

Powering a Green Progress:
The Effect of Electricity Deregulation on Environmental Research *

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Abstract:

This paper analyzes the impact of changing market structure on environmental research expenditure by investor owned utilities in the US electricity sector for the period 1989-1997. The main finding suggests that after controlling for firm characteristics and the “greenness” of the state, deregulation decreases such R&D expenditure, while effective competition increases it. When these opposing trends are factored in, the empirical model estimates that for a one percent increase in overall market competition, environmental research declines by 1.1 percent. It also finds that environmental regulations like the Clean Air Act, can help stem the decline in environmental research even in the face of market restructuring and competition.

Key Words: Electricity Deregulation, Environmental R&D, Clean Air Act

JEL Classification: O32, L94, L51

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Introduction

Electricity generation is responsible for a significant amount of air pollution¹ in the United States. Seventy percent of all sulfur dioxide emissions, one-third of all nitrogen dioxide emissions and one-third of all greenhouse gas emissions can be attributed to power generation. Deregulation and restructuring in the power market will have important consequences for environmental policy. Some incentive-based programs like the SO₂ Emission Allowance Trading Program could flourish with increased market competition². Current policies on pollution trading are inefficient as states often favor the use of in-state coal rather than low cost alternatives. This inefficiency would be solved post deregulation, as plants would be forced to use the lowest cost option to remain competitive in the market. On the other hand policies regarding ‘social costing’ will suffer a severe blow as companies cut costs to remain competitive and regulators have no instruments to force them to reflect environmental costs in their decisions and prices³. In addition, demand management initiatives may not fare well under competition, depending on the supplier response to competition. With the exception of sulfur dioxide⁴, the direction and role of environmental policy in a competitive electricity market is far from clear⁵.

¹ The main pollutants that are the by-products of power generation are waste discharges and pollutants like sulfur dioxide (SO₂), nitrogen oxides (NO_x) and carbon dioxide (CO₂). Several hazardous air pollutants including mercury are also emitted from coal-fired generation plants. But natural gas generation plants emit virtually no sulfur dioxide and lower NO_x, mercury and other hazardous air pollutants than coal. Natural gas emits less than half the carbon dioxide per kilowatt-hour of electricity generated with coal.

² In this program, coal-fired generation plants receive annual allowances of SO₂ emissions. They can distribute these amongst their own plants according to need, sell to other utilities or save for later use to meet the annual emissions cap.

³ This is a policy that is in use by seven states that requires the electric utilities to estimate the environmental damage that would result from alternative generation technologies and incorporate this damage into the calculation of private cost of generation. Any power plants that the utilities want to cite or contract with must take this into account.

⁴ Title IV of the Clean Air Act Amendments (1990) put a national cap on sulfur dioxide emissions that will be tightened every year. Hence its levels will fall irrespective of the uncertainties in the power industry structure.

⁵ The Clinton Administration’s Comprehensive Electricity Competition Plan (CECP) unveiled by the Department of Energy in 1996 provided some guidelines on the subject. It suggested the replacement of the utility-specific PURPA mandates with a tradable “renewable portfolio standard” (RPS). Under this all power companies would face a nominal requirement to produce some percentage of their power from renewable fuels. But the cap on costs of complying with this requirement has not been specified for fear of high cost of meeting the targets for some plants.

Much depends on the response of the incumbent investor owned utilities (IOUs) and new entrants to the changing industry structure. Even if environmental R&D and abatement efforts remain constant, with lower prices due to competition, demand for electricity may increase, which in turn, would increase emissions. On the other hand competition may spur the adoption of newer and cleaner natural gas plants, leading to decreased pollution. This is where the role of environmental R&D becomes crucial. If the regulators can induce more environmental R&D expenditure from the utilities and other generating firms, then pollution problems from the power generation could be mitigated⁶.

Common wisdom would argue that increased competition would lead firms to cut back on R&D funds directed towards social goals and “public interest” R&D would decline (Hirsch, 1998; Testimony, 1998). Environmental goals and energy conservation would be the biggest losers if R&D efforts were left to market forces. Carl Blumstein (1997) point out that, at least temporarily, R&D spending by utilities has been adversely affected by deregulation. It may even be argued the environmental R&D would suffer more than other forms of research because, unlike generation and transmission research, they do not confer any substantial short-term cost-reduction. The goal of this paper is to analyze how changes in market structure and conduct will influence environmental research priorities by IOUs and the consequent implications for policy.

This paper comprises five sections. The first section provides a brief background about the nature of deregulation and the R&D structure in the electricity industry. The second section discusses previous research in the field and provides a framework for the current study. Data

The main shortcoming of the CECP was its silence on carbon dioxide emissions. That, notwithstanding, the CECP was a step in the right direction in so far as the need for revised environmental policies in the competitive power market scenario.

⁶ Although major regulatory initiatives have been undertaken to reduce many of these pollutants, these largely deal with emission abatement technologies. Fuel switching as a means of pollution control has not, as yet, been aggressively pursued. Since the coal-fired power plants are responsible for a major share of all the pollutants, fuel switching would go a long way in preventing pollution.

issues and a detailed description of the variables are contained in the third section. The fourth section discusses the empirical results and the last concludes.

Section 1: Background

Section 1.1: Deregulation and Restructuring

The movement towards deregulation and competition in the U.S. power market began with the Public Utility Regulatory Policy Act (PURPA) of 1978.⁷ The Energy Policy Act of 1992⁸ and the subsequent FERC Orders 888 & 889⁹ provided an effective groundwork for retail competition, while strengthening wholesale competition. Most states have followed some basic tenets while deregulating their energy markets. The establishment of ancillary services markets, auction mechanisms, congestion management protocols and various settlement mechanisms through which these generators would be paid were put in place. Market based pricing schemes were put in place simultaneously with these new institutional structures to usher in competition

⁷ This act created a group of power generators called the “qualifying facilities” that were non-utilities (that met certain ownership and generation criteria) not subject to the rate and accounting regulation by FERC. Furthermore to ease their entry into the market they were guaranteed that whatever power they produced would have to be bought by the utilities at a rate equal to the “avoided cost” of the utilities. In addition PURPA aimed at improving the wholesale distribution of energy, promote conservation energy, increase the efficiency of electric utilities and develop more hydro-electric power.

⁸ The Energy Policy Act (EPACT) of 1992 gave impetus to wholesale power competition by creating a new class of power producers called the exempt wholesale generators (EWGs). This act also gave rise to open-access transmission grids for wholesale transactions. Along with this, the FERC also undertook several measures to ensure increased competition. It required utilities to provide a detailed account of their transmission capacities, it expanded the range of services that the utilities were required to provide to wholesale traders and it made it clear that approval of application for mergers or charging competitive rates by IOUs were subject to their filing open access transmission tariffs with comparable service provisions. These initiatives promoted the growth of wholesale competition in the US and prepared the industries subsequent transition to retail competition. For a detailed provision of the orders please refer to DOE/EIA (1997).

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in the electricity generation market. (Blumstein, 1997; Blumstein & Bushnell, 1994; Borenstein, & Bushnell, 1997; Bushnell & Stoft 1995; Hogan, 1997; Jordan, 1994; Joskow, 1989, 1997, 1999; Moyer, 1993; Sloan, 1994; Smith, 1998)

New companies could now site plants and not be subject to rate-based regulation or be limited by a geographic monopoly. This changed structure presumably has implications for environmental policy. Under price regulation, environmental policy was easier to administer as compliance could be achieved through strict regulatory oversight. Market structure, organizational networks, prices and financial systems all changed with deregulation. In the new scenario, the scope of regulatory bodies would be limited and thus environmental regulations would not only be more costly to implement, but also more difficult to enforce. Any future decrease in emissions is contingent on the continuance of R&D efforts on the part of private firms and the government. Strong competitive pressures in the retail market and cost cutting measures may adversely affect research efforts in this sector, especially for IOUs – the central focus of this paper. To analyze this issue, I first briefly describe of the organization of R&D in the U.S. power sector.

