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ORIGINAL ARTICLE

The effect of deregulation on environmental research by electric utilities

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Abstract This paper analyzes the impact of deregulation and restructuring on public-interest environmental research conducted by electric utilities in the US from 1990 to 2001. I find that deregulation has had a substantial negative impact on such expenditures, which have declined by 40%. However, restructuring has had no significant impact. In addition, the 1990 Clear Air Act Amendments have adversely affected such expenditures, contrary to the positive impact these regulations had on pollution abatement R&D as shown in the literature. Results also suggest that state and firm characteristics and regulator preferences play a strong role in the conduct of such research.

Keywords Electricity deregulation · Environmental R&D · Clean Air Act

JEL Classifications O32 · L94 · L51

1 Introduction

The deregulation of the electricity industry in the U.S. originated with The Energy Policy Act of 1992. The subsequent FERC Orders 888 & 889 laid the groundwork for retail competition, while strengthening wholesale competition. Subsequently, the industry has undergone dramatic changes in market structure, organizational networks, prices and financial systems (Blumstein, 1997; Blumstein & Bushnell, 1994; Borenstein & Bushnell, 1997; Bushnell & Stoft 1995; Joskow, 1997, 1999; Pechman, 1993). This changed structure presumably

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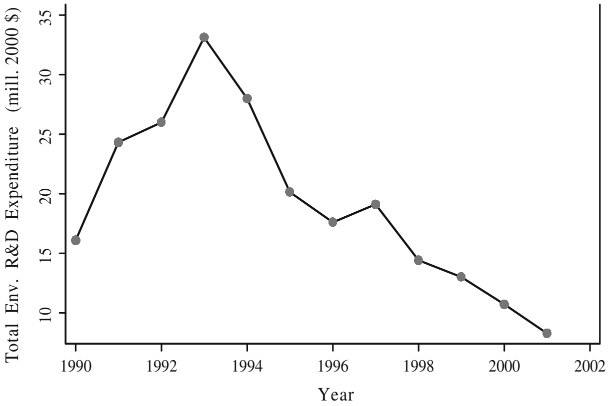

Fig. 1 Total environmental R&D expenditure for US electric utilities, 1994–2001

has implications for the environmental research and development (R&D) conducted by the industry (Energy and Environment Subcommittee, 1998; GAO Report 1996, 1998). One consequence is the sharp decline in environmental research expenditures after 1992, as seen from Fig. 1 above. This expenditure was primarily aimed at public-interest projects[1] and this raises concerns about the failure of the market adequately to provide such funds.

This paper seeks to explain this dramatic decline by focusing on the various factors influencing the environmental R&D decision of investor owned utilities (IOUs) when transitioning from a regulated to a market-based regime. I hypothesize that strong competitive pressures in the retail market and cost cutting measures may have resulted in such a decline and there may be a need for government intervention. I also study whether environmental regulations such as the 1990 Clean Air Act Amendments (CAAA) may mitigate such declines. The goal of this paper is to analyze how changes in market structure and conduct will influence such public-interest environmental research priorities by IOUs, the impact of the CAAA and firm and state characteristics on such research and the consequent implications for policy.

The influence of deregulation on environmental R&D expenditures depends on the nature of such research conducted. If the primary focus is on pollution abatement research, then competition may increase the incentive to adopt newer and cleaner technologies, leading to increased R&D expenditures. Environmental regulations such as the CAAA will give impetus to such spending. However, if the R&D is directed towards social goals and "public interest" research, such as research on global warming, common wisdom would argue that increased competition will lead firms to cut back on such spending (Blumstein, 1997; Hirsch, 1998; Testimony, 1998). In addition, pollution abatement

[1] There was very little pollution abatement research in this category since electric utilities conducted very little abatement research—rather the bulk of abatement expenditure was concentrated on compliance issues and is not considered R&D.

policies may have some unintended consequences of adversely affecting such research. Policies aimed at the expedited adoption of pollution control technologies may alter the incentive structure of firms and shift resources away from 'public interest' R&D to other short-term environmental expenditures aimed at meeting pollution standards. Under this scenario, research on energy conservation and other long-term environmental goals may be the biggest losers. Hence, a discussion on the nature and type of envirsonmental research conducted by the utilities is needed before we can blame deregulation for the decline in environmental R&D.

IOUs' environmental research expenditure comprise two main areas: (a) spending on 'public' projects such as research on global warming and effects of electromagnetic fields on health and (b) making plant-specific improvements to generic technologies. When analyzing the data, I find that the majority of such research spending by utilities was directed towards the former area.[2] Thus I argue that environmental R&D by electric utilities will be adversely affected due to competitive pressures since such research did not confer short-term cost reduction or efficiency enhancement benefits. In addition, as discussed earlier, policies such as the CAAA may negatively impact this expenditure by crowding out such expenditure in favor of other types of environmental spending.

