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Market Restructuring, Competition and the Efficiency of Electricity Generation: Plant-level Evidence from the United States 1996 to 2006

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Market Restructuring, Competition and the Efficiency of Electricity Generation: Plant-level Evidence from the United States 1996 to 2006[1]

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Abstract

Market restructuring commenced with the passing of the Federal Energy Policy Act of 1992 and FERC Order No. 888 in 1996. These measures permitted nonutilities to enter wholesale markets and placed greater emphasis on market-determined prices.[3] In 1996, California became the first state to pass independent market restructuring legislation that introduced competition into retail markets. The initiative was aimed directly at investor-owned plants and included increased use of wholesale trading of electricity, the unbundling of generation, transmission and distribution so that consumers could choose a supplier of generation services and the abolishment of cost-based regulation. Table I shows that 23 states followed California between 1996 and 2002 by passing similar restructuring initiatives. By the end of 2002, 17 of these states[4], along with California, had actually implemented restructuring and permitted retail competition in electricity markets. By removing restrictions on revenue and exposing plants to competitive forces, market restructuring should have incented managers to increase plant efficiency in order to decrease costs. We use variation in the timing of the implementation of market restructuring initiatives across states from 1996 to 2006 to transitioning toward retail competition. Fabrizio et. al. (2007) estimate input demand functions for 769 fossil fueled plants from 1981 to 1999. They show that the labor and non-fuel expenses of plants in states that passed market restructuring legislation were about 3 to 5 percent lower than similar plants in states that did not pass legislation. Furthermore, these efficiency gains almost double when compared to the municipality-owned plant benchmark. Fabrizio et. al. conclude that investor-owned plants in restructuring regimes increased their efficiency "in anticipation of increased competition." Zhang (2007) estimates a reduced-form model on 73 nuclear plants from 1992 to 1998 and shows that the passing of market restructuring legislation was associated with a reduction in fuel, operating and maintenance costs by about 11 to 23 percent.[5]

In addition to research on cost savings and efficiency improvements, many papers have looked at the effect of restructuring on prices. Joskow (2006) offers an investigation of industrial and residential retail prices following restructuring. He finds that wholesale and retail restructuring lead to lower retail prices. Taber et. all (2006) investigate prices for residential, industrial, and commercial prices, finding that results "do not support a conclusion that in aggregate deregulation has lowered electricity rates relative to those rates in still-regulated states."[6] For a more full review of the results of restructuring on prices and pitfalls associated with investigation read Kwoka (2008).

We contribute to this literature by developing a unique and comprehensive annual data set for of over 950 coal, natural gas and petroleum fueled generation plants from

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[5] Kleit and Tecrell (2001) use data from 78 gas plants at 1996 to estimate the possible cost savings from restructuring the electricity industry. Results from a Bayesian stochastic frontier cost model suggest that restructuring could reduce production costs by up to 13 percent.

[6] Taber et all. pg. 29

1996 to 2006. The data represent six different types of generation technology and that the efficiency gains from restructuring may have spilled over to non-restructured, publically-owned plants. We also estimate a selection model that measures the effect of market restructuring on efficiency, given the observable plant was an efficient producer to begin with. The results from this model suggest that the efficiencies from market restructuring stem from internal organizational and technological changes within the plant and are not due to plant attrition or mergers[8] over time.

The paper is organized as follows. Section II describes the competition-efficiency hypothesis in the context of U.S. electricity generation and outlines the empirical model we used to test the hypothesis. The data are described in Section III. Section IV presents the empirical results and Section V uses the results to calculate the potential reduction in greenhouse emissions due to market restructuring. Section VI concludes.

II. EMPIRICAL MODEL

II (i). *Competition-efficiency hypothesis*

About 90 percent of U.S. electricity was generated by steam-cycle technology in 2006 (Energy Information Administration (EIA), 2009). Coal, natural gas, nuclear fission or petroleum was used to heat a water boiler and the steam from the boiler rotates a turbine consumers through regulated prices. In contrast, managers in states with market restructuring are subject to entry, exit and competitive pricing. For example, when operating in wholesale market bid systems, firms can submit bids to the spot market that indicate the prices and supply from their generation plants. The ranking of bids from lowest to highest price determines the electricity dispatch order and the market wholesale price, which is the price bid from the marginal plant (Fabrizio et. al.; 2007). Plants with low variable costs are placed higher in the dispatch ranking and can earn higher expected profits through relatively larger price-cost margins and by increasing their likelihood of supply. Plants with high variable costs face the prospect of short-run losses and ultimately potential exit from the market place.

