described above, separating utilities that maintained traditional regulation through 1997 from those that had either a regulatory restructuring order or legislation by 1998.

Sales for resale reflect the extent to which a firm participates in the wholesale markets.[46] Thus the variables measure institutional features as well as firm characteristics. Of interest is whether these markets influence R&D in all states or only in states with restructuring plans. We

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4 and the lowest 0. For e.g. California is a 4 on this scale while Alabama is a 0. For more details please refer to Sanyal & Cohen, 2004.

45 We expected that firms with large nuclear investments would have larger R&D programs as the plants are technologically sophisticated. Nearly all of the large utilities have some nuclear capacity, so it is plausible that the engineering effect we anticipated is rolled our estimate of scale economies. Similarly, the nuclear utilities were among those likely to restructure due to poor financial performance, so some of the expected effect may be included in our restructuring estimates. However, including a variable for the share of power produced from nuclear plants has no systematic effect on either R&D investments or on the coefficients of these other variables. In subsequent work we plan to look at generating capacity according to its polluting characteristics, as these may be more relevant to the decisions of companies facing regulation.

46 The amount of power that a company purchases from other firms also measures participation in wholesale markets in the latter part of the sample period. We did not find any statistically consistent pattern in the response of utility RD programs to purchased power shares. We believe that it is due to two factors. For the traditional utilities, this effect, together with the apparent unimportance of production methods, is consistent with R&D programs that are oriented toward consumer activities rather than production. For restructured states, while greater purchases may indicate more market participation, it is balanced against the expected effect of power purchases, that is, that a company with more purchases is less likely to conduct R&D itself.

find no statistical evidence that EPAct alone shifted the relationship between the conduct of R&D and resale activity. Summary statistics for all variables are provided in Appendix Table 1.

Section 3.3: Econometric Issues

Our panel comprises of 9 years and 190 IOUs. It is highly unbalanced due to missing data. Therefore for estimation purposes, we select those utilities that have data for five or more years. The dataset contains some utilities that conduct either no internal or no external R&D[47] in some years, and as well as some firms that conduct no R&D of either type in any year, but are otherwise standard Investor-Owned Utilities.[48] Thus the data suggests that R&D takes on a zero value with some positive probability, but is a continuous random variable over strictly positive values. This poses the question of how to treat the zeros - should they be treated as a selection issue or a censoring problem, since we are ultimately interested only in the firms that conduct positive levels of research.

Theory would suggest that the decision to perform internal or collaborative R&D may be a two-stage process. In the first stage the firm decides whether it should engage in, say internal R&D not. If the answer is yes, then the second level decision involves determining the optimal amount of internal R&D expenditure that would maximize the present discounted value of the firm's ‘profit’ function subject to various institutional and revenue constraints. However we believe that this approach is not warranted in our case because the decision making process by the IOUs do not correspond to this two-step process – rather they interpret zero R&D expenditures as just that, i.e. zero spending and not a decision to disengage from R&D[49].

[47] 27 percent of internal R&D and 12 percent of collaborative R&D are zeroes.

[48] Deleted from the sample are firms that are connected with a single industrial plant, but sometimes sell extra power on the grid and thereby obtain public utility status (e.g., Alcoa) and firms that generate no power at any time in the series but rather purchase either for resale (transmission companies) or final sales. 132 utilities remained from the Class1 and Class2 IOU set.

[49] For a more formal econometric test of whether we could rule out the selection issue in our model, we estimated a Heckman type model with the decision to conduct internal of external R&D in the first stage (a panel data probit model), and in the second stage included a polynomial of predicted probabilities of conducting internal/external R&D in the levels equation. Had selection been an issue, the coefficients would be significant. In our case all the coefficient of the polynomial are insignificant supporting the anecdotal evidence of how of research decisions are made.

Thus we treat the zeros as a censoring problem. Although we are only interested in the positive R&D numbers, discarding the zeroes would bias our results. Thus we estimate a random effects tobit model[50] to account for the left-censored data or a "corner solution outcome" (Wooldridge, 2001)[51]. In our case, we first transformed the dependent variable (R&D expenditure) into logs to better reflect the assumption of a normal distribution. We substitute the zero values with a very small positive number (10^{-6}). Hence, the left censored point is the log of this number (approximately -11.529) and corresponds to the zero value in R&D levels.

Thus our basic equation is given by:

$$\ln RD_{it} = \gamma + \delta_1^{'} \ln X_{it} + \delta_2 M_{kt} + \delta_3 N_{it} + \delta_4^{'} Z_i + \delta_5 t + v_i + \varepsilon_{it}$$

where: M_{jt} and N_{it} are the vector of regressors that vary annually by state and individual firm characteristics respectively. M is a vector of institutional variables, whereas N denotes firm specific characteristics like profit. Z_i comprises individual firm characteristics that vary between individual firms but not by year. 't' is a time trend and γ is the constant term. The error has two components: v_i - the random disturbance that varies by group but not over time ($v_i \sim N(0, \sigma^2_v)$) and ε_{it} - is the idiosyncratic error component ($\varepsilon_{it} \sim N(0, \sigma^2_\varepsilon)$). In the actual estimation process some of the regressors are in logs. This arises from an underlying non-linear model where some variables affect R&D expenditure in an exponential manner while others serve to shift the distribution.

[50] (Refer to Stata Manual) We assume that the random effects, v_i, are normally distributed with zero mean and constant variance σ^2_v, i.e. $N(0, \sigma^2_v)$. Thus we have: $\Pr(y_i \mid x_i) = \int_{-\infty}^{+\infty} \frac{e^{-v_i^2/\sigma_v^2}}{\sqrt{2\pi}\sigma_v} \left(\prod_{t=1}^{n_i} F(x_{it}\beta + v_i) \right) dv_i$

where: $F(\Delta_{it}) = \begin{cases} (-1/\sqrt{2\pi\sigma_\varepsilon}) e^{-(y_{it}-\Delta_{it})^2 /)2\sigma_\varepsilon^2)} & \text{if } y_{it} \text{ is non-censored}, \quad \Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) \quad \text{if } y_{it} \text{ is left-censored} \\ 1-\Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) & \text{if } y_{it} \text{ is right-censored} \end{cases}$

This model is estimated in Stata by Gauss-Hermite quadrature.

[51] The issue here is not that we do not observe data below a certain threshold – as is the case with most censored models. But we are interested in E(y|x, y>0). Therefore a simple OLS model would be inconsistent.

Section 4: Empirical Results

Section 4.1: Empirical Results for the Basic Model (Appendix Tables 2 – 4)

Regression results are contained in Appendix Tables 2 through 7. Qualitatively, the results are consistent across model specifications. The results underscore the different incentives to conduct internal and external research in general and by firms facing different institutional constraints and policy uncertainty. In addition, the regressions provide some evidence about incentives to conduct R&D by regulated and unregulated firms. We address each of these topics below.

Section 4.1.2: Institutional Factors

External R&D

Restructuring in the electricity industry produced different patterns of spending on internal and external research. We consider first how a firm's external R&D program varies with changes in the institutional variables. The coefficient for the deregulation index is positive in all of the regressions. In semi-elasticities vary between 0.42 and 0.62. Evaluated at mean external R&D ($3.05 million), the marginal effect is 1.55, i.e. the progress of a state from one level of deregulation to the next level increases external R&D of an IOU in the state by $1.55 million. The second variable of importance is "years to retail competition," which measures the expected length of the transition period to deregulation. The positive coefficient means, the greater the number of years to competition, the higher the external R&D spending, i.e. if retail competition is closer by 1 year, collaborative R&D declines by $0.43 million. This means that utilities in states with a transition period spent less on external R&D than utilities in states that did not restructure at all.