My empirical results support the above hypotheses. I find that deregulation has had a tremendous negative impact on environmental research conducted by utilities and such expenditures have declined by 40% with the initiation of the deregulation process. Also, IOUs in states that have mandated the divestiture of generation, suffer an even greater decline in such expenditures hinting at crowding out issues. In addition, firm and state characteristics influence the conduct of environmental research as well. A larger, more profitable and primarily fossil fuel based firm invests more in environmental R&D as does IOUs in green states, wealthy states and states with a major share of coal generation. Last, I find that federal support for energy research is a complement to the environmental research conducted by utilities, pointing at a possible policy solution when faced with declining environmental R&D expenditures in the face of deregulation. In the discussion that follows these results are analyzed in detail against the backdrop of market restructuring and the conduct of environmental research in the electric power industry.

The rest of the paper comprises four sections. The first section provides a brief description of the organization of R&D in the U.S. power sector with specific reference to the conduct on environmental research by IOUs. The second section discusses previous research in the field and provides a framework for the current study. Data issues, detailed description of the variables and the empirical results are contained in the third section and the last section concludes.

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2 Most of the environmental research in pollution abatement technologies was conducted by electric equipment manufacturers such as Babcock and Wilcox and not by utilities.

2 Utilities and environmental research

R&D in the U.S. power industry was performed by four major entities during the regulated era—the utilities, Department of Energy (DOE), Electric Power Research Institute (EPRI) and the electrical equipment manufacturers such as General Electric. This paper focuses on the environmental R&D response of utilities. Restructuring led to 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. During 1990 through 1996, federal support for energy R&D had declined by 22%, (Dooley, 1996) while total R&D funding by the electric utilities fell by 33% to about $476 million, during the same period.

This paper focuses on the in-house R&D by the IOUs which was quite sizable during the period under consideration, although this varied greatly depending on the nature and size of the firm. The majority of research was conducted by big vertically integrated firms that owned generation, transmission and distribution assets. Companies that were solely distribution or transmission companies, invested very little in research. The composition of environmental research was biased heavily towards more 'public-interest' types of research and the subsequent discussion highlights this.

The environmental R&D expenditure by utilities needs to be understood against the role of electric equipment manufacturers, such as Babcock and Wilcox and General Electric. A majority of research and innovation in pollution control technologies was undertaken by equipment manufacturers in this industry. The major segment of a utility's in-house environmental research however, was directed towards social goals. In addition to organizations such as EPRI, which conducted fairly substantial amounts of long-term environmental R&D, utilities themselves investigated issues such as mitigating pollution in surrounding rivers, or making transmission lines safer for birds, effects of electromagnetic fields on health and global warming issues, to name a few. Air quality related research was also an important area for these utilities. For example in 1994, Southern California Edison spent $2.6 million on "Air Quality Enhancement", out of a total environmental R&D spending of $8.8 million as seen from the table below.

Table 1 below, shows the universe of environmental R&D projects undertaken by Southern California Edison from 1994 to 2000. The profile is fairly typical of other utilities as well. Three things are immediately clear. First, there has been a dramatic decline in spending over this period, from almost $9 million in 1994 to a mere $160,000 in 2000. Second, all the environmental research undertaken are 'public-interest' in nature and there is no project that focuses on pollution abatement efforts that would bring private benefits to the utility. Third, the big ticket items with potential externalities such as air quality research and environmental quality strategies have been replaced by smaller and more targeted research projects such as local climate modeling and hydro basic research projects.

Table 1 Southern California Edison's environmental expenditures, 1994–2000

Projects (1996 $)	1994	1995	1996	1997
Air quality enhancement	2,601,369	396,241	257,988	561,044
Natural habitat conservation	2,284,147	437,449	550,692	585,676
Occupational health and safety	1,226,857	0	0	0
Environmental quality strategies	2,707,278	747,511	617,727	1,109,398
Total	8,819,651	1,581,201	1,426,407	2,256,118
	1998	1999	2000	
Hydro Basin (DSS) research project	11,641	13,085	0	
ARCH+BIO resource application	631	7,882	550	
Dust mitigation in the desert	6,219	108,611	51,394	
Trans Lines (DSS) system	10177	0	0	
Temperature forecast	0	9,776	33,304	
Visualization tool	0	16,338	0	
EPRI Hydro relicensing	0	45,047	0	
Facility siting DSS	0	0	24,993	
Hydro resource management	0	0	45,584	
Local climate modeling	0	0	4,936	
Total	28,668	200,739	160,761	

Thus, given such an environmental R&D profile of utilities, I argue that both deregulation and the 1990 CAAA will have an adverse effect on such public-interest environmental R&D due to lack of cost pass-through, greater resource constraints and crowding out. However, some of these issues are not unique to the power industry and thus need to be analyzed in the context of broader and more general findings on market structure, regulation and innovation. The next section provides this background.