Because they are subject to competitive forces, plant managers that are located in states with restructured electricity markets have a strong incentive to increase efficiency by reducing their plant's heat rate. This is achieved by implementing industry best-practice maintenance and operational procedures, downsizing, upgrading to higher quality fuel, and/or by introducing new technologies. For example, refined technology equipment components provide a more reliable and accurate damper control of boiler temperature. This helps the plant opw[(ulwi)]TJ16.415 0 TD.0003 Tc-.0009 Tw(zte the cobdustion ofai(r ar

II (ii). *Model*

We test the competition-efficiency hypothesis with a DID model that compares the efficiency of generation plants located in states with market restructuring to the efficiency of similar plants in states without restructuring. The model for plant i = l, …, n in state s = 1, …, S at year t =1, …, T is:

$$logEFF_{ist} = \beta RESTRUCTURE_{st} + W_{is}\delta + X_{ist}\gamma + \alpha_s + \eta_t + \varepsilon_{ist} \qquad (1)$$

where *EFF* is thermal efficiency, *RESTRUCTURE* equals one when the plant is located in a state with market restructuring, as defined by state initiated major retail choice, and zero otherwise[10], *W* is a vector of time-invariant plant characteristics, *X* is a vector of time-varying plant characteristics, the α's are unobserved state fixed effects, the η's are unobserved time fixed effects and ε is an error.

The parameter of interest is $\partial logEFF/\partial RESTRUCTURE = \beta$, which indicates the percentage difference in efficiency due to market restructuring. A finding of $\beta < 0$ supports the hypothesis that the competitive forces from market restructuring lower the heat rate and increase thermal efficiency. The DID estimate of β is consistent when restructuring is randomly assigned between states. However, as noted by Grogger (2003) and Zhang (2007), policy endogeneity can arise when unobserved time varying state factors affect the timing of electricity market restructuring. For example, when changes in unobserved management practices, resulting in lower production costs, are positively correlated with changes in *RESTRUCTURE,* the estimate of β will be biased downwards. One way to minimize this bias is with instrumental variables. We employ an instrumental variable approach where the first stage is composed as:

[10] We will explore alternative measure of restructuring later

$$RESTRUCTURE_{ist} \qquad Z_{st} \quad W_{is} \qquad X_{is} \qquad a_s \qquad {}_{t} \qquad {}_{ist} \qquad (2)$$

Where again *W* is a vector of time-invariant plant characteristics, *X* is a vector of time-varying plant characteristics, the *α*'s are unobserved state fixed effects, the η's are unobserved time fixed effects and is an error. The vector of instruments used is Z, and comes from predictors found by Craig (2009) used to predict state restructuring. We estimate the first stage using linear regression instead of Hazard or probit estimation following along with the findings of Angrist & Krueger (2001) and Kelejian (1971), which conclude that using a linear first stage on dummy variables produces consistent second stage estimates.

Alternatively, it is possible to decompose the error term into observed and unobserved state-time components that may be correlated with *EFF* and *RESTRUCTURE* so:

$$ {}_{ist} \qquad TREND_{st} \qquad e_{ist} \qquad\qquad (3)$$

where *TREND* is a vector of state-specific time trends that control for unobserved state effects that vary through time and *e* is an error term that is not correlated with *RESTRUCTURE*, *X*, and *W*.

There are two specification issues we must address when estimating equation (1). The first concerns the elements within the *TREND* vector. We follow Ziliak et. al. (2000) and Grogger (2003) by estimating equation (1) with alternative state-specific time trends. Because our observations represent plants in geographic markets, it is possible that there are shocks or unobservables that are common or correlated across nearby markets. While this does not affect the consistency of our estimator, it does impact the standard error. To address this issue, we allow correlations in the residuals across plants in the same state when computing these standard errors. This is reasonable, for example, if some unobservable characteristics of plant efficiency are determined at the state level. The second issue concerns attrition bias whereby the dependent variable, thermal efficiency, is observed for a restricted non-random sample of annual observations for plants that survive the entire sample period. We address this potential bias with a selection model that estimates the effect of market restructuring on efficiency given the observed, "surviving" plant was a relatively more efficient generator of electricity to begin with.