The competition index and the probability of deregulation are not significant in any specification in Table 2(a). However, in Table 3(a), when interacted with a post-1993 dummy, this has a positive coefficient (Model 3(c)) implying that the probability only mattered once the EPAct was passed in 1992. In this specification, competition has a negative effect on collaborative R&D as would be expected from our earlier discussion. To control for endogeneity issues, i.e. regulator preferences may be such that they induce more R&D and greater deregulation, we include the LCV senate rating and a variable that characterizes the PUC nature. Both are insignificant in all specifications.

Finally, the coefficient for the time trend is negative in all models, and external R&D intensity declines for all utilities over the sample period.[52] However, putting our institutional variables together, we conclude that utilities in states that restructure maintain a lower level of external R&D intensity than those in states that do not. The transition corresponds to a high level of policy uncertainty and concerns about 'ownership' of research products would factor in to R&D decisions. The advantages of portfolio activities that explain firms' preference for external R&D are stronger in the early phases of deregulation but decline as competition becomes a reality. At the end of the transition we do observe investment patterns that are consistent with our expectations about incentives under regulation and competition.

Our competition index may in part be measuring a similar effect. But since it is an amalgam of eighteen different factors – effects may be canceling out each other in the aggregate index – and hence the imprecisely estimated coefficient. Thus in Model 2 (Appendix Table 2), we disaggregate the index into its components and observe some interesting patterns. The greater the portion of market open to retail competition (percent of eligible customers), the higher is the external R&D spending. Thus more future competition provides incentives for greater collaborative research. If the states mandate that a default provider will be assigned to customers, indicating increased effective competition, external R&D increases. Having competitive safeguards, uniform business rules in the market and policies that facilitate interconnection of distributed generation, positively affect external R&D as well, again via the channel of increased potential competition.

However, if a large portion of customers actually switch from the IOUs to other suppliers then, R&D expenditure declines as utilities lose their customer base and investment customer oriented R&D like DSM are not justified. Divestiture of generation also depresses R&D as a large portion of external R&D was invested in generation related activities. Using a fixed charge for stranded cost recovery and performance-based rates (PBR) for distribution facilities decrease external R&D investment probably due to the resource constraint implications that such policies

[52] As the focus of this paper is on relative programs, we treat the time trend here simply as a control. It raises interesting questions about the conduct of R&D across firms.

entail. Last, commission reengineering seems to foster uncertainties that decrease the amount on collaborative work undertaken by the utility[53].

Internal R&D

Internal R&D programs dance to a different beat. The coefficient for the deregulation index is negative, large and significant: as restructuring plans formally progress, firms divest of their internal R&D programs. Evaluated at the mean ($1.84 million), the marginal effect is 1.08, implying that without other mitigating factors a firm's at mean internal R&D level would lose 80 percent of its in-house research. However in our model, this drop is mitigated by the increase in internal research expenditures with increased competition and increased probability of deregulation. We find that a 1 percent increase in competition and the probability of deregulation increases research spending by .083 percent and 22 percent respectively. The trio of institutional variables show that internal R&D intensity increases for firms in states that restructure, on average reaching a higher level than in states that maintain traditional regulatory oversight.

Contrasted with external R&D, regulator characteristics seem to extremely important for the conduct of in-house research (Appendix Table 3(A)). Both the LCV rating and the PUC nature have a strong positive impact, implying that 'greener' and more pro-active regulators preferred utilities to invest more research dollars. The introduction of these variables leave the coefficient on competition unchanged, still suggesting that with regard to internal R&D firms are behaving as they would in a market context. Increased competition seems to portend an R&D 'arms-race'.

However, the competition response seems fairly low when compared to the reaction to the probability of deregulation. Hence, we used the disaggregated competition index in Model 2. Similar to external R&D, in-house research is positive influenced by having a mandated default provider, competitive safeguards in the market, uniform business rules and distributed resources interconnection. The negative coefficients on 'percent of customers switching, divestiture of generation, PBR and commission reengineering are also similar. Major differences between the two types of R&D lie in their response to default provider rates and risk. Both the default provider price risk and rates have a negative coefficient denoting that the uncertainty associated

[53] Two variables that behave counter-intuitively in the estimation are: the default provider price risk and regulatory convergence. The price risk variable should have a negative effect since a fixed rate should increase uncertainty

with such policies are detrimental to internal R&D while leaving collaborative expenditures unaffected. Market based stranded cost calculations and regulatory convergence, also have a positive effect on in-house research.

To make sense of how all these institutional variables fit in, to a larger picture, we derive the total effect on R&D for the four primary variables characterizing restructuring (Table 3(B)). Based on coefficients from Model 3(a), we find that a one standard deviation change in all significant restructuring variables will increase internal R&D by 1$3.6 million (195 percent) while decreasing collaborative research by $0.43 million (14 percent). Thus, in summary restructuring the electric utilities and all the associated changes that go hand-in-hand with such a process seems to foretell a decline in the collaborative part of R&D while giving a boost to in-house proprietarial research.

Section 4.2.2: Scale Economies in the Conduct of R&D

The coefficients for the revenue variables measure whether research intensity increases or decreases with size. A coefficient greater than one is evidence of a form of scale economies: larger firms are more research intensive than smaller firms. As firms become larger, they (or their regulator) increase research more than proportional to the firm's revenues. A coefficient for the revenue variable less than one implies the opposite, while a coefficient of one means that research programs exhibit constant returns to the scale of the firm.

The tobit estimates show that the coefficient for revenues is significantly larger than one (1.8) for the internal R&D case, and that it is less than one (0.87) for external R&D. Internal R&D activities are more valuable either to the larger utilities or to the regulators of larger utilities than to their smaller colleagues, while value of external R&D programs is more closely proportional to the size of a firm. The results are consistent with the restrictions on research activities discussed in sections 1 and 2. The very high coefficient for internal R&D suggests that utilities did not sell technology to each other. Research intensity scale economies can arise for a variety of reasons, but in each case a systematic scale economy conclusion requires that firms do not sell or trade technology. Here, regulatory restrictions and incentives intensified the normal transactional barriers to R&D sales.

The lower coefficient for external R&D confirms the hypothesis that external R&D in the utility industry was not done simply to substitute for in-house research. An increase in sales

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regarding resources.

yields only a modestly greater than proportional increase in spending on external R&D. Larger firms still seem to obtain an advantage over small firms from external R&D, but the benefits are more closely proportional to their size than for the internal R&D programs. A plausible interpretation of the result is that outcomes of external projects are not reserved solely for the sponsoring company, but rather shared among firms. In the electricity industry, research consortia and other external contractors apparently succeeded, as they initially advertised, at providing portfolio benefits or the benefits of projects with large fixed costs to firms of all sizes.

These coefficients do not change in any significant way over the time period examined in this study nor with changes in a utility's governance structure, which suggests that the gross nature of internal and external research activities did not change dramatically during the transition period.[54]

Section 4.2.3: Company Characteristics

Any utility with a high share of hydro generation in its portfolio has weak incentives to conduct research as this is a pretty stable technology where there is not much action. Therefore it is of little surprise that the coefficient is negative across the board. Ratio of purchase to generation has a negative effect on internal R&D for obvious reasons (Appendix Table 4). A firm that purchased most of its power had little incentive to conduct in-house research as it was not generating most of its power and did not have much to gain by this investment.