3 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 merge 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 such R&D expenditure and the interplay between market restructuring and environmental regulations.

3.1 Regulation and environmental research

The relation between market structure, R&D and technical progress has been the subject of extensive research (Kamien & Schwartz, 1975) in the industrial organization literature. Most studies however, have focused on the incentives of profit-maximizing firms. However, the utilities, subject to rate-based regulation, were subject to different incentives than maximizing profits and most major expenditures had to be approved by regulators. Hence, the framework for analyzing R&D in this sector differs from that of firms subject to market incentives.

From a theoretical perspective, research suggests that rate of return regulation produces slower technical progress when compared to other forms of regulation (Magat, 1976). In addition, regulation in general, can slow down preemptive technology adoption by firms and may also "preclude the adoption of superior technology" (Riorden, 1992). Hence deregulation should correct these inefficiencies and give impetus to technical progress and increase research spending. However, from a political economy perspective, one expects regulatory preferences to play a major role in determining research expenditures in a regulated industry. If regulators are social utility maximizers, then environmental research conducted by the IOUs under the regulatory regime should be socially optimal with regulators internalizing the externality and making the IOUs perform an optimal amount of public-interest environmental research. After deregulation, firms are concerned primarily with profit maximization and do not internalize the benefits of such research. Thus market restructuring would decrease such research spending.

3.2 Environmental regulation and innovation

From the above discussion we find that the impact of deregulation on environmental research can vary significantly depending on the type of regulation and research. However the relation between environmental regulation and innovation is less controversial with most authors documenting a positive relationship between innovation, R&D and the introduction of environmental regulation. Majority of the literature focuses on the impact of environmental regulation on pollution abatement R&D and technical change that confer private benefits to a firm (Jaffe, Newell, & Stavins, 2002). When investigating the impact of pollution control regulations on innovation, the induced innovation hypothesis postulates that such regulations provide incentive for expedited adoption of pollution abatement technologies. Based on a large panel of US manufacturing firms, Jaffe and Palmer (1997) have found that R&D is positively affected by regulatory compliance expenditures. Focusing on the CAAA, Popp (2002, 2003) finds that energy prices and energy policy has a significant impact on innovation and that the CAAA have increased innovation. In addition, Taylor, Rubin, and Hounshell (2003, 2005) have documented increases in environmental R&D both in anticipation of, and in response to, passage of environmental regulation such as the CAAA.

The primary contribution of this paper is that it focuses on public-interest environmental research by utilities. In addition, it investigates the impact of both market restructuring and environmental regulation on such R&D. It also studies the influence of firm characteristics and regulator preferences on the conduct of such R&D pre and post deregulation and offers insights about the conduct of public interest research in a deregulated market environment.

Table 2 Summary statistics

	Mean	SD	Min	Max
Dependent variable				
Total real environmental R&D (Mill. of 2000 $)	0.148	0.653	−1.347	9.771
Deregulation variables				
Deregulation index	0.979	1.229	0	3
Deregulation dummy	0.287	0.452	0	1
Restructuring dummy	0.229	0.420	0	1
IOU characteristics				
Profitability (ROA) (Lag: 1 Year)	0.140	0.039	−0.007	0.278
Log(Size) (Lag: 1 Year):Log(Total Assets, 2000$)	21.351	1.351	17.244	23.812
Share of hydro in generation	0.057	0.199	−4.360	1.002
Share of fossil fuel in generation	0.737	0.286	−0.003	1.013
Number of boilers in phase I & II	13.946	12.723	0	63
State characteristics				
LCV Senate rating	50.035	22.565	2	100
State wealth measure: Log(GSDP, Bill. of 2000$)	12.003	0.982	9.497	14.080
Divestiture policy dummy	0.438	0.496	0	1
Size of State Gen. Sector:Log(Tot. gen. in state, MWHs)	18.042	0.946	15.317	19.750
Coal state dummy	0.498	0.500	0	1
Log (Dept of energy electricity R&D support)	10.495	0.297	10.144	10.929

Note: No. of obs = 1389. In the estimation sample, the deregulation dummy has 398 ones, the restructuring dummy has 318 ones and the divestiture dummy has 608 ones