III. DATA

III (i). *Sample*

We follow the industry standard and define a plant as a facility that contains prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and fission energy into electric energy. A prime mover is the engine, turbine, water wheel or similar machine that drives an electric generator or a device that converts energy to electricity directly. Ideally, we would prefer to measure production from the individual generating units within each plant but this data is not publicly available.

Annual data on location, ownership structure and production for 977 steam-cycle plants were sourced from Ventyx Energy.[11] 717 plants are investor owned and 260 are municipality owned. These plants are used for the empirical analysis because they are observed at the beginning of the sample period and have no missing or unusual observations in subsequent years. The data are from 1996 to 2006 and represent plants in all 50 states and the District of Columbia. The sample plants are fired by coal, natural

[11] Ventyx Energy (formerly Global Energy Decisions) gather data from FERC and other reporting services, and package these data to private and government entities.

gas and/or petroleum and accounted for about 48 percent of total U.S. net generation by all energy sources at 2006, and about 67 percent of total U.S. net generation by coal, natural gas and petroleum (Ventyx Energy, 2007; Energy Information Administration (EIA), 2009).[12]

We merged our plant data with state-level information on median personal income, the relative size of industrial customers, electric utility revenue and policy makers' preferences for competition, obtained from the EIA (2009), Federal Communications Commission (FCC, The unit of observation is plant i = l, …, n in state s = 1, …, S at year t =1, …, T.[13] The outcome variable of interest is thermal efficiency, or, the net heat rate (*EFF*). This is the number of Btu's of fuel used to generate a mWh of electricity that is sent from the generation plant to the grid.[14] The key explanatory variable of interest is *RESTRUCTURE*, which equals one when the plant is located in a state that implemented market restructuring, and this restructuring remains active, and zero otherwise.[15]

The vector of time-invariant plant characteristics, *W*, describeh of e thm.00(e-iJ/movers-21.535)]T3 '

The vector *X* contains time-varying plant characteristics that may affect efficiency. *CAPACITY* (maximum sustainable amount of *mWh* of electricity generated per hour by the plant)[17] and *UNITS* (number of turbines within the plant) measure the potential for economies of scale. *MULTI PLANT* (equals one when the plant is owned by a firm that has acquired more than one plant and brought them under the umbrella of a single corporate entity and zero otherwise) measures potential economies of scope. *ZERO OUTPUT* (equals one when the plant had zero net generation of electricity for any month during the year) and *NEG OUTPUT* (equals one when the plant had negative net generation of electricity for any month during the year) control for down time[18]. *AGE* (equals *t* minus the year of initial operation divided by 100) and AGE^2 control for changes in operating efficiency through time due to plant vintage. *MULTI PRIME* (equals one when the plant has more than one type of prime mover for generating electricity) controls for plant heterogeneity.[19]

The vector *Z* contains observed state-time determinants of the state's decision to implement market restructuring (Craig, 2009). *RES PRICE* (the average price of residential consumers in cents per kilowatt hour), *STATE INCOME* (median income of the state's population in thousands of dollars), and *STATE INCOME*RES PRICE*, control for the political influence of residential customers. *SIZE INDUST* (the average amount of megawatt hours purchased by industrial customers in the state) controls for the influence of industrial customers. *REP GOV* (equal to one when the state has a republican governor

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[17] This is calculated during summer months when electricity generation is at a maximum.
[18] This effect can run either way. Plant efficiency can increase when downtime is used for maintenance programs. However, efficient plants are often selected for downtime because it is less costly to shut them down and start them up again.
[19] Because of coordination problems, efficiency may be lower in plants with several different types of prime mover.

and zero otherwise); *REP PUC* (equal to one when the st

Table V presents summary statistics for the municipality-owned plants in the net sample. Interestingly, the typical municipality-owned plant has similar operating characteristics to the typical investor-owned plant, but has smaller operating capacity (228 mWh vs. 449 mWh) and is younger (38 years vs. 44 years).