The regressions provide some illumination about how customer load affects R&D (Appendix Table 4). Firms with a high share of commercial customers relative to residential and industrial customers invest more in collaborative R&D while utilities with a greater share of industrial customer invest more in in-house activities. Restructured firms with a high share of resale customers do more external. This story is consistent with the activities of restructured firms only if we appeal to uncertainty. The increase in external R&D (more than making up for the initial shortfall) by restructured firms supports the Schumpeterian view that R&D is more valuable when customers are demand elastic. Following restructuring, sales-for-resale would be the most competitive part of the electricity business. But these utilities shift from internal into external spending. On net, the effect is positive: they do more R&D in total than equivalent firms with a smaller sale-for-resale share. Last we explore the effect of pending mergers on

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[54] The results lend confidence to the classification of data as internal or external in the Form 1 accounts. We view the coefficients with deep satisfaction.

R&D spending. Neither internal nor external seems to be affected by this variable. In summary, controlling for regulator and firm characteristics, we find that competition spurs internal R&D and ultimately depresses consortia work. In the next section we investigate issues of complementarity between in-house and collaborative R&D and draw inferences about the behavior of research under restructuring if indeed these two are complementary.

Section 4.3: Exploring Complementarities (Appendix Tables 5&6)

The literature on R&D suggests that the two investments are complementary rather than independent. External R&D is likely to be more valuable if a firm has an internal R&D program. Ignoring possible complementarity in the above specifications may lead to an under-estimate of the institutional impact. If the two are complementary, then the impact of competition on internal R&D is larger than we estimate, for it has to compensate for the loss in absorptive value due to the reduction in the external program.

We investigate this issue in two ways. First, we introduce internal research expenditures as a regressor in the external R&D equation (Appendix Table 5). Since there may be some endogeneity concerns while implementing this model, we use the lagged R&D expenditures. Evidence shows that internal R&D increases the absorptive capacity of a firm and hence makes collaborative R&D more valuable. But the impact of collaborative research on a firm's internal R&D projects is at best, weak. Our model supports this finding. We find that lagged external research spending has no effect on internal R&D (Model 5(A)) while the latter has a small but significant impact on the former (Model 5(B)). A one percent change in internal R&D increases collaborative R&D by 0.04 percent.

Further investigation shows that this effect is in fact non-linear – decreasing returns set it after a certain level (as implied by the negative coefficient on the lagged internal R&D squared) (Model 5(C)). In this case the total impact is even smaller. Evaluated at the mean ($3.05 million), a one percent increase in internal spending increases collaborative R&D by .004 percent or by about one hundred and twenty-two thousand dollars at the mean. In addition restructuring activities do not affect this complementarity between the two types pf R&D (Model 5(D)). However, although significant, the magnitude on the lagged internal R&D coefficient is small. We suspect that this arises from using lagged values – the complementarity should be stronger for contemporaneous values.

Endogeneity concerns imply that ideally we should be estimating as instrumental variables model. However, the nonlinearities involved in estimating a panel data instrumental variables model with censored observations, make estimation intractable. Thus, keeping in mind the necessary caveats, we only use the non-censored observations in our panel and estimate a simple IV panel data model (Appendix Table 6). The first stage estimates an equation for internal R&D with external R&D as one of the regressors. Exclusion restriction area satisfied because PUC nature and Share of commercial customers are not included in the first and second stage respectively. From the second stage equation we find that the effect of internal on external R&D is stronger by an order of magnitude from the estimates before. In this model a one percent increase in internal R&D increases collaborative work by .25 percent. Thus all specifications in Appendix Tables 5 and 6 support our absorptive capacity story and this effect remains unchanged with restructuring.

Section 5: Conclusions

In recent years industry analysts have expressed concerns about the apparent decline in R&D expenditures by the electricity companies. Our research points in a more nuanced direction. We find that although deregulation has adversely affected R&D investment by electricity companies, the reduction in spending may be at least partly transitory, although the composition of activities will likely continue to change.

The results reported here emphasize the relationship between characteristics of R&D, incentives to conduct R&D, and the structure of the institutions that conduct and regulate it. The collaborative programs developed in a regulatory environment and appear to remained relevant during the early restructuring period as utilities found the portfolio and hedging benefits that external research provides particularly valuable during the period of policy uncertainty. EPRI's attempt to fulfill a different role as a contract research facility has far more dubious prospects, for, like other external R&D activities, it loosens a firm's control on intellectual property without providing the benefits of traditional public-goods oriented consortia.

Market firms, we predict, are *less* likely to be interested in external research projects that address near-term, now-strategic issues than regulated firms. The decision by EPRI to move in a direction that emphasizes greater property rights protection concentrates on the part of its portfolio probably of least interest to firms in deregulated markets. Alternatively, the restructured companies' preference for consortia activities in areas subject to policy uncertainty remains as strong, or possibly stronger, than for regulated firms.

Our analysis raises some interesting possibilities for technology policy more broadly. The federal government undertakes a broad array of programs intended to promote technological advance. Some state governments, most notably California and New York, have established programs to advance "public interest" technology in electricity in order to substitute for the decline in utility R&D following restructuring. These efforts by both state and federal agencies are what the utilities would consider "external" R&D. Governments favor collaborative efforts and consortia;[55] even single-firm projects (which are rare) require far greater diffusion of results than firms would normally undertake on their own.

Government technology programs attempt to identify projects "in the public interest" (a difficult concept) that firms would be unlikely to fund on their own. They usually seek projects that are technologically risky, require substantial investments, and may have a longer gestation period than industry prefers for R&D investments.[56] Our study suggests a different criteria. We predict that firms will be more enthusiastic about collaborative activities when they face policy uncertainty. Of course, restructuring is an extreme example, but the same incentives may hold for other cases of regulatory uncertainty. Anecdotal evidence suggests that the federal programs are more successful when a research program looks at technology that may address or influence potential regulatory standards.[57] Our results point in the same direction. Thus, it may be useful in general to direct government R&D towards areas characterized more strongly by policy uncertainty than the other criteria commonly applied to such projects. While restructuring perhaps presented an unusual set of uncertainties relevant to R&D programs, other candidates for consortia activities include global climate change issues and transmission policies. Both could have profound implications for the activities, investments and governance structure of the electricity companies, and present opportunities for government to support the type of technology program it has found most successful, with the active cooperation of private firms.