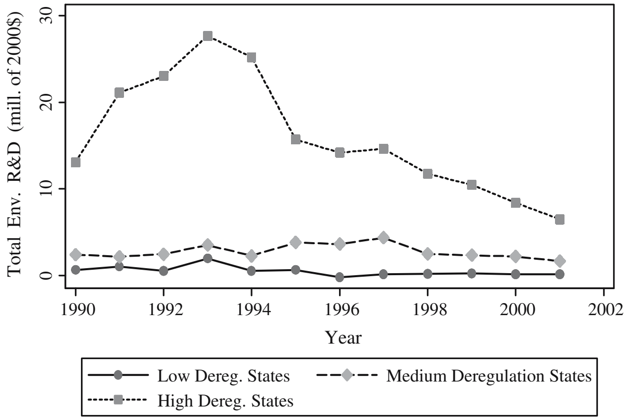
4 Data and empirical estimation

To analyze the above issues, I use utility level data from FERC Form 1 that all regulated utilities filed with the Federal Energy Regulatory Commission (FERC). This form contains generation data, financial variables and expenditure data such as R&D expenditures. The major source for the state-level data is the EIA (Energy Information Administration). The regulation variables are drawn from EIA's publication on the status of deregulation in each state. The unit of observation is the firm (utility) and not a plant, since R&D decisions are made at the firm level. Years range from 1990 to 2001. In addition I use state level restructuring data to capture market structure changes and prevailing ground conditions in a state. Summary statistics are provided in Table 2 above. Detailed variable descriptions and results are provided in the next sections.

4.1 Dependent variable

The environmental spending considered in this study is the discretionary part of a firm's budget[3]—and is a component of the internal R&D expenditure by

[3] 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 are different from research spending, since plants still need to satisfy basic EPA guidelines concerning environmental protection and pollution control.



Note: Data based on estimation sample

Fig. 2 Total environmental R&D expenditure for electric utilities by deregulation status, 1990 - 2001

the IOUs. Focusing on this segment permits me to study firm behavior under regulation and competition, and thus provides insights into the R&D decision process under various market structures. First, I disaggregate the R&D response by status of deregulation (High, Medium and Low) to see whether utilities in high deregulation states really behave different from those faced with low deregulation (Fig. 2).[4] I classify states according to the stage of deregulation they reached in 1996. For example if a state reached full deregulation in 1996 (i.e. legislation has been passed to implement retail access), then it is classified as a high deregulation state for all years. A medium deregulation state is one where order has been issued for retail access by 1996, and low states are those that show little activity of have investigations ongoing in 1996. The choice of 1996 stems from the observation that this is the first year that showed widespread deregulation activity and IOUs could form expectations about the pace of deregulation based on activities in this year.

Two important points emerge, (a) states with high deregulation show the greatest decrease in environmental research and (b) medium and low deregulation states show very little change and their R&D is very small to begin with. Thus when investigating the impact of deregulation on such research expenditures, one needs to control for state regulatory preferences that may have made IOUs in some states invest more in environmental research.

There is considerable heterogeneity across firms as well. Figure 3, which plots environmental research expenditures by firm id and year, shows some interesting trends. Firms that were outliers before deregulation (i.e., conducted considerably more environmental research than other IOUs) such as Southern California Edison (161),[5] Pacific Gas and Electric (133) and Niagara Mohawk

[4] Electric utilities conducted very little pollution abatement research—rather the bulk of abatement expenditure was concentrated on compliance issues and is thus not considered R&D.

[5] Firm identifier in parenthesis.

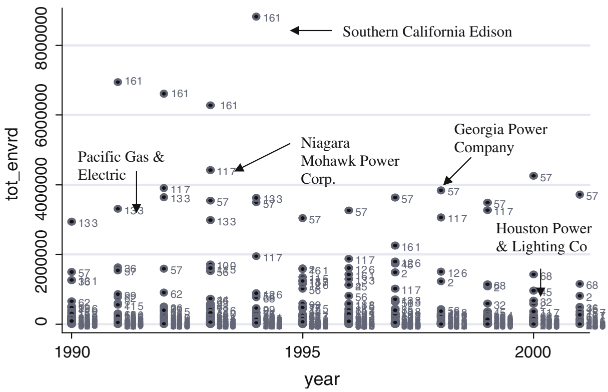


Fig. 3 Environmental R&D expenditures by IOUs

Power Corp (117), are located in California and New York, the pro-reform green states. These are the utilities that show the maximum decline after deregulation. On the other hand, utilities such as Georgia Power Company (57) and Houston Power and Light Company (68) show increasing environmental R&D expenditures during the sample period. The empirical model attempts to explain such variations and analyzes how much of the decline in environmental research expenditures can be attributed to the electricity market deregulation after controlling for firm and state characteristics.