Section 1.2: R&D in the US Electricity Industry

Under the regulatory regime, R&D in the U.S. power industry was performed by four major entities – the utilities, Department of Energy (DOE), Electric Power Research Institute (EPRI) and the electrical equipment manufacturers such as General Electric. Restructuring is likely to lead to dramatic changes in the structure and conduct of research, particularly regarding investments in basic science, long-term research, and projects involving environmental benefits that cannot be internalized. Signs of such change have already begun to appear. During 1990 through 1996, federal support for energy R&D had declined by 22 percent, (Dooley, 1999) while

total R&D funding by the electric utilities fell by 33 percent to about \$476 million, during the same period. This paper primarily focuses on the utilities that invest in both in-house R&D expenditure and collaborative R&D. For the period in consideration, in-house R&D by the IOUs is quite sizable, although the expenditure varies greatly depending on the nature and size of the firm. Majority of research was conducted by big vertically integrated firms that owned generation, transmission and distribution. Companies that were solely distribution or transmission companies, invested very little in research¹⁰. To analyze how restructuring and competition affects environmental research, and hence innovation, I outline some important findings in the next section.

Section 2: Literature Review

Till date, relatively little attention has been devoted to the impact of market restructuring on environmental research in the power industry. However, there is a substantial body of literature that studies the effect of market structure on R&D on one hand and the impact of environmental regulations on innovation and productivity on the other. This paper is an attempt to marry the two fields. While primarily investigating the effect of market structure changes on environmental R&D, I also study the impact of environmental regulations on R&D expenditures. To put these issues in context, I briefly review the two segments of the literature.

Section 1.1: R&D, Innovation and Market Structure

The relation between market structure, R&D and technical progress has been the subject of extensive research (Kamien & Schwartz, 1975). The Schumpeterian paradigm claims that

¹⁰ One of the largest R&D investors was Southern California Edison, which spent 74 million dollars on electricity R&D in 1991

generally competition does not lead to socially optimal R&D investment, but rather to over or under-investment. This is supported by Cohen & Levinthal's work (1989) that show, if knowledge spillovers increase with industry concentration, then R&D investments will increase as competition declines. According to this view, environmental research in the power industry would be socially optimal during regulation and any deviation post-restructuring would be sub-optimal. The opposite side of this claim has been fueled by Arrow's argument that a monopolist has less incentive to innovate than is socially optimal. Thus, extending the above argument, for regulated IOUs, the incentive to invest in research would be very low before restructuring.

Regulated IOUs do not exactly behave like profit maximizing monopolists –most expenditures have to be approved by regulators and hence regulatory preferences play a major role in determining research expenditures. If we believe that regulators are social utility maximizers then environmental R&D would be socially optimal under the regulatory regime. However, there seems to be consensus that regulation, in general, can slow down preemptive technology adoption by firms and may also “preclude the adoption of superior technology” (Riorden, 1992). From a theoretical perspective, rate of return regulation produces slower technical progress when compared to other forms of regulation, like ceilings (Magat, 1976). Since a major portion of environmental R&D conducted by these IOUs is ‘social’ in nature, I believe that the above arguments may not be applicable to the power industry. I expect competition to decrease such spending. However, the environmental research aimed at short-term cost-reduction goals may indeed increase.

Section 1.2: Environmental Regulation, Innovation and Productivity

The commonly held belief is that environmental regulations hamper productivity growth and dampen technological advancement. Examples abound from various sectors of the economy.

There is substantial literature showing that investments are adversely affected in areas with stringent environmental regulation, and power plants and other polluting industries migrate to areas with less stricter standards (Becker & Henderson, 2000; Henderson, 1996). For the pharmaceutical industry the same results are evident (Grabowski et. al, 1978). For paper mills sector, Gray et. al (1998) find that stringent environmental regulations increase pollution abatement related expenditures which crowds out productive investments, hence adversely affecting productivity. However there is also evidence to the contrary.

Jaffe et. al (1995) find that there is relatively little evidence that the competitiveness of US manufacturing firms have been adversely affected by environmental regulation. With regard to innovation, the evidence is mixed. In a large panel of US manufacturing firms, R&D is positively affected by regulatory compliance expenditures, while patenting is unaffected (Jaffe & Palmer, 1997). In addition, when studying the building industry, Jaffe & Stavins (1995) do not find any adverse effect of regulation on technology diffusion, while Popp(2001) finds that energy prices and energy policy has a significant impact on innovation. An important factor that needs further attention when assessing the impact of environmental regulation on innovation, is the nature of the regulation. Depending on the type of environmental regulation (for e.g. pollution taxes versus permits), one can reach different conclusions about the innovation benefits associated with each instrument (Fischer et. al, 2003).

This paper builds on the existing literature in several ways. I examine the impact of market restructuring and competition on environmental research by focusing on the (1) effect of both market restructuring and pollution abatement regulation on environmental R&D (2) discretionary R&D expenditures, as opposed to mandatory expenditures dictated by EPA regulations and (3) several facets of deregulation and restructuring and their separate effect on environmental R&D. Besides these issues, I also study the impact of firm characteristics and

regulator preferences on the conduct of such research, pre and post deregulation. Finally, I use detailed firm-level micro data from 1989-1997, that allow us to capture changes in the power market as well as the Clean Air Act provisions.

Section 3: Data and Variables

To analyze the above issues, I primarily use data from FERC Form 1, that all regulated IOUs filed with the Federal Energy Regulatory Commission (FERC). This contains generation data such as such as the amount of electricity produced from steam, nuclear, hydro; financial variables such as debt, revenue, equity; customer data about the share of sales and revenue of residential, commercial and industrial customers and expenditure data like R&D, wages and salaries etc. The other major source of data is the EIA (Energy Information Administration). Our unit of observation is the firm and not a plant, since R&D decisions are made at the firm level. In addition I use state level restructuring and competition data to capture market structure changes and prevailing ground conditions in a state. A detailed description is provided below.

Section 3.1: Dependent Variable

The environmental spending considered in this study is discretionary part of a firm's budget¹¹ – the in-house or internal R&D expenditure by the IOUs. Although, EPRI and the DOE conduct sizeable amounts of environmental research, the micro-data needed for model estimation is unavailable. Hence, I focus on the IOUs, with the caveat that focusing on twenty to thirty million dollars of research in an industry with 300 billion dollars of revenue, will not give us a

¹¹ The focus is not on the IOUs' total environmental expenditure. Some of this expenditure is a part of their daily operating and maintenance costs and thus, the incentives for this portion of the spending is unlikely to change after deregulation, since plants still need to satisfy basic EPA guidelines concerning environmental protection and pollution control.

comprehensive picture. However, focusing on this segment permits us to study firm behavior under regulation and competition, and allows insights into the R&D decision process under various market structures. The environmental R&D conducted by these firms constitute research on global warming issues, nitrogen oxide (NO_x) control technologies, making transmission lines safe for birds, effect of generating plants on rivers and aquatic life, to name a few. Air quality related research appears to be an important research area for these utilities. For example, in 1994, Southern California Edison spent \$2.7 million on “Air Quality Enhancement”, out of a total environmental R&D spending of \$9 million.

Appendix Figure 1(A) shows IOUs internal R&D expenditures (millions of 1996 dollars) for two major groups – generation and environment. The generation R&D is further disaggregated into expenditure on fossil fuel research, hydroelectric research, nuclear and unconventional energy R&D. I find that all the generation sub-groups, especially fossil fuel R&D have undergone a dramatic decline, however, the decline in environmental R&D has not been as dramatic. This leads us to believe that the effect of restructuring on such expenditures warrant closer attention. Figure 1(B) shows environmental R&D shares¹² disaggregated by stages of deregulation (High, Medium and Low)¹³. The states with high deregulation show the greatest decrease in the share of environmental R&D. Medium and low deregulation states show an increase in the share of environmental R&D showing that such expenditures are falling less relative to other kinds of R&D.

In addition there is considerable heterogeneity across firms. Appendix Figure 2(A) plots environmental research expenditures by firm id and year. The outliers, 161 (Southern California Edison - CA), 133 (Pacific Gas and Electric - CA) and 117 (Niagara Mohawk Power Corp -NY),

¹² Share of Environmental R&D = Environmental R&D / Total R&D

¹³ We classify states according to the stage of deregulation they reached in 1997. For example if a state reached full deregulation in 1997 (deregulation index = 3), then it is classified as a high deregulation state for all year. A medium deregulation state is one with deregulation index 2 in 1997 and low states are those with index = 0 or 1 in 1997.

conduct considerably more environmental research than other IOUs. From Figure 2(B), we observe that comparing two New York and California companies, the ones located in California have suffered the most due to deregulation. Similar pictures emerge when California companies are compared to those located in other states. Thus when estimating the model, I will segregate the California effect to study whether the results are being driven by these companies.

Section 3.2: Regressors

Restructuring Characteristics

Over the past several years the electric utility industry has been in a state of flux. Deregulation, mergers, acquisitions and divestitures have dramatically changed the environment under which utilities operate. The pace and nature of deregulation and restructuring has been different in every state and any one variable is not adequate to capture the dynamic nature of this change. The empirical analysis uses four variables¹⁴ to characterize this change.