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[55] Cohen (1994)
[56] Branscomb and Keller (1997).
[57] NRC (2001)

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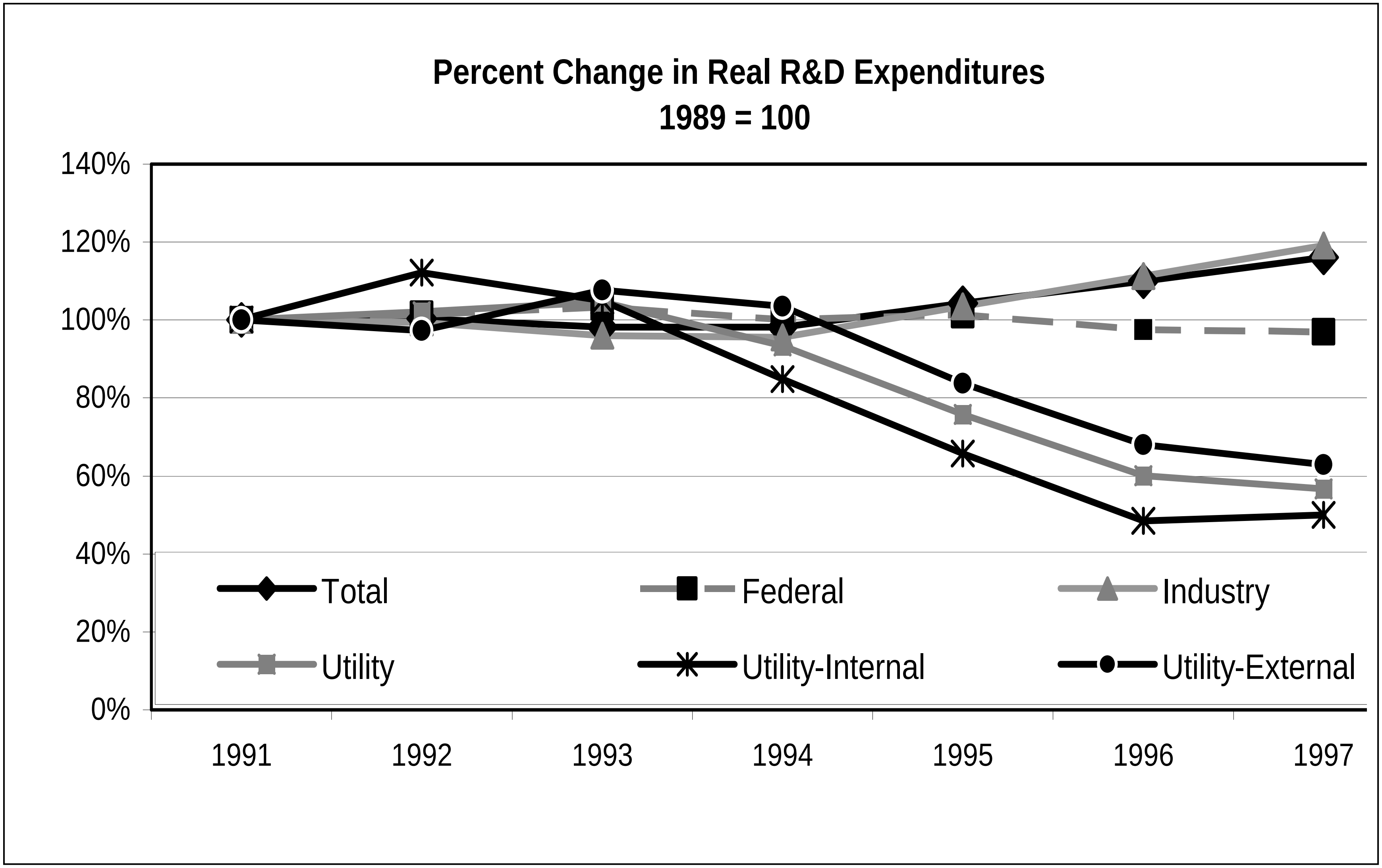

Percent Change in Real R&D Expenditures
1989 = 100
140%
120%
100%
80%
60%
40%
20%
0%
1991
1992
1993
1994
1995
1996
1997
Total
Federal
Industry
Utility
Utility-Internal
Utility-External