IV. RESULTS

The empirical model and data are used to examine the effect of market restructuring on the thermal efficiency of electricity generation plants. We estimate several alternative model specifications of the efficiency equation (1) for investor-owned and municipality-owned plants, respectively. We then estimate a sample selection model that controls for attrition bias, and re-estimate the efficiency equation for subsamples of natural gas-, petroleum-, and coal-fired plants.

IV (i).

number of turbines used within the plant decreases thermal efficiency. Both of the coefficients on *ZERO OUTPUT* and *NEG OUTPUT* are negative and significant, and suggest that down time is used for maintenance programs that increase plant efficiency. The estimated coefficients on *AGE* and AGE^2 indicate that older plants are relatively more efficient which is not altogether surprising given that older plants have, by definition, survived longer because they are relatively good at generating electricity. The estimated coefficient on

Model (ii) IV uses the vector *Z* as instruments in the first stage and reports the results in the third column of table VI.[24] The coefficients on vectors *X* and *W* come out almost identically and the coefficient on *RESTRUCTURE*, β = -0.166. Additionally the joint F test that the instruments are equal zero indicates that our instruments predict the decision to restructure quite well, and overidentification tests indicate that the instruments are valid. This estimate is not as precise as other specifications, but indicates that when not controlling for possible omitted variable bias, and endogeneity concerns biases the coefficient downward in magnitude, meaning that our estimates can be seen as lower bounds of the effect of restructuring on efficiency.

The efficiency gains reported above could be driven by the competitive effects from market restructuring within the plant and/or by attrition effects, whereby low-efficiency plants shut down or exit the market. The efarke(ates cai6t do)5e(ndogd)la8(ket)]T1w[(aree005 Tv and/or reported no observations for conti and of plausible magnitude, but is not significantly different from zero. The estimates for the gas subsample in column one is statistical

IV (iii). *Alternative measures of restructuring*

As pointed out in Kwoka (2008), measuring electricity restructuring is a difficult task. Problems may arise in terms of how restructuring is measured. Restructuring occurred at the national level through wholesale initiatives such as EPAct, open access, and RTOs. Individual states paralleled these movements with efforts targeted at retail access (the focus of this paper), divestiture of generating assets, and occasional centralized markets for wholesale trading. Kwoka also points out that restructuring is often not a simultaneous event measured as either present or not present.

To address both of these concerns we introduce three new variables: *RETAIL*, a variable ranging from zero to one indicating the percent of customers having access to their choice of power providers; *WHOLESALE*, dummy variable equal to one if a majority of states power producers has access to some form of wholesale market; *DIVESTITURE,* a variable ranging from zero to one indicating the percent of a states generating assets had been divested. We then re estimate tables VI and IX, using all three of these measures of restructuring, presenting the results in tables XII and XIII respectively. Focusing first on table XII, the coefficient on *RETAIL* is statistically significant at the one percent level across the first two specifications, and significant at the 10 percent level for the IV specification, and almost identical in magnitude to the ves such as EPAct1 significant in specification (i) only. Additionally *RETAIL* is statistically significant in specification (ii) only. We read this as evidence that for municipally owned plants it may be that divestiture constitutes a risk that they will be sold off as well if greater efficiency is not achieved.[27] We conclude that misspecification of the variable *RESTRUCTURE* is not an issue for the purposes of this paper.

V. EFFICIENCY GAINS

The electricity industry is one of the largest contributors to greenhouse gas emissions in the U.S. The National Archives and Records Association (1998) estimate that the generation, transmission, and distribution of electricity accounts for about 30 percent of U.S. annual greenhouse emissions.[28] A natural question arising from our empirical findings above is how much carbon dioxide was abated due to the efficiency gains from electricity market restructuring?

In 2006, 291 of our IOU sample plants were located in states that had restructured electricity markets, producing approximately 524 million mega-watt hours of net generation. Applying our estimate of β = -0.1365 from column two in Table VI to fuel savings means that enough fuel was saved to generate about 72 million mega-watt hours of electricity. Using estimates from EIA (1999) a mega-watt hour of electricity generation translates into 1,341 lbs of carbon dioxide for the average fossil fuel plant and 2,095 lbs of carbon dioxide for the average coal plant.[29] Because most of the efficiency

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[27] Results of specification (iii) for *RETAIL*, *DIVESTITURE*, and *WHOLESALE*, separately show no major differences in results and are available on request.
[28] http://clinton4.nara.gov/Initiatives/Climate/electric.html.
[29] According to 1999 estimates (EIA). To convert this into carbon dioxide pollution we use estimates of an Energy Information Administration (EIA) study conducted from 1999 to 1998 which concludes that one megawatt hour of electricity produces 1341 lbs of $C0_2$ for the average fossil fuel electricity generating

savings in our sample were achieved by plants using coal as their primary input, we will use the coal estimate as an upper bound, and the fossil fuels number as our lower bound for emission reductions.