First, I create an ordered deregulation index (*DEREG*) to measure the level of deregulation that a firm faces in a particular year. This variable takes the value zero for states that have not taken any action on deregulation till 1997. In addition, it assigns a 0 value to all states before 1995, since this was the first year when investigations into restructuring started at the state level. It is constructed from EIA’s publication “Status of State Electric Industry restructuring Activity as of May 2000”¹⁵. The table gives details on this index.

0 = No Activity,	2 = Order Issued For Retail Competition
1 = Investigations Ongoing or Orders and Legislation Pending	3 = Legislation Enacted to Implement Retail Access

¹⁴ For a more detailed analysis of the variables please refer to the paper titled “Deregulation, Restructuring and Changing R&D Paradigms in the US Electric Utility Industry” in P. Sanyal’s dissertation (2001) titled “Essays on research and Development”

¹⁵ This publication outlines the regulatory orders, legislations and the investigative studies that have been undertaken by each state till present.

Second, the probability of deregulation (*PROB_DEREG*) is used to capture firms' expectations (in 1993) about the status of deregulation in a particular state. This probability is obtained from modeling deregulation in a state and is based on the economic and political factors in 1993 that could affect the pace of deregulation. I estimate an ordered probit model where the dependent variable is the status of electricity deregulation in a state at the end of 1998. 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 influence¹⁶. The predicted probabilities of deregulation are generated from this model and used in the R&D model to capture the forward looking behavior of IOUs. This variable is interacted with the EPACT dummy (takes the value 1 for 1993 and all years after that), because all deregulation and restructuring variables become relevant only after the EPACT was passed in 1992. Thus, it takes the value zero before 1993 and a constant predicted probability¹⁷ derived from the model for 1994 – 1997.

The third variable measures the number of years left till retail competition goes into effect (*STR_DAT*). When no start date is provided I assume that the state has 20 years from any given date¹⁸, and for years before 1993 (before EPACT). If a start date is mandated this variable turns on in 1993 and in each year counts the number of years left till the markets are open to retail competition. Like any other rational forward-looking firm, we would expect utilities to plan future expenditures conditional on their expectations about the time they have till their

¹⁶ Please refer to the Supplementary Appendix Note 1 for a discussion on this model.

¹⁷ This predicted probability varies by state but not by year. Hence the firms do not update their expectations, which arguably is a weakness of this variable.

¹⁸ The empirical results are not sensitive to reasonable variations in this number.

markets opened up to competition.¹⁹ Two states may have passed a deregulatory order in the same year, but one may mandate the start of retail competition twenty years from the order date and the other may mandate retail competition immediately. Presumably firms will behave differently in the two situations.

Passing a deregulatory order, or even mandating the date for the start of retail competition is not sufficient to engender effective competition in the market. For example, a state may be officially deregulated, but a lack of competitors or a lack of customers actually switching to other companies may imply low levels of effective competition. Thus a fourth variable is introduced to capture potential competition (*COMP*) in the state, based on the RED (Retail Energy Deregulation Index 2000). This was developed by the Center for Advancement of Energy Markets (CAEM) as a composite measure of effective competition (Malloy, 2000), and is a weighted index of 18 different attributes that the center has chosen as the most important characteristics that would enable states to make a transition to a competitive market²⁰. This variable can potentially take values between 0 and 100, the highest in the dataset being 65.1 and the lowest being 0²¹. This variable is also interacted with the EPACT dummy and turns on in 1993²².

¹⁹ So far 18 states have set concrete dates for the start and phasing in of full retail competition. For states that have not set a date, we assume that they have 20 years till retail competition begins (that is at any point of time, their expected start date is 20 years in the future). For the states with a specific start date, this variable takes the value: start-date of retail competition minus current year and is bounded below at zero.

²⁰ These attributes are – deregulation plan, percent of customers who are eligible to choose a provider, percent of customers who have already switched, nature of divestiture of generation, default provider, default provider risk and rates, competitive standards, uniform business rule, stranded cost calculation and recovery mechanism, billing, metering, wholesale market model, distribution resources interconnection, regulatory convergence, performance based pricing for network facilities and commission reengineering.

²¹ For estimation we use 17 of the attributes. We the ‘deregulation plan’ variable that is contained within the RED index is not used as we already use the dynamic deregulation index to capture the progress of deregulation in each state.

²² Please refer to the Supplementary Appendix Note 2 for a detailed description of these variables.

IOU Characteristics

Focusing on the EPA Green Lights Program, DeCanio and Watkins (1998) find that firm characteristics influence environmental technology adoption. To capture the effect of firm characteristics in environmental R&D in the electricity industry, we include the nature and type of firm as explanatory variables. The net generation variable (*GEN_ELEC*), measured in millions of megawatt hours, is used as an indicator for the type of firm – generation, transmission or distribution. Presumably a large generation plant would conduct more environmental R&D as generation of power is one of the major pollution sources. This variable serves the dual purpose of controlling for size and nature of firm. In addition, the type of generation should also affect environmental R&D expenditure. A hydro-electric plant, traditionally a clean operation, may invest less or nothing at all in environmental research compared to fossil fuel plants. I thus use the share of hydro (*HYD_SH*) and fossil fuel (*FOSS_SH*), in total fuel input, to capture the generation mix of a firm.

The financial health of the firm is measured by the rate of return on average common stock equity (*ROR*). The hypothesis is that a company with more spare resources would spend more in research spending. However, whether environmental research is going to increase is debatable. In addition to in-house research spending, utilities also made contributions to the Electric Power Research Institute (EPRI), usually proportional to their revenues. It could be argued that, since a substantial portion of EPRI expenditure was on environmental research, this contribution may have substituted for internal environmental R&D spending. Thus I investigate this substitutability issue by using each IOU's EPRI contribution (millions of real dollars).

In addition, I look at the effect of the 1990 Clean Air Act on environmental R&D spending. This Act could have a positive impact of such expenditures as firms investigate better ways to meet the Title IV requirements. To capture this effect I first count the number of boilers

that fall under Phase I for each IOU (EIA, Clean Air Database). This is then interacted with a 1995 dummy²³, since this is when Phase I went into effect. We expect to find a positive relationship with environmental R&D expenditures as firms with a higher number of boilers in Phase I may increase environmental R&D to search for better compliance strategies.

State Characteristics

For any firm, the R&D decision process is influenced by its internal profit motive and nature of its operations. However, for regulated firms, regulatory pressure, implicit or overt, is an additional factor that firms take into account while making investment decision. Such external pressure is captured by the variable denoting the political attitude towards environmental issues. This is obtained from the scorecard of the League of Conservation Voters (*LCV*). A higher score implies a more favorable environmental record and thus ‘greener’ regulators who may be willing to take strict action against pollution. Thus the decrease in environmental R&D after deregulation should be less for IOUs located in ‘green’ states, or conversely, being located in a ‘green’ state should increase environmental R&D.

In addition I use several other variables that capture ground conditions in a state. It could be argued that the fuel mix in a state would determine regulators preferences towards environmental R&D expenditure. For example, all else equal, a state with a very high percentage of coal in its generation mix may spend more on environmental research than another state that primarily uses cleaner natural gas. To account for this effect, I use a state coal dummy. This dummy takes the value 1 if the share of coal in generation is greater than other fuel shares. The state fuel mix data is from the EIA. In an alternative specification, I also include a California dummy²⁴. It is often argued that California is an outlier when it comes to environmental issues.

²³ Takes the value 1 for all years starting at 1995.

²⁴ The California dummy takes the value 1 when the IOU is located in California.

In fact when looking at the data, we observe that one of the largest environmental R&D expenditures was undertaken by Southern California Edison Company (Appendix Figure 1(c)). Thus a dummy is introduced to account for California's environmental preferences.

The environmental justice literature proposes that richer areas usually have greater environmental consciousness. Hence it could be argued that regulators in richer states would push for more environmental R&D expenditure, in keeping with the preference of their constituents. To observe how state wealth affects environmental R&D, I use gross state product (millions of real dollars) (*GSP*) (Bureau of Economic Analysis). In addition I use the share of GSP that can be attributed to electricity sector. This serves as a measure of the importance of the power sector in the state. It is possible that a bigger electricity sector may wield more political power and regulatory capture theory would predict lower environmental R&D spending. But since the generation plants are one of the biggest pollution sources in a state, a large presence may compel regulators to push for more environmental R&D as well. The next section outlines the empirical methodology and interprets the empirical findings.