Chart 2

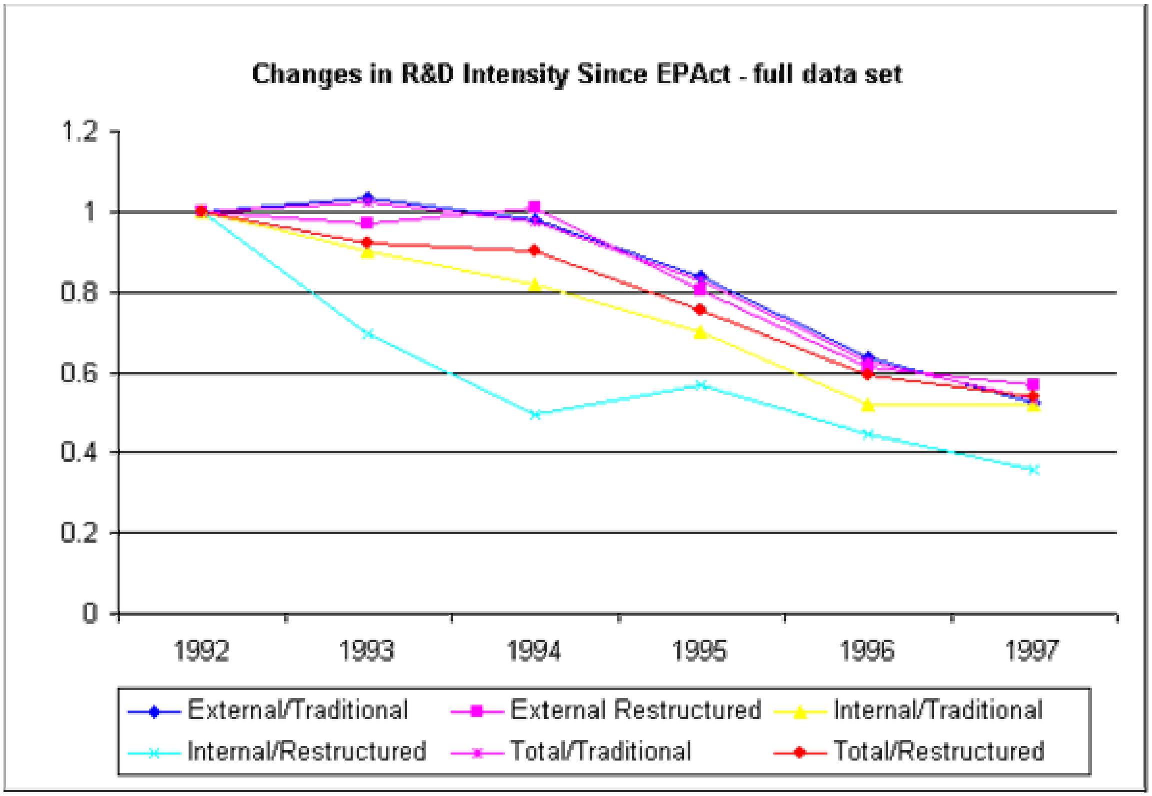


Chart 3

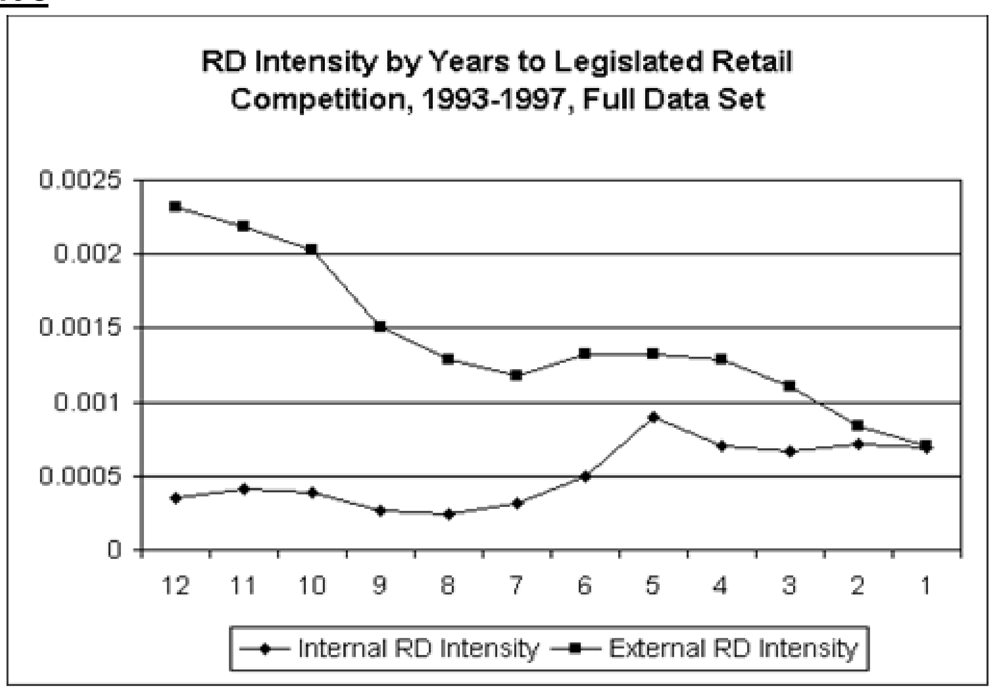


Chart 4

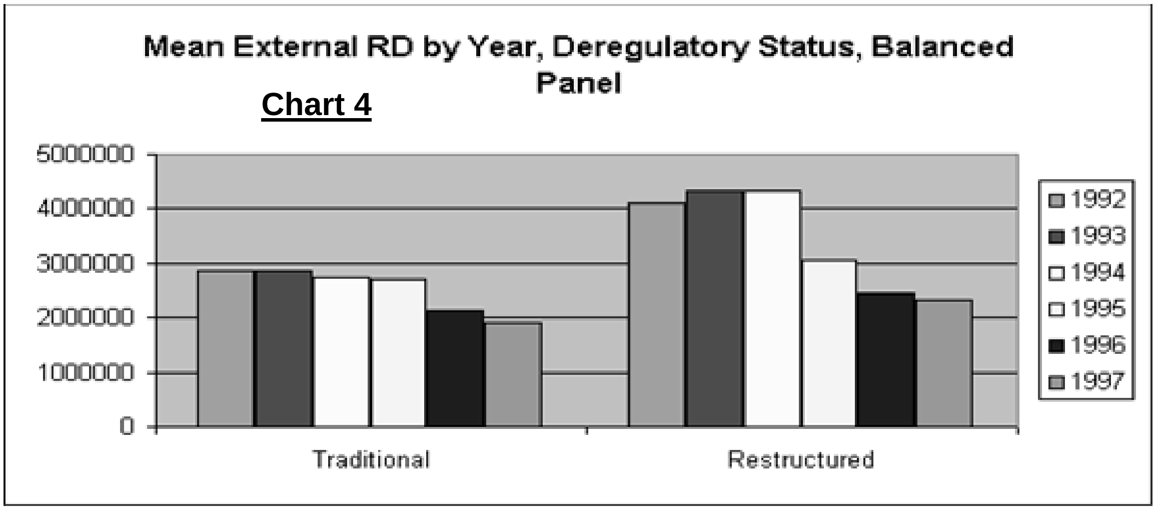


Chart 5

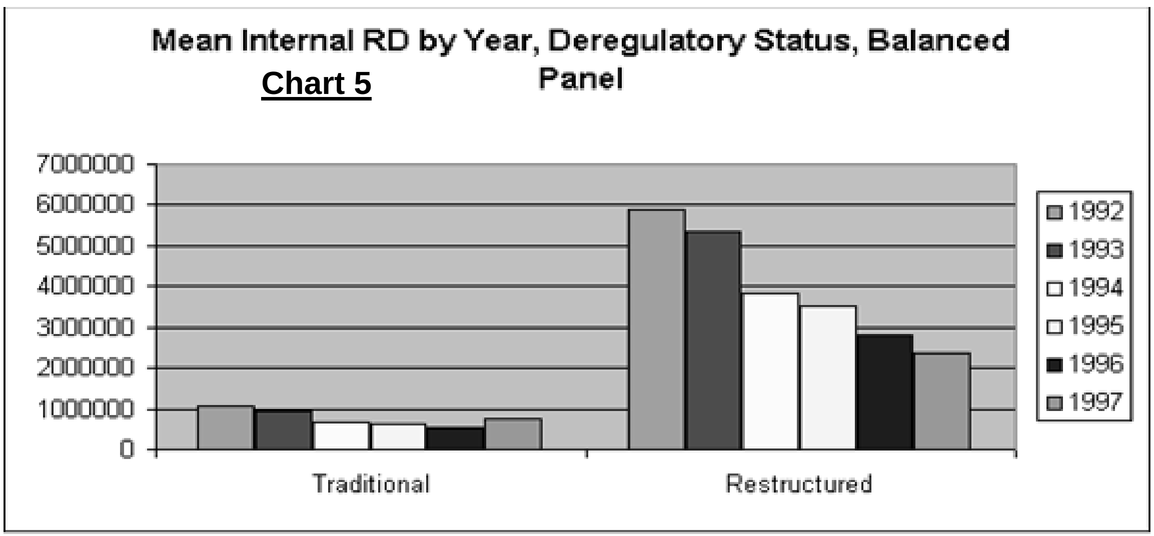
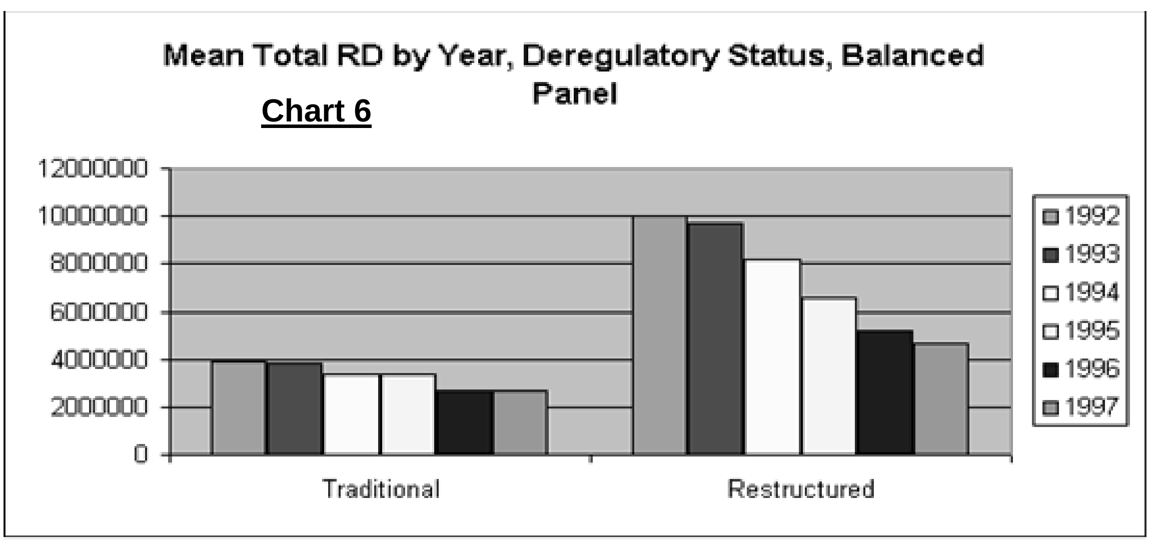