Table XIV presents our upper and lower bound calculations of pollution savings in terms of: tons of carbon dioxide; cars and light trucks taken off the road; cars converted to hybrids; and airplane flights not taken.

that these gains stem from organizational and technological changes within the plant, not through attrition effects. Additionally the gains are most precisely estimated when working with the subset of coal-fired plants indicating much of the efficiency gains come through this subset. Although not directly targeted by restructuring initiatives, we also find similar efficiency effects for municipality-owned plants. This result suggests that the benefits from restructuring have spilled over to public electricity generation. Lastly we find that restructuring has additional benefits to societal welfare through reduction of greenhouse emissions comparable to removing approximately 9 to 14 million cars of the road.

Future research focuses on 2 main prongs of investigation. First, investigation into whether customers actually realized lower prices for electricity as a result restructuring (one of the major stated goals of restructuring), passing societal gains on to customers. Secondly, what other side effects were a result of restructuring, such as possible inconsistency with access to electricity such as black outs and brown outs.

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TABLE I
STATES WITH MARKET RESTRUCTURING

Year passed	State	Year implemented	Current status
1996	California	1998	Suspended
1996	New Hampshire	1998	
1996	New York	1998	
1996	Pennsylvania	1999	
1996	Rhode Island	1998	
1997	Illinois	1999	
1997	Maine	2000	
1997	Massachusetts	1998	
1997	Montana	1998	Suspended
1997	Nevada	2000	Suspended
1997	Oklahoma	2000	Suspended
1998	Arizona	2001	Suspended
1998	Connecticut	2000	
1999	Arkansas	2002	Suspended
1999	Delaware	2001	
1999	Maryland	2000	
1999	New Jersey	1999	
1999	New Mexico	2001	Suspended
1999	Ohio	2001	
1999	Oregon	2002	Suspended
1999	Texas	2002	
1999	Virginia	2002	Suspended
2000	Michigan	2001	
2000	D.C.	2001	

SOURCES: NARUC (2009); NEAAP (2009); State PUC web sites.

TABLE II

STATE CHARACTERISTICS 1996 - 2006

	All states		States with market restructuring		States without market restructuring	
Variable	mean	s.d.	mean	s.d.	mean	s.d.
Net generation (1000 mWh)	1,360.8	3,181.9	1,267.6	3,098.7	1,451.6	3,258.5
Area (miles^2)	92,760	103,670	99,553	97,231	86,141	109,179
Population (millions)	11.100	9.927	15.400	9.976	8.813	9.097
Population per mile^2	215.12	322.96	334.11	420.45	99.17	80.30
Median household income ($)	43,269	6,578	45,336	5,969	41,254	6,519
Republican PUC	0.5847	0.4824	0.6687	0.4556	0.5030	0.4936
Number of states	51		18		33	

NOTES: s.d. is standard deviation. Industrial concentration is the percentage of electricity from a state that goes to industrial customers. Local telephone competition equals one when the incumbent one when the incumbent Bell Operating Company within the state had obtained state and federal approval that its local markets were irreversibly open to competition. Republican PUC equals one when the majority of state's PUC commissioners are Republican.

SOURCES: EIA, FCC (2007),.NARUC (1995, 2001), US Census Bureau, Ventyx Energy (2007).

TABLE III
VARIABLE DESCRIPTIONS

Variable	Description
EFF	

TABLE IV
SUMMARY STATISTICS: INVESTOR-OWNED PLANTS

Variable	Mean	S.D.	Min	Max
EFF	11,910.85	19,637.34	13.75	1,133,333
RESTRUCTURED	0.3126	0.4636	0	1
CAPACITY	448.62	429.02	4.925	2600
UNITS	3.6662	2.4506	1	32
MULTI PLANT	0.8683	0.3382	0	1
ZERO OUTPUT	0.2000	0.4000	0	1
NEG OUTPUT	0.3283	0.4696	0	1
AGE	.4401	.1916	0	1.06
MULTI PRIME	0.4844	0.4998	0	1
STATE INCOME	4.2143	.6870	2.5086	6.8059
STATE REVENUE	8.375	6.759	.4680	35.4482
FIXED COSTS	12.7103	16.3033	-4.4337	307.0000

NOTES: Number of observations is 7,454. S.D. is standard deviation.