Section 4: Empirical Evidence

Section 4.1: Estimation Issues

The dependent variable (environmental R&D expenditure measured in millions of 1996 dollars) is continuous and contains a substantial portion of zeros. Thus a random effects tobit specification^{25, 26} is used to estimate the model²⁷, with the lower bound set at zero. The period

²⁵ The random effects tobit model assumes that the random effect u_i has a normal distribution, $N(0, \sigma_u)$ and ε_{it} is the

idiosyncratic error term. From this we get: $\Pr(y_i | x_i) = \int_{-\infty}^{+\infty} \frac{e^{-u_i^2/2\sigma_u^2}}{\sqrt{2\pi\sigma_u}} \left(\prod_{t=1}^{n_i} F(x_{it}\beta + u_i) \right) du_i$ where:

$$F(\Delta_{it}) = \begin{cases} \left(-\frac{1}{\sqrt{2\pi\sigma_\varepsilon^2}} \right) e^{-(y_{it}-\Delta_{it})^2/(2\sigma_\varepsilon^2)} & \text{if } y_{it} \in C; \\ \Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) & \text{if } y_{it} \in L; \\ 1 - \Phi\left(\frac{y_{it}-\Delta_{it}}{\sigma_\varepsilon}\right) & \text{if } y_{it} \in R \end{cases}$$

under consideration is 1989-1997. The panels are unbalanced with a minimum observations of one and a maximum of nine. The basic model I estimate is given by:

$$RD_{it} = \alpha + \delta_1 DERE G_{it} + \delta_2 PROB_DEREG_{it} + \delta_3 STR_DAT_{it} + \delta_4 COMP_{it} + \gamma_1 ROR_{it} + \gamma_2 GEN_ELEC_{it} + \gamma_3 HYD_SH_{it} + \gamma_4 FOSS_SH_{it} + \lambda LCV_i + \varepsilon_{it}$$

In later specifications I use additional state and firm level variables to test sensitivity. Tables 2 and 3 present seven alternative specifications that explore how market regulations, the Clean Air Act and other factors influence the conduct of environmental research by the utilities.

Section 4.2: Results from the Basic Model (Table 2)

The four variables characterizing the regulatory environment in a state have a significant impact on internal environmental research expenditures, in the basic model. The deregulation index has a negative effect and when deregulation progresses one step further, there is a reduction of environmental R&D by 0.113 million dollars. This is significant given that the mean environment R&D expenditure for an IOU is 0.121 million. I also find that as the probability of deregulation increases, environmental R&D declines. This could be associated with increasing uncertainty in the market. Evaluated at the mean, a 1 percent increase in this probability decreases expenditures by 0.75 percent.²⁸ Also, greater the number of years left till deregulation, the greater the investment in environmental research. Conversely, if the start date gets closer by a

where: C denotes the uncensored observations, L is the left-censored observations and R is the right censored observations. We cannot estimate a fixed effects tobit model as the sufficient statistic that would allow us to condition out the fixed effects from the likelihood function, does not exist.

²⁶ The estimation technique uses the Gauss-Hermite quadrature approach to estimate the models and the quadrature is set to 12. I also check the stability of models by varying the quadrature between 8 and 16. The results do not change significantly.

²⁷ Since environmental R&D is a discretionary expenditure, we might consider that the decision process to invest in it, being done on two steps. The firm may first decide whether to do environmental R&D or not. Conditional on the fact that it decides to invest in environmental R&D, it then decides the amount it wants to invest. Thus, in such a scenario a Heckman-type selection model for on panel data would be appropriate. However, I do not find evidence of selection.

²⁸ Elasticity =(Coefficient)*(*PROB_DEREG*_{mean}/*RD*_{mean}) = (-.394)(.230/.121)=0.749

year, environmental R&D falls by 0.011 million dollars. These results could be explained by the fact that uncertainties associated with the deregulation process make firms withhold R&D expenditures. This argument is similar to the option valuation literature that posits withholding investments till the arrival of more information (Hassett & Metcalf, 1993; Dixit & Pindyck, 1994).

In contrast, effective competition in the market has a positive impact on environmental research. An increase in effective competition by one point increases environmental R&D spending by 0.011 million dollars. This implies that environmental spending is less adversely affected in states that have policies in place that engenders a competitive market. However, this increase is modest compared to the overall decline. In Table 2(a) (column 2), I present the elasticities²⁹ for each of the market characteristics. The total effect of a one percent change in all these variables, such that overall market competition increases, is to decrease environmental R&D expenditure by 1.1 percent.

Turning now, to the effect of firm characteristics, one finds that the financial health of an IOU, as captured by the rate of return on average common stock equity has no impact on environmental research. The size of generation is a very important determinant of environmental R&D and an increase in generation by 1 percent increases such expenditure by almost 2 percent. Thus IOUs generating a large amount of electricity, perform more environmental R&D. This may be due to three reasons. First, there is substantial literature showing positive link between firm size and R&D (Cohen & Levin, 1989; Lunn, 1986). Second, the power generation process yields pollutants such as NO_x and sulfur dioxide as by products. Hence, the larger the generation, the greater will be the need to invest in environmental research, to mitigate the

²⁹ Since all the variables are in different units, a one standard deviation change seems an appropriate measure, instead of a percent change.

problem. Third, the political economy literature suggests that dirtier IOUs may curry favor with regulators by investing in environmental research.

The fuel mix also impacts environmental R&D in predictable ways. Hydro plants perform less environmental research than more polluting fossil fuel plants. A 1 percent increase in hydro share decreases R&D by 1.2 percent, whereas for fossil fuel share R&D increases by almost 3 percent. The coefficient on LCV rating, measuring the ‘greenness’ of a state, is positive and significant. Thus political pressure seems to play a role in the conduct of environmental R&D by these firms, although the impact is smaller than the restructuring variables. This implies that in ‘greener’ states such expenditures will decline by less than other states, but such political pressure will not be sufficient in stemming the entire decline.

Section 4.3: Alternative Specifications

In all specifications in Table 3(A) and 3(B) the deregulation index, years till start date of retail competition and the effective competition variables behave as before. However, the probability of deregulation is not significant in most specifications. This leads us to believe, that when factors like state wealth, effect of the Clean Air Act and EPRI contribution are controlled for, this is not an important decision variable for IOUs. The generation and hydro-share variables have similar impacts as in the basic model. However with the introduction of the California Dummy and controls for the Clean Air Act, the steam share variable becomes insignificant. Below, I discuss how state characteristics, the Clean Air Act and EPRI contributions influence the conduct of environmental research by IOUs.

Table 3(A)

Specifications in Table 3(A) investigate the importance of state characteristics on environmental R&D expenditure by IOUs. First, I find that the state coal dummy is positive and

significant. Thus IOUs in dirtier states, i.e. ones with higher coal generation, tend to invest 11.6 to 23.8 percent³⁰ more in environmental research than non-coal states. From a political economy perspective, one reason a regulated utility may have a strong environmental research program (quite apart from its own incentives), is if the regulatory commission orders it to. Regulators use environmental research programs to logroll under controversy. Current cash subsidies go to constituents with high discount rates and a research program investigating alternatives of interest is offered to constituents with greater patience. For example, a regulated utility might support a long-term research project of interest to environmentalists, trading off concessions to current polluters to extend the operation of dirty equipment. Greater environmental R&D spending in coal heavy states may be attributed to such behavior.

Keeping in line with findings from the environmental justice literature, I find that firms in richer states conduct more environmental research. Environmental preferences and ability to take collective action is greater in richer areas than poorer ones and this translates into differential environmental strategies adopted by firms, within the bounds of the federal regulations. I also find that post EPACT (1993 onwards), the impact is smaller³¹. This could be explained by the fact that, after EPACT, the regulatory commissions would not have as much control over the IOUs and hence, would not be able to pressure IOUs in conducting environmental R&D, in keeping with their constituents' preferences. Last, I find that the importance of the power sector in a state, as captured by the share of GSP attributable to this sector, has no impact on environmental research spending.

³⁰ Since the regressor is a dummy: the percentage effect is calculated as: $100(\exp(b - v(b)/2)) - 1$. See: Kennedy, AER, 1981

³¹ To compute the effect of GSP after EPACT, we add the coefficient for GSP (0.003) and that for the interaction term (GSP* EPACT Dummy) (-0.001). Post EPACT, the coefficient is 0.002.