Chart 6



APPENDIX TABLE 2(A): Basic Model & Disaggregated Competition Index

	Model 1		Model 2	
Variable	*Internal R&D*	*External R&D*	*Internal R&D*	*External R&D*
Deregulation Index	-0.589 (0.370) *	0.509 (0.296) *	-0.305 (.374)	0.484 (0.296) *
Probability of Deregulation	12.44 (1.123) **	0.132 (0.866)	17.59 (1.715) **	-0.809 (1.368)
Years Till Start of Retail Competition	-0.034 (0.063)	0.142 (0.059) **	0.022 (0.063)	0.138 (0.050) **
Effective Competition Score	0.045 (0.017) **	-0.002 (0.013)	-	-
Log(Real Operating Revenue)	1.800 (0.286) **	0.868 (0.175) **	0.882 (0.263) **	1.086 (0.188) **
Share of Hydro in Total Electricity Generation	-10.34 (1.801) **	-0.818 (1.142)	2.134 (1.663)	-10.84 (1.126) **
Purchase to Generation Ratio	-0.344 (1.299)	-0.988 (1.069)	-0.167 (1.369)	-0.365 (1.057)
Percentage of Eligible Customers	-	-	0.579 (0.444)	2.171 (0.357) **
Percent Customers Switching	-	-	-0.896 (0.541) *	-3.015 (0.438) **
Divestiture of Generation	-	-	-1.444 (0.219) **	-1.045 (0.145) **
Default Provider	-	-	0.828 (0.309) **	0.766 (0.256) **
Default Provider Price Risk	-	-	-0.271 (0.084) **	0.154 (0.071) **
Default Provider Rates	-	-	-0.586 (0.266) **	0.298 (0.220)
Competitive Standards	-	-	1.047 (0.287) **	1.181 (0.234) **
Uniform Business Rule	-	-	1.326 (0.466) **	2.195 (0.398) **
Stranded Cost Calculation	-	-	1.231 (0.757) *	0.474 (0.512)
Stranded Cost Implementation	-	-	0.119 (0.503)	-1.535 (0.434) **
Billing	-	-	1.203 (0.732) *	-0.894 (0.599)
Metering	-	-	-1.118 (0.757)	0.681 (0.623)
Wholesale Market Model	-	-	-0.169 (0.187)	0.033 (0.123)
Distributed Resources Interconnection	-	-	1.279 (0.545) **	1.925 (0.422) **
Regulatory Convergence	-	-	2.114 (0.684) **	-3.981 (0.554) **
Performance-Based Pricing For Network Facilities	-	-	-1.282 (0.598) **	-2.331 (0.507) **
Commission Re-Engineering	-	-	-5.053 (1.125) **	-5.114 (0.992) **
Observations	948	956	948	956

Note: The estimation technique is a random effects tobit model. The lower limit is set to log(total R&D) = -11.5 which corresponds to total R&D being zero. Censoring occurs for 27% for internal and 12% of external R&D. The panel is unbalanced with min obs. of 5 and a max of 9. The period under consideration is 1989-1997. The models also include a time trend (negative and significant) and a constant (positive and significant). The panel-level variance (rho) is significant in all specifications. Standard errors are in parenthesis. '**' denotes significance at 5 percent and '*' denotes significance at 10 percent.

APPENDIX TABLE 3:Effect of Institutional Factors

	Model 3(A)		Model 3(B)		Model 3(C)	
Variable	***Internal R&D***	***External R&D***	***Internal R&D***	***External R&D***	***Internal R&D***	***External R&D***
Deregulation Index	-0.293 (0.369)	0.552 (0.293) *	-0.545 (0.377)	0.583 (0.288) **	-0.545 (0.367)	0.562 (0.291) **
Probability of Deregulation	4.993 (1.239) **	-0.154 (0.763)	0.826 (1.080)	0.056 (0.818)	-	-
Probability of Dereg. * 1993 Dummy	-	-	-	-	5.619 (1.652) **	2.406 (1.252) **
Years Till Start of Retail Competition	0.039 (0.067)	0.120 (0.050) **	-0.030 (0.064)	0.121 (0.049) **	-0.028 (0.061)	0.120 (0.049) **
Effective Competition Score	0.047 (0.177) **	-0.005 (0.013)	0.030 (0.017) *	-0.006 (0.013)	-0.047 (0.028) *	-0.038 (0.020) **
Log(Real Operating Revenue)	4.160 (0.292) **	1.008 (0.182) **	1.400 (0.243) **	0.937 (0.166) **	1.481 (0.246) **	0.943 (0.166) **
Share of Hydro in Total Electricity Generation	-2.879 (2.189)	-7.895 (2.549) **	-13.90 (1.990) **	-1.740 (1.025) *	-12.79 (1.807) **	-1.626 (1.005) *
Purchase to Generation Ratio	-3.291 (1.678) **	0.673 (1.154)	-2.951 (1.345) **	-0.121 (0.995)	-2.659 (1.432) *	-0.232 (0.946)
LCV House Rating	0.183 (0.034) **	0.025 (0.021)	0.116 (0.026) **	0.011 (0.017)	0.095 (0.024) **	-0.226 (0.156)
PUC Nature	-	-	3.300 (0.268) **	-0.164 (0.165)	3.213 (0.265) **	0.004 (0.016)
Time Trend	-0.510 (0.133) **	-0.187 (0.101) *	-0.344 (0.127) **	-0.187 (0.098) *	-0.473 (0.127) **	-0.229 (0.099) **
Observations	948	956	948	956	948	956

Note: For both the above models, the estimation technique is a random effects tobit model. The lower limit is set to log (total R&D) = -11.5 which corresponds to total R&D being zero. Censoring occurs for 27% for internal and 12% of external R&D. The panel is unbalanced with min obs. of 5 and a max of 9. The period under consideration is 1989-1997. The models also include a constant which is positive and significant. The panel-level variance (rho) is significant in all specifications. Standard Errors are in parenthesis. '**' denotes significance at 5 percent and '*' denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

APPENDIX TABLE 3(B)

Effect of One Standard Deviation Change in the Institutional Environment on Real Internal / External R&D Expenditure
(Evaluated at Mean R&D)

	Deregulation	Probability of Deregulation	Start Date of Retail Comp.	Effective Competition	Total Effect on R&D	Percentage Change in R&D
Internal R&D						
Coefficient	-0.293	4.993 **	0.039	0.047 **		
Standard Deviation	0.665	0.322	4.282	17.452		
Mean RD = $ 1.84 million						
Marginal Effect	**-**	**9.187**	**-**	**0.087**		
1 Standard Deviation Change in Deregulation					-	-
1 Standard Deviation Change in the Probability of Deregulation					2.958	160.76
1 Standard Deviation Change in the Start Date of Retail Competition					-	-
1 Standard Deviation Change in Effective Competition					0.648	35.22
1 Standard Deviation Change in all Significant Variables					3.606	195.97
External R&D						
Coefficient	0.552 *	-0.154	0.120 **	-0.005		
Standard Deviation	0.676	0.321	4.285	17.500		
Mean RD = $ 3.05 million						
Marginal Effect	**1.684**	**-**	**0.366**	**-**		
1 Standard Deviation Change in Deregulation					1.138	37.31
1 Standard Deviation Change in the Probability of Deregulation					-	-
1 Standard Deviation Change in the Start Date of Retail Competition					1.568(-)	-51.41
1 Standard Deviation Change in Effective Competition					-	-
1 Standard Deviation Change in all Significant Variables					-0.430	-14.10

Note: ‘**’ denotes significance at 5 percent and ‘*’ denotes significance at 10 percent.