TABLE V
SUMMARY STATISTICS: MUNI-OWNED PLANTS

Variable	Mean	S.D.	Min	Max
EFF	11820.22	6610.43	316.25	96799.59
RESTRUCTURED	0.2123	0.4090	0	1
CAPACITY	227.47	280.16	4.5	1800
UNITS	3.2222	1.9666	1	8
MULTI PLANT	0.6991	0.4587	0	1
ZERO OUTPUT	0.2252	0.4178	0	1
NEG OUTPUT	0.3613	0.4805	0	1
AGE	.3766	.1701	0	1.06
MULTI PRIME	0.4205	0.4937	0	1
STATE INCOME	4.1242	.6216	2.5086	6.8059
STATE REVENUE	9.3866	8.8776	.4680	35.4482
FIXED COSTS	7.6120	10.9052	-.1872	115.0000

NOTES: Number of observations is 2,416. S.D. is standard deviation.

TABLE VI
EFFICIENCY ESTIMATES FOR INVESTOR-OWNED PLANTS

	Model (i)	Model (ii)	Model (ii) IV
RESTRUCTURE	-0.1349***	-0.1365***	-0.1656*
	[0.0375]	[0.0414]	[0.0907]
CAPACITY	-0.0001**	-0.0001**	-0.0001***
	[0.0000]	[0.0000]	[0.0000]
UNITS	0.0117**	0.0117**	0.0117***
	[0.0046]	[0.0046]	[0.0045]
MULTI PLANT	-0.0093	-0.011	-0.0116
	[0.0260]	[0.0255]	[0.0252]
ZERO OUTPUT	-0.1501***	-0.1529***	-0.1526***
	[0.0345]	[0.0339]	[0.0331]

TABLE VII
TWO-STEP EFFICIENCY ESTIMATES FOR INVESTOR-OWNED PLANTS

TABLE VIII
EFFICIENCY ESTIMATES FOR INVESTOR-OWNED GAS, PETROLEUM AND GAS FIRED PLANTS

	Model (ii)		
	Gas	Petroleum	Coal
RESTRUCTURE	-0.1829**	-0.0102	-0.1215***
	[0.0688]	[0.3116]	[0.0283]
CAPACITY	0	-0.0001	-0.0001***
	[0.0001]	[0.0002]	[0.0000]
UNITS	0.0098*	0.014	0.0139
	[0.0057]	[0.0692]	[0.0157]
MULTI PLANT	-0.0181	0.1121	-0.0228
	[0.0537]	[0.1552]	[0.0221]
ZERO OUTPUT	-0.1473**	-0.1928	-0.1015***
	[0.0550]	[0.1554]	[0.0347]
NEG OUTPUT	-0.1997***	-0.0767	-0.1886***
	[0.0556]	[0.1465]	[0.0348]
AGE	0.4432	1.2305	0.2727
	[0.3326]	[1.4286]	[0.3490]
AGE^2	-0.3104	-2.2399**	-0.3158
	[0.2518]	[1.0297]	[0.3028]
MULTI PRIME	-0.0764	0.2648**	-0.0552**
	[0.0468]	[0.1094]	[0.0222]
CONSTANT	8.8219***	9.9116***	9.2104***
	[0.1649]	[0.3228]	[0.0660]
Plant prime mover fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes
State specific linear time trends	Yes	Yes	Yes
Observations	2748	392	4314
R-squared	0.1848	0.3381	0.1949

NOTES. Dependent variable is log*EFF*. *** significant at the 0.01 level;** significant at the 0.05 level; * significant at the 0.1 level; Robust standard errors in parenthesis are clustered at the state level. Estimates of fixed effects and time trends not reported.