Table 3(B)

In Table 3(B), I add a California dummy to the specification in Table 3(A). Often, concerns are raised about the environmental preferences of California driving the results. I find evidence to the contrary. Although, the California dummy is positive and significant as expected from discussion earlier, this does not change any of the primary results about the influence of restructuring on environmental R&D expenditures. However, this result emphasizes the importance of accounting for such state fixed effects when estimating these types of models.

I also investigate the impact of the Clean Air Act, as the change in environmental regulation occurred concurrently with the restructuring process, and it is important to disaggregate the two effects. I find that the Clean Air Act mitigates the adverse effect of deregulation to some extent. As the number of boilers affected by Phase I of the Act increases, spending on environmental R&D goes up as well. For every boiler in Phase I, spending increases by \$39,000 or alternatively, a 1 percent increase in the number of Phase I boilers increases environmental R&D by 13 percent (Table 3(B), column 2). Thus without this additional environmental regulation, such R&D would have declined even further. This supports the evidence presented by Jaffe & Palmer (1997), which suggests that there is a positive relationship between environmental stringency and R&D.

Last, I investigate the relationship between an IOU's EPRI contribution and its internal environmental R&D expenditure. It can be argued that the EPRI contribution may be a substitute for internal spending, since a significant portion of EPRI's research was on environmental issues. I find that pre-EPACT, EPRI contribution had no impact on internal environmental spending. However, post EPACT, these two expenditures have a positive relationship. This may imply that after deregulation, firms increase internal environmental R&D in tandem with EPRI contributions to better take advantage of EPRI research.

Thus the empirical evidence suggests the following: while deregulation decreases environmental R&D expenditure, effective competition increases it, controlling for firm characteristics and the “greenness” of the state. More polluting plants and firms in coal-heavy states invest more in environmental R&D, partly due to the need of meeting the Clean Air Act requirements and generation has a strong positive relationship with R&D expenditure. The models also suggest that the results are not due to the California effect, and post-deregulation, EPRI contribution and internal environmental R&D by firms are substitutes.

Conclusion

Restructuring of an industry always raises concerns about competition adversely affecting funds for pursuing social goals like pollution abatement. The electric utility industry is a good example. I find that factor associated with restructuring and deregulation led to a substantial decline in environmental R&D. However, I also find that if firms expect to operate in a true competitive environment post-deregulation, environmental R&D is less adversely affected. However, the positive effect of competition does not offset the adverse effect of deregulation and overall, restructuring leads to a 29 percent decline in environmental R&D for every one standard deviation change in the institutional variables.

Rate of return regulation led to overcapitalization in the power industry (the Averch-Johnson effect) (Courville, 1974), and hence deregulation was an attempt to bring market correction and enhance efficiency. When looking at R&D expenditure, one may argue that under such regulation, the companies over invested in R&D and the decline is an efficient market correction. While some of the decrease may indeed be efficiency driven, a close look at the R&D projects reveal that the cutbacks have been across the board and programs like air quality management have been hard hit.

So as deregulation progresses, will R&D by IOUs suffice in meeting the environmental goals or will the federal government have to step in? Evidence suggests that there is need for outside intervention. If such research is left solely to IOUs, even the pressure of competition will not be enough to push environmental R&D expenditures to their pre-deregulation levels. Another important factor that emerges from the empirical models is the effect of environmental regulation (the Clean Air Act in this case) on environmental R&D expenditures. As IOUs fall under stricter environmental guidelines (like the increase in the number of boilers covered by the regulation), they spend more on environmental research. Thus, an alternative way to enhance such R&D is to impose stricter pollution abatement requirements on power plants³². However the recent amendments to the Clean Air Act will slow any such increase in environmental R&D.

Plans for deregulating the electric utility industry have been underway for quite sometime and the market has had time to react. There are some interesting trends in consortia research that this paper has not studied. EPRI has implemented several R&D programs like tailored collaboration and the Progressive Flexibility Membership, that create incentives for utility firms to stay within the consortia research structure and also increase their R&D spending in areas they need. From Appendix Figure 2(A), I find that in 1997, funding for all environmental sub-groups has increased in nominal dollars and The “Air Quality, Health and Risk Assessment” group^{33,34}

³² Gollop and Roberts (1983) find that sulfur dioxide regulations have led to higher generating costs and have adversely affected productivity growth in power plants. Our paper presents evidence that such regulation may have a positive impact on environmental research and hence may mitigate productivity slowdown in the future.

³³ EPRI conducts research in a wide variety of fields related to air pollution. Some of the key areas are - air toxics assessment, research in tropospheric ozone, atmospheric particulates and precursors, and worker safety and health. The organization’s research has been very important in providing members with data methods and analysis needed to meet the regulatory requirements. The main focus of EPRI’s research in this area are - to develop models and observational data to characterize the atmospheric concentrations and receptor exposures to emissions from power plants with emphasis on air toxics, ozone, and particulates. Another important area is the research to estimate the health and environmental effects of alternative exposure levels. This is crucial in developing a rational risk management framework, which can be used to design and evaluate alternative management options, including market-based compliance strategies.

³⁴ With cumulative investments amounting to more than \$25 billion, maintenance of air quality standards is the most costly of all utility environmental regulations.

and the “Water Toxics and Watershed Management” groups have been the biggest gainers with 37 percent and 64 percent increase in funding respectively. The investment increase in the air pollution management group is especially important. This is additional evidence that environmental regulations, like the Clean Air Act, may spur environmental R&D.

An analysis of the sources of funding for the environment group show that market funded sources and tailored collaboration were not as important as the base funding³⁵, which accounted for 60% of the funds. Figures 2(B) and (C) show the funding patterns for the two main groups, once again pointing to the fact that market sources may not provide the required boost to environmental research. Such trends in EPRI need closer investigation, if we want to obtain a complete picture of the impact of deregulation on environmental research in the power sector.

However, deregulation is far from complete. With the turmoil in California, other states have taken a very cautionary approach towards deregulation. Some have completely stopped the deregulation process. But, from the above analysis we can conclude that deregulation, when it happens, is going to have an adverse effect on environmental R&D for the power industry. The impact of the Clean Air Act points to the fact that stricter environmental controls can induce utilities to invest in environmental research, even when the short-run gains from such research may not be substantial. For the period under consideration, the market seems to be doing a less than adequate job regarding environmental R&D funding. Whether this decline will continue in the future depends on the emerging market structure, the role of consortia research and the policy response of bodies like the EPA.

³⁵ There are two main types of funding in EPRI - base funding and market based funding. EPRI base funding reflects the total membership dues committed by EPRI's members for 1996 reduced by 25% to reflect the amounts necessary for Tailored Collaboration matching funds. Market-funded revenues are - (i) Cofunding: Funding paid to EPRI by other product participants in an EPRI managed project. (ii) Tailored Collaboration: Both EPRI's share and the utility share of funding in Tailored Collaboration projects. This is a special option provided for members since 1991 to increase flexibility in funding specific program areas. (iii) International Affiliates: Payments expected from International Affiliate members allocated to specific targets. (iv) Royalties and Licensing: Revenue anticipated from royalties and licensing of products developed under a specific target. (v) Progressive Flexibility Membership Solicitation funds. The relative levels of funding from different sources varies widely between Business Groups.

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APPENDIX TABLES

TABLE 1 (A) : SUMMARY STATISTICS

Variable	Obs.	Mean	Std. Dev.	Min	Max
Total Real Environmental R&D	1392	0.121	0.563	0	9.186
Deregulation Index	1392	0.279	0.726	0	3
Probability of Deregulation	1392	0.230	0.311	0	0.975
Years till Start of Deregulation	1392	16.58	6.735	0.600	20
Competitive Score	1392	15.68	22.06	0	65.1
Rate of Return	1392	14.84	22.88	0	625.7
Amount of Electricity Generation	1392	11.52	15.65	0	94.90
Hydro Share	1392	0.124	0.293	0	1
Fossil Share	1392	0.625	0.396	0	1
LCV Rating	1392	53.62	29.46	6	97
Gross State Product (billions of 1996 dollars)	1392	197.2	180.3	12.78	1025.6
Share of GSP Attributable to the Electricity Sector	1392	0.031	0.009	0.007	0.086
No. of Boilers Affected by Phase I Clean Air Act	1392	0.402	1.621	0	19
EPRI Contribution (millions of 1996 dollars)	1367	1.603	3.047	0	25.23

TABLE 2: BASIC MODEL
 Dependent Variable is Environmental R&D Expenditure (1996 \$)
 (Standard Errors in Parenthesis)

Variable	Coefficients	Elasticity [§]
Constant	-1.815 ** (0.202)	
<i>Restructuring Characteristics</i>		
Deregulation Index	-0.113 ** (0.040)	-0.261
Probability of Deregulation	-0.394 ** (0.182)	-0.749
Years Till Start of Retail Competition	0.011 ** (0.006)	1.507 [#]
Effective Competition Score	0.011 ** (0.003)	1.426
<i>IOU Characteristics</i>		
Financial Health	0.001 (0.002)	0.123
Generation	0.020 ** (0.002)	1.904
Share of Hydro in Total Generation	-1.149 ** (0.325)	-1.178
Share of Fossil Fuel in Total Generation	0.609 ** (0.140)	3.146
<i>State Characteristics</i>		
LCV Senate Rating	0.004 ** (0.001)	1.773
<i>Variances, Log Likelihood, No. of Obs.</i>		
Fraction of Variance Due to U _i	0.765	
Log Likelihood	-607.5	
No. of Observations	1392	

Note: The estimation technique is a random effects tobit model. 436 observations are uncensored. The lower limit is set to zero. The panel is unbalanced with min obs. Of 1 and a max of 9. The period under consideration is 1989-1997. ‘***’ denotes significance at 5 percent and ‘*’ denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

[§]Elasticity=(coefficient) *(Mean Regressor/Mean Environmental R&D). Show the percentage change in environmental R&D for a 1 percent change in the regressor.