APPENDIX TABLE 4: Utility Characteristics & Pending Mergers

	Model 4(A)		Model 4(B)		Model 4(C)	
Variable	***Internal R&D***	***External R&D***	***Internal R&D***	***External R&D***	***Internal R&D***	***External R&D***
Deregulation Index	-0.679 (0.368) **	0.415 (0.285)	-0.606 (0.373) **	0.476 (0.287) *	-0.612 (0.377) *	0.574 (0.292) **
Probability of Deregulation	13.09 (1.236) **	-1.625 (0.829) **	12.95 (1.188) **	-0.324 (0.734)	12.32 (1.201) **	-0.079 (0.701)
Years Till Start of Retail Competition	-0.060 (0.063)	0.106 (0.050) **	-0.056 (0.064)	0.131 (0.049) **	-0.022 (0.066)	0.125 (0.051) **
Effective Competition Score	0.048 (0.016) **	-0.002 (0.013)	0.058 (0.019) **	-0.024 (0.014) *	0.048 (0.017) **	-0.007 (0.013)
Log(Real Operating Revenue)	1.758 (0.262) **	1.318 (0.213) **	1.714 (0.285) **	0.913 (0.172) **	1.773 (0.295) **	0.905 (0.167) **
Share of Hydro in Total Generation	-10.50 (1.818) **	-7.209 (1.212) **	-10.44 (1.874) **	-1.744 (1.034) *	-10.37 (1.803) **	-1.928 (1.010) *
Purchase to Generation Ratio	-0.282 (1.312)	-1.346 (1.130)	-0.061 (1.435)	-0.304 (0.990)	-0.257 (1.365)	0.187 (0.951)
Share of Commercial Customers	3.274 (2.856)	8.365 (2.588) **	4.567 (3.326)	4.985 (2.577) **	-	-
Share of Industrial Customers	5.556 (2.749) **	1.959 (2.618)	6.733 (3.249) **	4.076 (2.391) *	-	-
Resale Share	-	-	2.530 (1.905)	0.700 (1.413)	-	-
Resale Share For Deregulated Firms	-	-	-2.968 (2.645)	5.321 (1.817) **	-	-
Pending Merger Dummy	-	-	-	-	-0.536 (0.657)	0.056 (0.468)
Observations	948	956	948	956	948	956

Note: For both the above models, the estimation technique is a random effects tobit model. The lower limit is set to log (total R&D) = -11.5 which corresponds to total R&D being zero. Censoring occurs for 27% for internal and 12% of external R&D. The panel is unbalanced with min obs. of 5 and a max of 9. The period under consideration is 1989-1997. The models also include a negative and significant time trend and a positive and significant constant. The panel-level variance (rho) is significant in all specifications. Standard Errors are in parenthesis. '**' denotes significance at 5 percent and '*' denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

APPENDIX TABLE 5:Exploring Complementarities Between Internal and External R&D

Dependent Variable	*Log(Internal R&D)*	*Log(External R&D)*		
	Model 6(A)	**Model 6(B)**	**Model 6(C)**	**Model 6(D)**
Log(Lagged External R&D)	-0.025 (0.038)	-	-	-
Log(Lagged Internal R&D)	-	0.041 (0.019) **	0.053 (0.019) **	0.046 (0.021) **
Log(Lagged Internal R&D) Squared	-	-	-0.008 (0.004) **	-0.006 (0.004)
Log(Lagged Internal R&D) * Deregulation Index	-	-	-	0.022 (0.026)
Log(Lagged External R&D) Squared * Deregulation Index	-	-	-	-0.006 (0.004)
Deregulation Index	-0.590 (0.372) *	0.378 (0.282)	0.355 (0.271)	1.255 (0.691) **
Probability of Deregulation	13.33 (1.037) **	-1.350 (0.768) *	-1.075 (0.705) *	-1.065 (0.704)
Years Till Start of Retail Competition	-0.052 (0.064)	0.093 (0.046) **	0.075 (0.045) *	0.075 (0.045) *
Effective Competition Score	0.051 (0.017) **	0.006 (0.012)	-0.002 (0.012)	-0.002 (0.012)
Log(Real Operating Revenue)	1.857 (0.262) **	0.722 (0.205) **	1.047 (0.197) **	1.057 (0.197) **
Sh. of Hydro in Total Elec. Generation	-10.47 (1.834) **	-1.612 (1.230)	-1.898 (1.012)	-1.875 (1.010) *
Purchase to Generation Ratio	-0.932 (1.334)	0.733 (1.029)	1.734 (0.931) **	1.835 (0.918) **
Time Trend	-0.503 (0.147) **	-0.167 (0.107) **	-0.140 (0.103) **	-0.145 (0.103) **
Observations	816	819	819	819

Note: For both the above models, the estimation technique is a random effects tobit model. The lower limit is set to log (total R&D) = -11.5 which corresponds to total R&D being zero. Censoring occurs for 27% for internal and 12% of external R&D. The panel is unbalanced with min obs. of 5 and a max of 9. The period under consideration is 1989-1997. The models also include a constant which is positive and significant. '**' denotes significance at 5 percent and '*' denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

APPENDIX TABLE 6:Instrumental Variables Regressions

	First Stage	**Second Stage**
Dependent Variable	***Log(Internal R&D)***	***Log(External R&D)***
Log(External R&D)	0.113 (0.049) **	-
Log(Internal R&D) - Instrumented	-	0.258 (0.050) **
Deregulation Index	0.010 (0.110)	0.171 (0.106) *
Probability of Deregulation	-3.525 (1.549) **	-0.208 (0.252)
Years Till Start of Retail Competition	0.008 (0.022)	0.098 (0.018) **
Effective Competition Score	-0.001 (0.005)	0.010 (0.005) **
Log(Real Operating Revenue)	0.996 (0.095) **	0.445 (0.092) **
Share of Hydro in Total Electricity Generation	0.264 (0.725)	-0.310 (0.461)
Purchase to Generation Ratio	-0.602 (0.476)	-0.658 (0.352) *
PUC Nature	1.010 (0.241) **	-
Share of Commercial Customers	-	2.182 (0.563) **
State Fixed Effects	Yes	No
Time Trend	-0.048 (0.040)	-0.198 (0.037) **
R-Square	-	0.288
Observations	958	958

Note: The estimation technique is a panel data instrumental variables model. The estimation sample is identical to the non-censored observations of the tobit model, i.e. this model is run for those firms where both internal and external R&D is positive for a particular year. The panel is unbalanced with min obs. of 5 and a max of 9. The period under consideration is 1989-1997. The models also include a constant which is positive and significant. ‘**’ denotes significance at 5 percent and ‘*’ denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

SUPPLEMENTARY APPENDIX

PART A

Dates of Effective Retail Competition

State	Restructuring Act that introduced competition	Date when the Act was enacted	Date when large or a portion of residential customers would get retail access	Date when all customers would get retail access
Arizona	HB 2663	5/98	1/1/99	1/2001.
California	AB 1890	9/96	-	3/1998
Connecticut	RB 5005	4/98	1/2000	7/2000
Illinois	HB 362	12/97	10/99	5/2002
Maine	LD 1804	5/97	-	3/2000
Maryland	-	12/97	7/2000	7/2000
Massachusetts	-	11/97	-	3/1998
Michigan	-	6/97	3/98	1/2000
Montana	SB 390	4/97	7/98	7/2000.
Nevada	AB 366	7/97	-	12/1999
New Hampshire	HB 1392	5/96	-	7/1998
New Jersey	-	4/97	10/98	7/2000
New York	-	5/96	1/98	-
Oklahoma	SB 500	4/97	-	7/2000
Pennsylvania	HB 1509	12/96	1/99	1/2001
	HB 2286	3/98		1/99
Rhode Island	-	8/96	7/97	7/98
Vermont	-	12/96	1/98	12/1998
Virginia	HB 1172	4/98	1/2002	1/2004