In the empirical model, environmental R&D expenditure (measured in millions of 2000 dollars) is the dependent variable. The basic model I estimate is given by:

$$RD_{it} = \alpha + \delta_1 \text{Deregulation\_Dum}_{jt} + \delta_2 \text{Restructuring\_Dum}_{jt} + \sum_{m=1}^{M} \phi_m \text{Firm\_Characteristics}_{it} + \sum_{k=1}^{K} \lambda_k \text{State\_Characteristics}_{jt} + \varepsilon_{it}$$

where i denotes the firm, j denotes the states and t denotes the year. The dependent variable contains a substantial portion of zeros. 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.

Thus I use a random effects tobit specification[6] to estimate the model, with the lower bound set at zero. The period under consideration is 1990–2001. The

[6] 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. 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.

panels are unbalanced with a minimum observation of five and a maximum of eleven, due to missing observations. If utilities have not reported a positive number or zero in a particular year, I set the value to missing. As a robustness check, I have substituted the missing values with zeroes and have re-estimated the model and the results do not change significantly.

4.2 Basic model (Table 4)

4.2.1 Deregulation & restructuring

The pace and nature of deregulation and restructuring has been different in every state. Table 3 below shows the four main stages of the deregulation process. This is obtained from EIA's publication "Status of State Electric Industry Restructuring Activity, 2003" that outlines the regulatory orders, legislations and the investigative studies that have been undertaken by each state till present.

To capture the different stages, I construct two dummies. The *deregulation dummy* turns on when a state passes an order for retail competition. The *restructuring dummy* takes the value 1 when the state has either enacted or implemented legislation for retail access. I expect the deregulation dummy to have a negative coefficient since a major portion of a utility's environmental research is 'public' and long-term in nature and hence will react adversely to the first signs of competition. The restructuring dummy may or may not have any impact on environmental research expenditures.

From Table 4, I find that deregulation has had a strong negative impact while restructuring has no effect. When a state passes a deregulatory order, utilities in that state decrease environmental research by almost 40%. If this was ordinary investment of R&D aimed at short-term efficiency enhancement, this response would suggest that the decline is being driven by the regulatory uncertainty associated with the transition phase. This would be similar to arguments in the option valuation literature that posits withholding investments till the arrival of more information (Dixit & Pindyck, 1994; Hassett & Metcalf, 1993).

However, with 'public-interest' environmental research the decline is probably due to utilities' profit-maximizing response after deregulation and not merely a reaction to uncertainty. Market failure theories suggest socially sub-optimal investment when externalities cannot be fully internalized by firms. Thus after deregulation, utilities should decrease all research that do not confer efficiency benefits or are not needed to meet environmental compliance

Table 3 Stages of deregulation

Stage I: No activity,	Stage III: Order issued For retail competition
Stage II: Investigations ongoing or orders and legislation pending	Stage IV: Legislation enacted to implement retail access

Table 4 Basic Model: Dependent variable is real environmental R&D expenditure (2000 $)

	(1)	(2)	(3)	(4)
Basic restructuring variables		Conditional marginal effect	Unconditional marginal effect	Semi-elasticity (%)
Deregulation dummy	−0.280**	−0.059*	-0.059*	−39.865
	(0.133)	(0.032)	(0.031)	
Restructuring dummy	−0.085	−0.016	−0.016	-
	(0.139)	(0.033)	(0.033)	
IOU characteristics				Elasticity (%)
Profitability	6.993***	1.566***	1.616***	1.528
	(1.123)	(0.298)	(0.331)	
Log(Size)	0.648***	0.141***	0.145***	0.980
	(0.054)	(0.010)	(0.011)	
Share of hydro in total generation	−0.098	−0.009	−0.009	-
	(0.234)	(0.054)	(0.056)	
Share of fossil fuel in total generation	1.330***	0.264***	0.272***	1.355
	(0.283)	(0.057)	(0.057)	
"Greenness"& federal R&D support				
LCV Senate rating	0.004*	0.002**	0.002**	0.676
	(0.002)	(0.001)	(0.001)	
Log (Department of energy electricity R&D support)	0.314***	0.079**	0.081**	0.534
	(0.118)	(0.028)	(0.030)	
Constant	−20.084***			
	(1.881)			
Fraction of variance due to U_i	0.689			
Wald Statistic: Chi-Square	329.62			
No. of firms	134			
No. of observations	1389			

Note: The estimation technique is a random effects tobit model. 465 observations are uncensored. The lower limit is set to zero. The panel is unbalanced (min obs = 5, max = 11). Range: 1990-2001. '**' denotes significance at 5% and '*' denotes significance at 10%. A Wald test shows that all coefficients are jointly significant. Conditional Marginal Effect in column 2 shows the marginal effects for the expected value of y conditional on being uncensored and Unconditional Marginal Effect in column 3 shows the marginal effects for the unconditional expected value of y. The elasticities and semi-elasticities in column (4) are based on the unconditional marginal effects in column (3). Standard errors in parenthesis

regulation. The restructuring dummy is not significant since utilities anticipating further deregulation, may have already cut back on environmental research following the first signs of change. Therefore, actual restructuring, when it happens, has little impact. In all subsequent specification this result holds and there is no statistical difference between the coefficients.