[#] The effect of years till retail competition has negative meaning, the lesser the number of years till retail competition, the lower is R&D. Thus when adding up the effect of 1 percent change in each of the market structure variables, this quantity enters as a negative number. Hence for a 1 percent change in all market structure variables, R&D declines by 1.1 percent.

TABLE 3(A): EFFECT OF STATE CHARACTERISTICS
 Dependent Variable is Real Environmental R&D Expenditure
 (Standard Errors in Parenthesis)

Variable	Effect of State Fuel Generation Mix (1)	Effect of State Wealth (2)	Effect of Large State Power Sector (3)
Constant	-1.781 ** (0.188)	-2.613 ** (0.194)	-2.679 ** (0.214)
<i>Restructuring Characteristics</i>			
Deregulation Index	-0.115 ** (0.040)	-0.124 ** (0.040)	-0.121 ** (0.040)
Probability of Deregulation	-0.339 * (0.189)	- 0.056 (0.208)	- 0.073 (0.209)
Years Till Start of Retail Competition	0.012 * (0.006)	0.011 * (0.006)	0.011 * (0.006)
Effective Competition Score	0.010 ** (0.004)	0.010 ** (0.003)	0.009 ** (0.004)
<i>IOU Characteristics</i>			
Financial Health	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)
Generation	0.020 ** (0.002)	0.026 ** (0.002)	0.025 ** (0.002)
Share of Hydro in Total Generation	-1.099 ** (0.305)	-1.014 ** (0.279)	-0.989 ** (0.277)
Share of Fossil Fuel in Total Generation	0.483 ** (0.122)	0.263 ** (0.110)	0.239 * (0.126)
<i>State Characteristics</i>			
LCV Senate Rating	0.004 ** (0.001)	0.004 ** (0.001)	0.004 ** (0.001)
State Coal Dummy	0.149 * (0.078)	0.247 ** (0.067)	0.242 ** (0.066)
Gross State Product (billions of 1996 dollars)	-	0.003 ** (0.0002)	0.003 ** (0.0002)
Share of GSP Attributable to the Electricity sector	-	-	2.434 (3.562)
Interaction Term: Gross State Product * EPACT Dummy	-	-0.001 ** (0.0002)	-0.001 ** (0.0002)
Interaction Term: Share of Electricity Sector GSP * EPACT Dummy	-	-	0.891 (2.331)
Fraction of Variance Due to U _i	0.770	0.731	0.730
Log Likelihood	-605.61	-579.65	-579.23

Note: The estimation technique is a random effects tobit model. 436 observations are uncensored (total obs. = 1392). The lower limit is set to zero. The panel is unbalanced (min obs = 1, max = 9). Range: 1989-1997. ‘***’ denotes significance at 5 percent and ‘*’ denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

TABLE 3(B): EFFECT OF THE CLEAN AIR ACT, CALIFORNIA AND EPRI

Dependent Variable is Real Environmental R&D Expenditure

(Standard Errors in Parenthesis)

Variable	Effect of California (1)	Effect of Clear Air Act (2)	Effect of EPRI Contribution (3)
Constant	-2.060 ** (0.213)	-1.780 ** (0.201)	-1.776 ** (0.239)
<i>Restructuring Characteristics</i>			
Deregulation Index	-0.107 ** (0.039)	-0.123 ** (0.038)	-0.124 ** (0.041)
Probability of Deregulation	0.278 (0.230)	0.272 (0.236)	0.261 (0.252)
Years Till Start of Retail Competition	0.016 ** (0.006)	0.014 * (0.006)	0.010 * (0.006)
Effective Competition Score	0.007 ** (0.004)	0.007 * (0.004)	0.007 * (0.004)
<i>IOU Characteristics</i>			
Financial Health	0.0004 (0.002)	0.0004 (0.002)	0.001 (0.002)
Generation	0.018 ** (0.002)	0.016 ** (0.002)	0.017 ** (0.002)
Share of Hydro in Total Generation	-1.118 ** (0.328)	-1.049 ** (0.344)	-0.660 ** (0.331)
Share of Fossil Fuel in Total Generation	-0.483 (0.073)	-0.088 (0.126)	0.270 ** (0.117)
No. of Boilers Affected by Phase I Clean Air Act	-	0.039 ** (0.011)	0.043 ** (0.013)
EPRI Contribution	-	-	-0.011 (0.010)
Interaction Term: EPRI Contribution * EPACT Dummy	-	-	0.026 ** (0.012)
<i>State Characteristics</i>			
LCV Senate Rating	0.002 * (0.001)	0.001 (0.001)	0.002 * (0.001)
State Coal Dummy	0.418 * (0.073)	0.338 ** (0.074)	0.216 ** (0.080)
Gross State Product (billions of 1996 dollars)	0.002 ** (0.0002)	0.002 ** (0.0002)	0.003 ** (0.0003)
Interaction Term: Gross State Product * EPACT Dummy	-0.001 ** (0.0002)	-0.001 ** (0.0002)	-0.001 ** (0.0003)
California Dummy	2.234 ** (0.208)	1.886 ** (0.186)	1.558 ** (0.199)
Fraction of Variance Due to U_i	0.681	0.652	0.684
Log Likelihood	-575.57	-571.08	-559.63

Note: The estimation technique is a random effects tobit model. 436 observations are uncensored (total obs. = 1392 in (1) & (2); = 1366 in (3)). The lower limit is set to zero. The panel is unbalanced (min obs = 1, max = 9). Range: 1989-1997. ‘***’ denotes significance at 5 percent and ‘**’ denotes significance at 10 percent. A Wald test shows that all coefficients are jointly significant.