Attributes of the Competition Index

Attribute	Description	Range of Scores	Weight
Deregulation Plan	Has the state adopted a pro-customer choice policy? Is there a detailed plan enabling customer choice?	Detailed Plan -10 General Policy only – 5 No plan or policy – 0	10%
Percentage of Eligible Customers	How much of the market is open to competitors?	Over 75% -10 51 to 75% - 7 1 to 50% - 3, 0 otherwise	5%
Percent Switching	What % of the state's electric customers have actually switched from the traditional utility's service to the services of a different supplier?	50 to 100% - 10 25 to 50% - 5 10 to 25% - 2 2 – 10% - 1, 0 otherwise	10%
Divestiture of Generation	Is the incumbent utility required to divest its electric generation assets?	Required Divestiture– 10 Incentive for Divestiture– 7 Voluntary Divestiture – 3, 0 otherwise	10%
Default Provider	Has the state mandated that a provider will be assigned to customers who do not choose a competitive supplier, or are the consumers required to choose an alternative supplier? If such a default provider is mandated, must the utility be the default provider or can a non-utility company be the default provider?	All customers must switch – 10 Any co. can be default – 7 Only non-utility can be default – 5 Utility is default provider – 0 No policy - 0	8%
Default Provider Price Risk	If a default provider exists, is it required to sell at a firm price or is there provision for an adjustment after the fact?	Fixed price – 10 After the fact Adjustment – minus 10 No action - 0	8%
Default Provider Rates	If a default provider exists, how is the default rate established?	No Default provider – 10 Retail – 7 Wholesale – minus 10 Market & No Action - 0	5%
Competitive Safeguards	Has the state adopted rules that prevent utilities from using market power over distribution facilities to favor their competitive functions (provided by either the utility or its affiliate)?	Complete Prohibition – 10 Corporate Separation – 7 Functional Separation – 5 No Action - 0	10%
Attribute	**Description**	**Range of Scores**	**Weight**

Uniform Business Practices	Has the state adopted uniform business practices for all utilities in the state? Has the state agreed to implement uniform business practices in concert with other states?	Uniform Natonal/Regionsl Standards –10 Statewide Standards (including EDI) – 7 Statewide Standards (no EDI) - 5 Varying Rules Among Cos. – minus 5 No Action - 0	5%
Stranded Cost Calculation	How does the state determine the amount of stranded costs that a utility will be permitted to recover?	Divestiture – 10 Administrative – 5 No Amount Established - 0	3 %
Stranded Cost Implementation	How does the state permit utilities to recover its stranded costs?	Fixed – 10 Varying or Residual & None - 0	3%
Billing	Which billing method has the state adopted? Does the utility send both its own and another provider's bill, or are bills for both services sent by the other provider? Or does each company send its own bill?	Sent By Provider or Marketer Consolidated – 10 Each Sends Its Own Bill – 5 Sent By Utility or No Policy - 0	3%
Metering	Does the state allow metering to be a competitive service provided by a third party?	Yes – 10 No - 0	3%
Wholesale Market Model	Does the state require bilateral contracts or a pool structure for wholesale electric transactions?	Bilateral – 10 Both – 5 Pool or No Action – 0	5%
Distributed Resources Interconnection	Has the state adopted policies to facilitate interconnection of distributed generation to the grid?	Aggressive Action – 10 Some Action – 5 No Action - 0	3%
Regulatory Convergence	Does the state link the restructuring of its electric market to the restructuring of its gas market?	Complete – 10 Some – 5 None - 0	3%
Performance Based Pricing For Network Facilities	Has the state adopted performance-based pricing for distribution facilities?	Yes – 10 Some – 5 None - 0	3%
Commission Reengineering	Has the state comprehensively reformed its internal organization, practices, procedures, and processes to take into account the changing dynamics of regulation in moving from a monopoly model to a customer choice mode?	Yes – 20 Some – 5 None - 0	3%

PART B

Deregulation Model

The deregulation model builds on work by previous authors (primarily Ando and Palmer (1998) and serves as a validation for the deregulation index that we use and generates predicted probabilities of deregulation. It attempts to explain the varied status of electricity reform in different states based on the economic and political environment of the state. Following Ando Palmer (1998), White (1996), Stigler (1971), Noll (1989) and Peltzman (1976), we identify several factors that help explain these differing rates. This model helps us construct the probability of deregulation. This is included in the subsequent R&D model as a measure of a firm's expectations about deregulation status in its home state.

The status of deregulation of the industry in 1998 is the dependent variable and goes from 0 to 3, 0 being "No ongoing activity" to 3 being "Restructuring Legislation Enacted" (Refer to Appendix Table). The independent variables (price, import and export price gap, weighted standard deviation on prices, share of municipal power entities in state, power of industrial and other customer groups, LCV rating) are from 1993 – before EPACT had any significant influence. This is done to avoid potential endogeneity problems. The deregulation model is estimated using an ordered probit model. In the table below we show two alternative specifications.

Deregulation Model

Dependent Variable is Deregulatory Status in 1998

(Standard Errors in Parenthesis)

Variable	1	2	Variable	1	2
Price (1993)	31.94 * (20.73)	34.28 * (19.61)	Share of Munis & Co-ops (1992)	-1.88 ** (0.91)	-1.24 (0.78)
"Import" Price Gap (1993)	-1.23 (26.82)	-12.07 (27.62)	League of Conservation Voter's Rating	0.217 (0.666)	0.35 (0.79)
"Export" Price Gap (1993)	41.50 ** (18.40)	43.02 ** (18.54)	Price Reform History	-	0.07 (0.21)
Weighted Standard Deviation of Price	10.51 (14.76)	8.24 (14.44)	Customer Concentration Index	-	-1.39 (1.84)
Share of Industrial Revenue (1993)	-0.31 (1.64)	-	Stranded Cost (1995) (billions of dollars)	0.009 * (0.005)	0.009 * (0.006)
Log Likelihood	-45.28	-39.53	Obs.	50	47

The coefficient of price is positive and significant at 10 percent and validates the claim that high priced states were the first ones to deregulate. 'Export' price gap is positive and significant implying that the utilities did not strongly opposing the move to retail competition (as opposed to pushing for it) when the “export” price gap was large. The 'import' price gap and weighted standard deviation of price are insignificant. This implies that customers did not have a strong role to play in the deregulation process. This is also borne out by the insignificant coefficient of the customer concentration index and the share of industrial revenues. The coefficient of municipality and cooperative share is significant and negative. This implies that in states where the municipalities and electric co-operatives account for a large amount of power sold, the pace of deregulation has been slow. The environmental group proxy is insignificant, implying that as a pressure group environmental groups did not have much influence on the deregulation process. The amount of stranded cost has a positive and significant (at 10 percent) coefficient implying that states with high stranded costs have a faster pace of deregulation, due to reasons explained previously.