As a robustness check, I re-estimate this basic model by including state fixed effects (results not reported here). This is done to partially address concerns about endogeneity. It addresses the problem that state unobservables may not be adequately controlled for in the estimated equations and these may be influencing both the environmental R&D and regulatory variables and contaminating the results found so far. I find that including the fixed effects in the basic model leaves the deregulation results unchanged. This makes earlier results less suspect to endogeneity concerns.

4.2.2 Firm characteristics

Firm size Any financial decision undertaken by a firm is influenced by firm-specific characteristics. DeCanio and Watkins (1998) show that firm characteristics influence environmental technology adoption and hence become important as explanatory variables when modeling environmental research expenditures. I use the log of total assets as an indicator for the *firm size*. Presumably a large firm would conduct more environmental R&D since it can better internalize R&D spillovers. From Table 4, I find that larger firms invest more in environmental R&D confirming findings from previous literature (Cohen & Levin, 1989; Lunn, 1986). Specifically, a 1% increase in firm size increases environmental R&D by a similar or slightly lower percentage suggesting mildly decreasing returns to scale.

Firm type In addition to size, the type of generation should also affect environmental research. A coal-based plant may invest heavily in, say, air pollution research, to placate regulators compared to hydro plants. I use the *share of hydro and fossil fuel in total generation*, to capture the generation mix of a firm. I expect the share of fossil fuel to positively impact environmental research and the share of hydro in generation to have negligible or negative impact. I find that as the share of fossil fuel in the generation mix increases, environmental R&D increases by almost 1.4% on average, while hydro generation has no impact on such expenditures.

Profitability The financial health of the firm is measured by *profitability*. The definition is taken from the finance literature where it is constructed by: EBITDA (Earnings before interest, taxes, depreciation and amortization) divided by total assets (Rajan & Zingales, 1995). The hypothesis is that a company with more spare resources would spend more in research activities. Results in Table 4 show that profitability has a strong positive impact on environmental research and a one percent increase in profitability increases such spending by 1.5%.

4.2.3 Greenness and federal R&D support

Green Regulators For any regular 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 undertaking such decisions. 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). This scorecard evaluates the annual voting records of state congressmen and senators on various environmental bills and assigns a value for each pro-environment vote. These are then summed up to come up with a score for each state. A higher score implies a more favorable environmental record and thus 'greener' regulators, who may be willing to take strict action against pollution.

I use the *LCV Senate Rating* to capture this characteristic and argue that the post-deregulation decrease in environmental R&D should be less for IOUs located in 'green' states, or conversely, being located in a 'green' state should increase environmental R&D. Table 4 shows that the coefficient on LCV rating is positive and significant and a 1% increase in the rating increases environmental expenditures by 0.7%. Thus political pressure seems to play a role in the conduct of environmental R&D by these firms, although the impact is much smaller than the deregulatory 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 sharp decline.

Federal energy R&D support The federal government invests substantial amounts in energy research by way of matching grants to states, over and above the R&D directly conducted by the Department of Energy. As pointed out earlier, there has been a significant decline in federal R&D support during our sample period and this effect needs to be controlled for, since it would otherwise contaminate the results. I find a complementary relationship between federal support and a utility's environmental research spending. My results suggest that about 0.5% of the environmental R&D decline can be directly attributed to a decline in federal support.[7]

4.3 Impact of state characteristics and the CAAA (Table 5)

4.3.1 Additional state characteristics (Column 1)

Divestiture policy One of the fundamental premises of deregulation was the introduction of competition through the unbundling of generation assets from transmission and distribution. However, states varied widely in their approach towards meeting this goal. Some states such as New York adopted mandatory divestiture of generation assets. In states such as Massachusetts and California, divestiture was encouraged but not required, while others did not require divestiture at all. Thus, I construct a *divestiture dummy* to capture state policy regarding the divestiture of generation assets. The dummy takes the value 1 if the state mandates or actively encourages divestiture of generation assets. This should have a negative impact on environmental research since a majority of the environmental research is connected in some way to generation activity, such as air pollution and hydro basin research. Empirical results confirm that encouraging or mandating the divestiture of generation assets depresses environmental research (Table 5). A point to note is that the coefficient on the deregulation dummy is not significantly different from before which lends credence to the

[7] The elasticity is 0.5 and federal R&D support for energy fell by almost 25% during the sample period.