APPENDIX FIGURES

FIGURE 1(A): Disaggregated Internal R&D Expenditure by IOUs

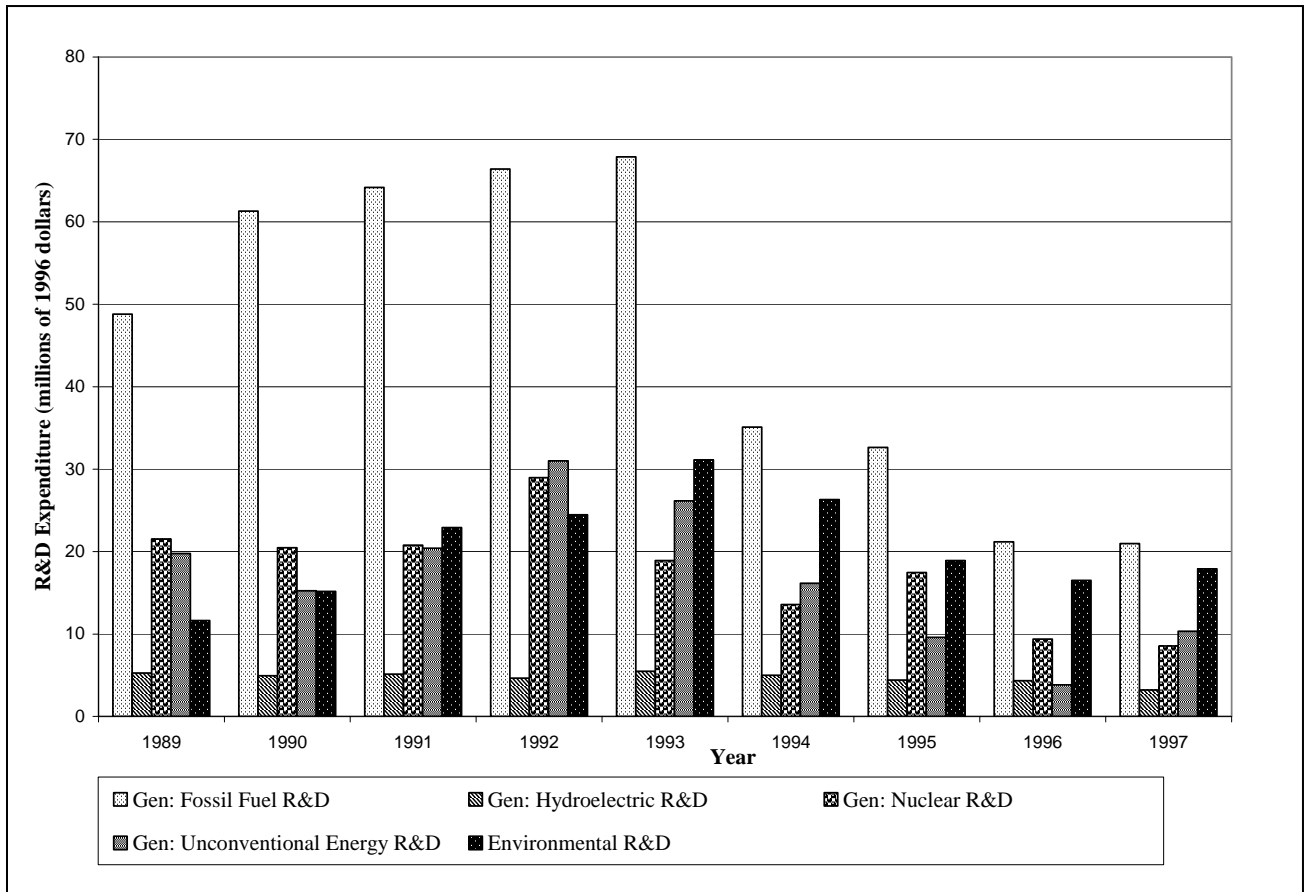


Figure 1(B): Proportional R&D Expenditure By Different Stages of Deregulation

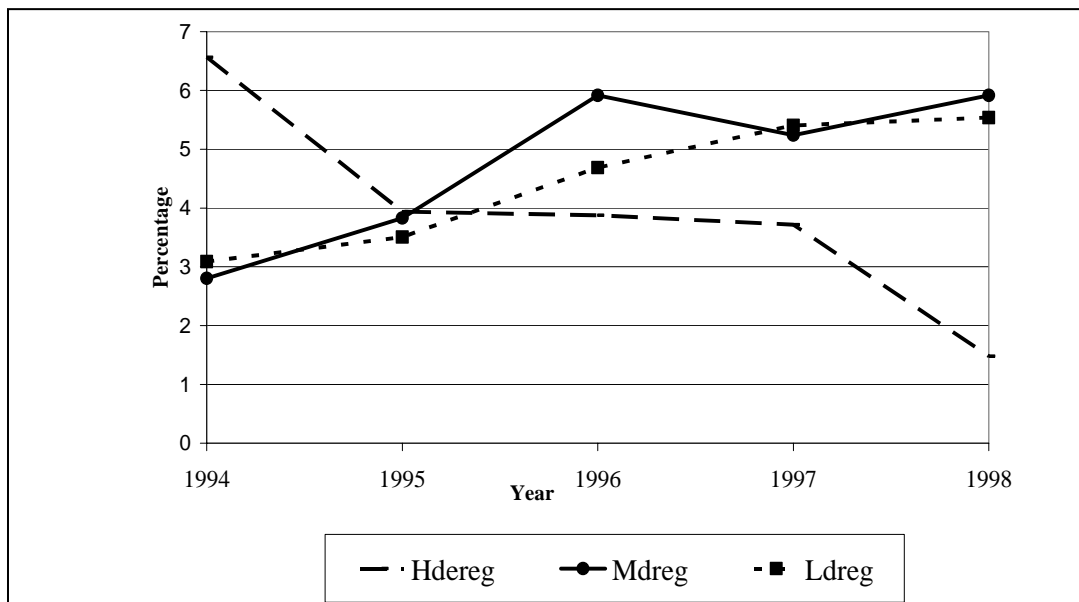


Figure 2(A): Environmental R&D Expenditures By IOUs

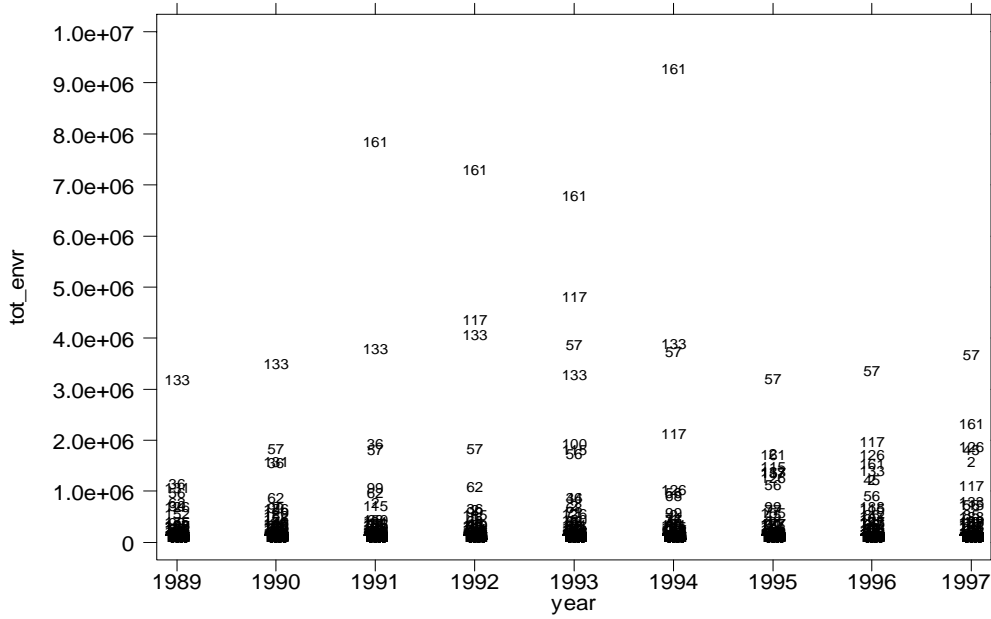


Figure 2(B): Environmental R&D Expenditures By Large IOUs in CA & NY

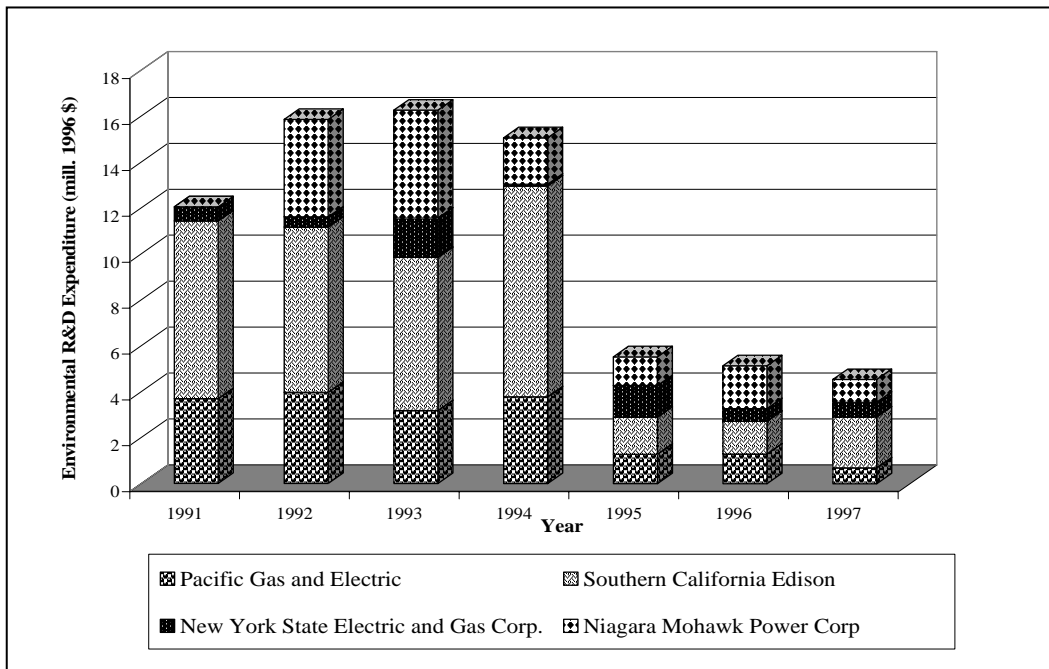


FIGURE 3(A)