TABLE IX
EFFICIENCY ESTIMATES FOR MUNICIPALITY-OWNED PLANTS

	Model (i)	Model (ii)	Model (ii) IV
RESTRUCTURE	-0.0937	-0.1201**	-0.2640***
	[0.0623]	[0.0569]	[0.0883]
CAPACITY	-0.0002**	-0.0002**	-0.0002***
	[0.0001]	[0.0001]	[0.0001]
UNITS	0.0151	0.0171	0.0166
	[0.0131]	[0.0132]	[0.0127]
MULTI PLANT	-0.0155	-0.0123	-0.0131
	[0.0367]	[0.0365]	[0.0355]
ZERO OUTPUT	-0.1622***	-0.1565***	-0.1594***
	[0.0513]	[0.0511]	[0.0495]
NEG OUTPUT	-0.1874***	-0.1947***	-0.1953***
	[0.0607]	[0.0604]	[0.0586]
AGE	-0.0139	-0.0339	-0.0318
	[0.2173]	[0.2238]	[0.2178]
AGE^2	-0.2321	-0.2259	-0.2234
	[0.2782]	[0.2822]	[0.2728]
MULTI PRIME	-0.005	-0.0045	-0.0055
	[0.0418]	[0.0456]	[0.0442]
CONSTANT	9.1911***	8.9057***	8.9045***
	[0.0784]	[0.0765]	[0.0731]

TABLE X

TWO-STEP EFFICIENCY ESTIMATES FOR MUNICIPALITY-OWNED PLANTS

	Model (ii)	
RESTRUCTURE	0.2057	-0.1201**
	[0.3449]	[0.0569]
CAPACITY	-0.001	-0.0002**
	[0.0015]	[0.0001]
UNITS	-0.0353	0.0171
	[0.0241]	[0.0132]
MULTI PLANT	-0.0559	-0.0123
	[0.0901]	[0.0365]

ZERO OUTPUT -7.f56 .9.0 5977T621 5977T*.969.7

TABLE XI
EFFICIENCY ESTIMATES FOR MUNICIPALITY-OWNED GAS, PETROLEUM AND GAS FIRED PLANTS

	Model (ii)		
	Gas	Petroleum	Coal
RESTRUCTURE	-0.2184*	0.4456	-0.0717**
	[0.1106]	[0.7538]	[0.0325]
CAPACITY	0	-0.0093	-0.0001***
	[0.0003]	[0.0090]	[0.0000]
UNITS	-0.0146	0.3347***	0.0270**
	[0.0286]	[0.0317]	[0.0124]
MULTI PLANT	0.0591	-0.0848	-0.0591
	[0.0741]	[0.1176]	[0.0522]
ZERO OUTPUT	-0.1284	0.4390**	-0.2592***
	[0.0941]	[0.1811]	[0.0518]
NEG OUTPUT	-0.1194	-0.4975*	-0.1799***
	[0.0789]	[0.2309]	[0.0574]
AGE	-0.8396	-33.8965*	0.2707
	[0.6210]	[16.6996]	[0.4355]
AGE^2	0.7675	33.673	-0.6075
	[0.5954]	[19.5825]	[0.5231]
MULTI PRIME	0.0295	0.0498	-0.0185
	[0.1014]	[0.1363]	[0.0298]
CONSTANT	9.1559***	16.9575***	8.9401***
	[0.1732]	[3.4115]	[0.0496]
Plant prime mover fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes
State specific linear time trends	Yes	Yes	Yes
Observations	841	83	1492
R-squared	0.2422	0.6873	0.2849

NOTES. Dependent variable is log*EFF*. *** significant at the 0.01 level;** significant at the 0.05 level; * significant at the 0.1 level; Robust standard errors in parenthesis are clustered at the state level. Estimates of fixed effects and time trends not reported.

TABLE XIII

TABLE XIV ESTIMATES OF SAVINGS FROM ELECTRICITY RESTRUCTURING IN 2006		
Savings achieved	Lower Bound	Upper Bound
Tons of CO2	52,228,192	81,594,378
Cars off the road	9,122,828	14,252,293
Percent of cars off road	6.74	10.53
Light trucks off the road	6,514,274	10,177,035
Percent of light trucks off road	6.57	10.27
Flights not taken	39,321	61,430
Cars switched to hybrids	16,907,799	26,414,496
Percent of cars traded for hybrids	12.49	19.51

Appendix