Table 5 Effect of state characteristics. & CAAA: Dependent variable is real environmental R&D expenditure (2000 $)

Variable	Effect of state characteristics	CAA & Coal states	CAA pre and post deregulation
Deregulation dummy	−0.255*	−0.280**	−0.358*
	(0.148)	(0.129)	(0.198)
Restructuring dummy	−0.128	−0.127	−0.118
	(0.154)	(0.132)	(0.211)
IOU characteristics			
Profitability	5.464***	6.738***	6.818***
	(1.084)	(1.082)	(1.086)
Log(Size)	0.451***	0.607***	0.613***
	(0.048)	(0.061)	(0.062)
Share of hydro in total generation	−0.082	-	-
	(0.213)		
Share of fossil fuel in total generation	1.117***	1.102***	1.105***
	(0.179)	(0.176)	(0.175)
"Greenness"& federal R&D support			
LCV Senate Rating	0.005*	0.007**	0.007**
	(0.003)	(0.003)	(0.003)
Log(Department of energy electricity R&D support)	0.412***	0.419***	0.421***
	(0.115)	(0.116)	(0.116)
State characteristics			
Log(State wealth measure)	0.580***	0.475***	0.479***
	(0.107)	(0.065)	(0.066)
Divestiture policy dummy	-0.298**	−0.238**	−0.242**
	(0.122)	(0.101)	(0.100)
Log(Size of state's generation sector)	−0.135	-	-
	(0.124)		
Coal state dummy	0.201*	0.192**	0.194**
	(0.105)	(0.094)	(0.094)
Clean air act characteristics			
Number of Phase I & II Boilers	-	−0.011**	−0.013**
		(0.005)	(0.006)
Interaction: No. of phase I & II Boilers * Deregulation dummy	-	-	0.004
			(0.008)
Interaction: No. of phase I & II Boilers * Restructuring dummy	-	-	-0.0001
			(0.009)
Constant	−21.062***	−26.253***	−26.057***
	(2.056)	(1.897)	(2.152)
Fraction of Var. due to U_i	0.651	0.630	0.632

Note: The estimation technique is a random effects tobit model. 465 observations are uncensored (total obs. = 1389). The lower limit is set to zero. The panel is unbalanced (min obs = 5, max = 11) and comprises 134 IOUs. Range: 1990-2001. '**' denotes significance at 5% and '*' denotes significance at 10%. A Wald test shows that all coefficients are jointly significant. Standard errors in parenthesis

result that it was deregulation and not any peripheral policies connected to it that led to the sharp decline in environmental research expenditures.

State wealth. In addition to the above state characteristics state wealth may influence environmental research expenditures. The environmental justice literature proposes that richer areas usually have greater environmental consciousness (Arora & Cason, 1999). 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 the gross state product (billions of real dollars) (Bureau of Economic Analysis) for each state in a given year. I find that firms in richer states conduct more environmental research. I argue that 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.

Size of generation sector. Another factor that may affect environmental expenditures by utilities is the *size of the generation sector* in the state. I use the log of total electricity generated in a state (in megawatt hours) to capture this. Since 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. However, I find that the size of the generation sector has no effect on a firm's conduct on environmental R&D.

State fuel mix. Last, the fuel mix in a state may also determine regulators preferences towards environmental R&D expenditure. 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 obtained from the EIA database. However apriori, the impact of this variable on environmental R&D is not clear. On one hand, 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 counter the effects of coal-based generation. However, one may also argue that states with a greater coal share are less concerned with environmental issues and thus would not pressure their utilities to conduct environmental research. Hence, there is no apriori expectation about the sign of the coefficient.

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 2.68%[8] 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. 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. For sensitivity analysis I also construct dummies where the dummy takes the value 1 if coal

[8] The marginal effect for the unconditional expected value of y is 0.037 and the standard error is 0.018.The Since the regressor is a dummy: the percentage effect is calculated as: 100(exp (b–v(b)/2))−1. See Kennedy (1981).

accounts for 75% of the generation, 85% of the generation, or is above the U.S. mean or median in that particular year. Results remain unchanged.

4.3.2 Impact of the Clean Air Act Amendments CAAA (Column 2 and 3)

During the period under study, major environmental regulations were enacted that specifically targeted electric utilities. In 1990, Congress adopted Title IV of the Clean Air Act whose primary goal was to decrease emissions of sulfur dioxide and nitrogen oxide from power plants.[9] Earlier empirical evidence suggests that firms have increased environmental R&D both in anticipation of, and in response to, passage of the CAAA (Taylor et al., 2003). Thus to avoid confounding effects, one needs to control for the effect of the CAAA on environmental research by utilities before making definitive statements about the magnitude of impact attributed to deregulation.