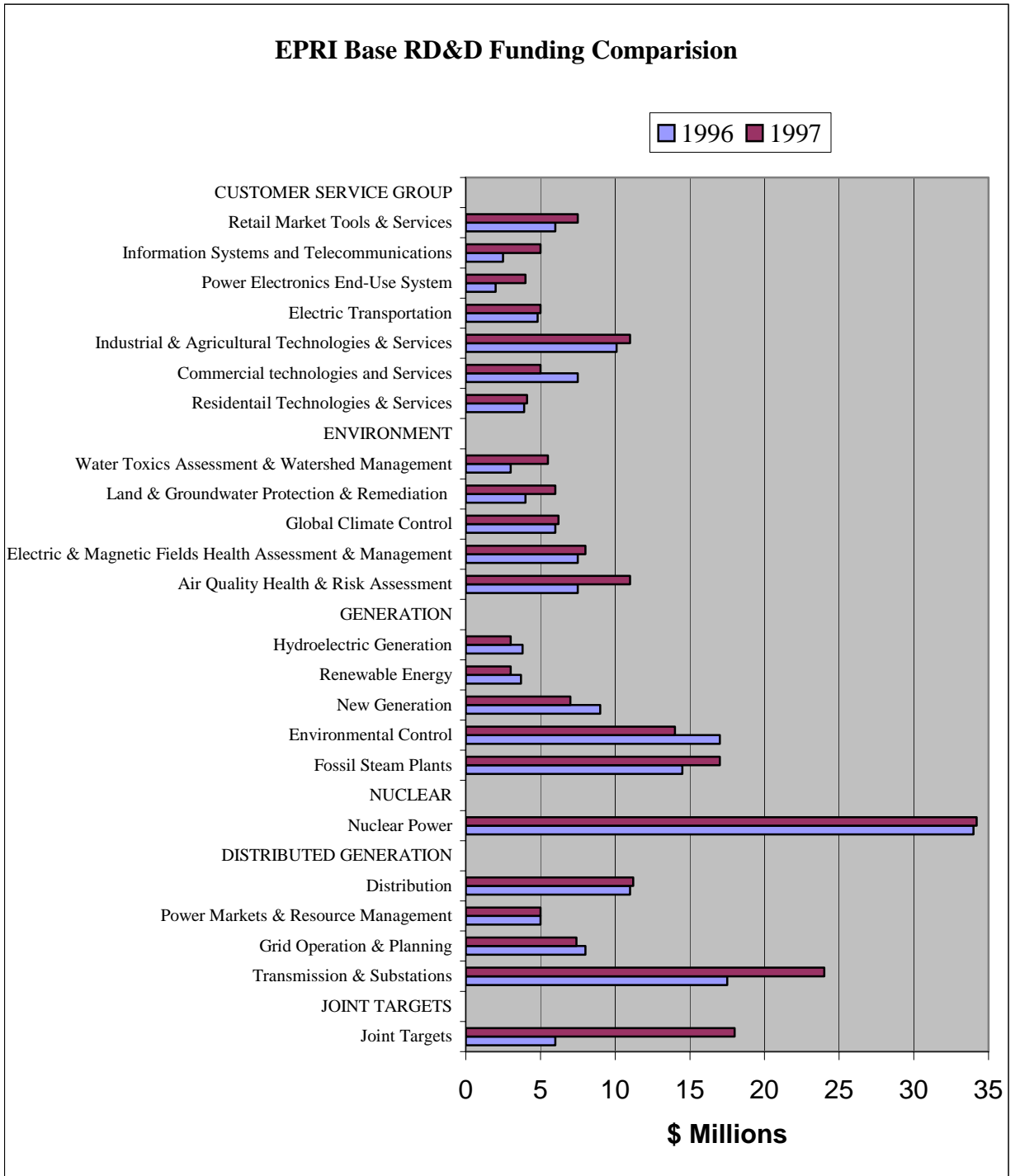


FIGURE 3(B)

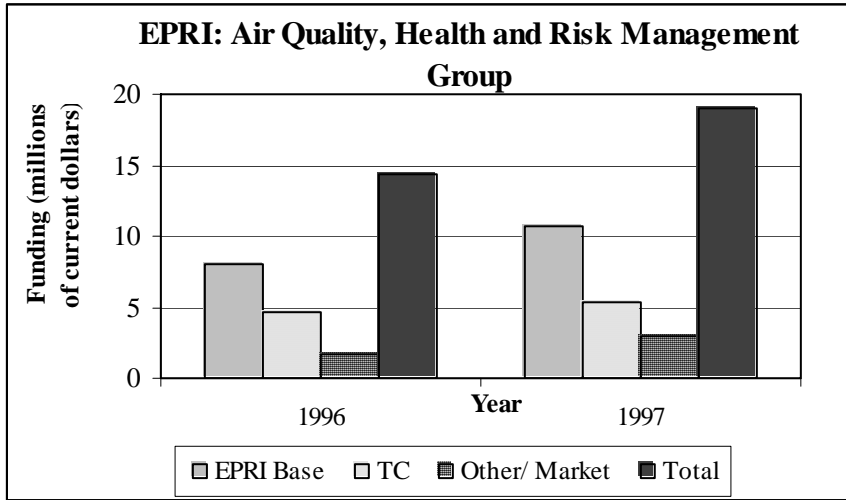
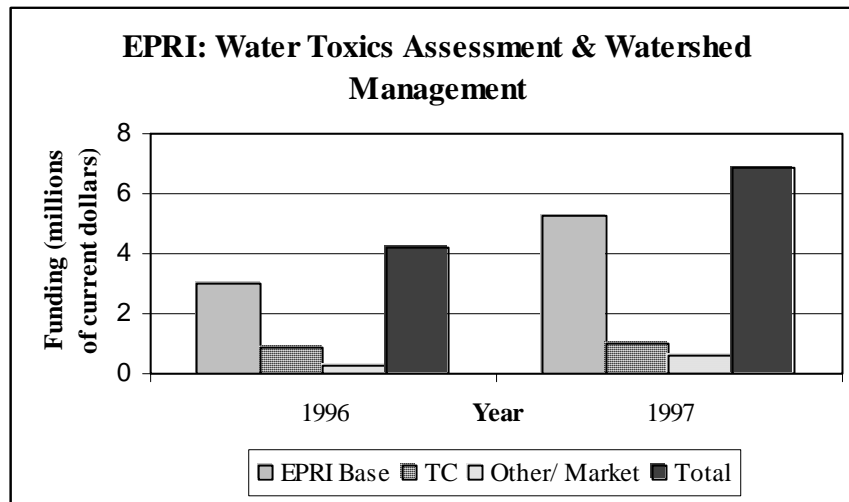


FIGURE 3(C)



SUPPLEMENTARY APPENDIX NOTE 1

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 and results are presented in the table below.

The "export" price gap measures the IOU's incentive to push for deregulation and is the difference between the state's price and that of the highest price neighbor bounded at zero. The incentive of retail customers to push for deregulation is measured by the "import price gap" (difference between the state's price and lowest price in a neighboring state bounded below at zero). The weighted standard deviation of utility-level average prices is used as another explanatory variable. The weight used is the utility-level electric sales revenue. If the variance in prices is large within the state, then customers of high priced utilities would pressure for deregulation. As a direct measure of the influence of pressure groups we use the share of the industrial and industrial plus commercial revenues. The size and strength of municipalities and co-ops is measured by the share of state electric revenue attributed to municipalities and electric co-operatives.

Ordered Probit Estimation

Dependent Variable is Deregulatory Status in 1998

Variable	Coefficients (Standard errors)
Price	31.94 (20.73)*
"Import" Price Gap	-1.23 (26.82)
"Export" Price Gap	41.50 (18.40)**
Weighted Standard Deviation of Price	10.51 (14.76)
Share of Industrial Revenue	-0.31 (1.64)
Share of Munis & Co-ops (1992)	-1.88 (0.91)**
League of Conservation Voter's Rating	0.217 (0.666)
Stranded Cost (billions of dollars)	0.009 (0.005)*
Obs.	50
Log Likelihood	-45.28

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.

SUPPLEMENTARY APPENDIX NOTE 2

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 National/Regional 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%