To capture the effect of the CAAA, I include the *number of Phase I and II boilers* for each IOU (EIA, Clean Air Database) as a regressor in the estimation equation. For each utility, this variable counts the number of boilers that have to be brought under compliance according to the new guidelines. This measures the amount of CAAA exposure that each utility is faced with. When faced with the immediate threat of emissions reduction and bringing boilers under compliance, firms move money away from long-term social-goal oriented R&D and focus on the immediate pollution abatement issues. I expect that may greater the exposure to new regulations, the larger should be the reduction to such public-interest environmental research. From Table 5 column 2, I find that the CAAA (as captured by the number of Phase I and II boilers that have to be brought under compliance) has a negative impact on a utility's environmental research.

This result is in direct contrast to the evidence presented by Jaffe and Palmer (1997) and Taylor (2003), which show a positive relationship between environmental stringency and R&D. These earlier works focused on profit maximizing firms and their investment in pollution abatement technology as a response to meeting the challenges posed by environmental regulation. However, the environmental research expenditure by utilities is different. It is more long-term and social in nature. Thus I argue that meeting compliance requirements takes priority after the passing of the CAAA and such 'social' research is crowded out. However, although significant the economic impact of the CAAA on such R&D is small compared to the effect of deregulation. On average, a 1% increase in the number of targeted boilers decreases such expenditure by 0.2% or alternatively, for every boiler brought under compliance, this research expenditure drops by $2000. When compared to the effect of deregulation, which leads to a

[9] This raises an important caveat to this paper's findings. Since the 1990 CAA and the deregulatory activity were influencing a firm's decisions at the same time, the time-series portion of this identification is weakened by the 1990 CAA. However, since the econometric specification relies both on time series and cross-section variation in deregulatory status to identify the changes in environmental R&D the results are robust.

40% decline in such expenditures, the impact of the CAA is not economically significant.

In addition, I also study whether the impact of the CAA is different pre and post deregulation. One could argue that the decline in environmental R&D expenditure would be greater post deregulation since the threat of future competition and lower regulator oversight would further dampen such expenditure in firms with a big compliance goal. However, from Table 5 column 3, I find that the effect of the CAA is the same pre and post deregulation and restructuring.

Last, as a robustness check and to investigate whether utilities with a greater compliance burden behave differently when they are located in coal states, I interact the coal state dummy with the number of Phase I and II boilers for each utility. This study's earlier finding suggests that IOUs in coal-heavy states conduct more environmental research than their counterparts in non-coal states. Given this result, one would expect this interaction term to be positive, implying that being located in a coal state would mitigate the crowding out of such expenditure. However, I find no such effect (results not shown). In addition, the impact of deregulation is robust to all alternative specifications and underlines the fact that the significant decline in environmental R&D can be primarily to regulatory changes in the electricity market.

5 Conclusion

Restructuring of an industry always raises concerns about competition adversely affecting funds for pursuing social goals such as pollution abatement and global warming research. The electric utility industry is a good example, where the majority of research conducted by IOUs was long-term 'public-interest' projects. I find that deregulation has led to a substantial decline in such environmental R&D. Results indicate that the greatest adverse impact follows the passing of a deregulation order. Subsequent restructuring legislations have little impact on such expenditures. So as deregulation progresses, will research expenditures by IOUs suffice in meeting the environmental goals or will the federal government have to step in? Evidence suggests that in the absence if regulation, the government may need to step in and conduct such long-term research. In addition increasing federal R&D support of energy research by way of matching grants to states will also have a positive impact on utility research as shown by the empirical analysis.

Another important factor that emerges from the empirical models is the effect of the Clean Air Act Amendments on public-interest environmental R&D expenditures by utilities. As IOUs fall under stricter environmental guidelines (like the increase in the number of boilers covered by the regulation), they spend less on public-interest environmental research, most likely as a result of resource constraints and crowding out of such long-term research in favor of short-term expenditures on compliance. Thus stricter pollution abatement requirements on power plants may have the unintended consequence of decreasing long-term environmental R&D and exacerbating the decline (Gollop & Roberts, 1983).

The size and nature of a firm also influences environmental research expenditures. I find that a large, profitable and fossil fuel based utility invests more in environmental R&D than a small, less profitable non-fossil fuel based firm. State characteristics also matter for the conduct of such research Utilities in 'green' and wealthy states spend more on environmental research, as do those in coal states. However, none of these effects are big enough to counter the major decline in environmental research brought about by deregulation. After robustness checks and inclusion of different control variables, the result that deregulation leads to a 40% decline in environmental research remains unchanged. This, coupled with the fact that federal R&D support is a complement to utility environmental research, hints at a role for the government in the conduct of such research in the post-deregulation period. Thus, for the period under consideration, the market seems to be doing a less than adequate job regarding environmental R&D funding and in the future, government R&D support may be needed to makeup for the shortfall.

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