Energy Institute WP 354R

Does Regulation Distort Exit Decisions? Evidence from U.S. Power Plants

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Revised October 2025

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Abstract

Hundreds of power plants have closed in the United States since 2010, including 130+ gigawatts of coal and 50+ gigawatts of natural gas. In this paper, we highlight the potential for regulation to distort this type of exit decision. Using generator-level data from 2010–2023, we show that regulated units have been 45% less likely to exit than unregulated units. For unregulated units, exit decisions are made based on wholesale electricity prices, ongoing capital costs, and other traditional economic factors. In contrast, owners of regulated units are largely insulated from these factors and, in some cases, have a strong incentive to continue operating capital-intensive equipment. Previous work documents how this regulatory distortion affects investment decisions. Our paper emphasizes that these same incentives affect exit decisions as well.

Key Words: Regulatory Bias, Averch-Johnson Effect, Electricity Markets, Carbon Emissions
JEL: D24, L94, Q41, Q48, Q54

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1 Introduction

Hundreds of power plants have closed in the United States since 2010, including 130+ gigawatts of coal and 50+ gigawatts of natural gas. These exit decisions have important implications for electricity markets, grid reliability, and the environment. Holland et al. (2020), for example, calculate that the total damages from U.S. power plants decreased by more than \$100 billion annually between 2010 and 2017, with plant closures being one of the largest single factors.

In this paper, we highlight the potential for regulation to distort this type of exit decision. Using generator-level data from 2010–2023, we show that regulated units have been 45% less likely to exit than unregulated units. This difference remains after controlling for observable characteristics and implies that regulated units operate 8.4 years longer than unregulated units on average.

Our analysis focuses on coal and natural gas, the two largest sources of electricity generation in the United States as of 2010. In both cases, we find that regulated units are less likely to exit than unregulated units. The effect is large in magnitude and strongly statistically significant in all specifications. We also find similar effects for investor-owned utilities and publicly-owned utilities, with both forms of regulation associated with significantly lower exit rates than unregulated companies.

We interpret these results by pointing out that regulated and unregulated firms have very different incentives. Unregulated firms – known as "independent power producers" in electricity markets – make exit decisions based on wholesale electricity prices, ongoing capital costs, and other traditional economic factors. In contrast, regulated firms are largely insulated from these factors and instead subject to the preferences and priorities of local regulators. For investor-owned utilities, there is also a guaranteed rate-of-return, which creates a strong incentive to continue operating capital-intensive equipment.

Our findings for investor-owned utilities are consistent with the well-known Averch-Johnson effect. Averch and Johnson (1962) showed that rate-of-return regulation biases firms toward capital-intensive technologies. Subsequent studies have shown, for example, that regulated companies are more likely to invest in capital-intensive emission control technologies (Fowlie, 2010; Cicala, 2015) and that capital investments increase with the allowed rate of return (Dunkle Werner and Jarvis, 2025). Although the literature has focused mainly on new investments, our paper emphasizes that this same regulatory distortion also affects exit decisions.

We also report results from an alternative specification aimed at testing for market power. High exit rates for unregulated companies might alternatively reflect efforts to push up prices for remaining units owned by the same company. However, when we divide unregulated companies into those with small, medium, and large portfolios, we do not find higher exit rates for larger portfolios, nor do we find smaller exit rates for smaller portfolios. Thus, we conclude that our main results are unlikely to be driven by market power.

In addition, we tested whether regulated units were less likely to exit in states that are major producers of coal or natural gas. Our hypothesis was that in states like Wyoming, West Virginia, and Kentucky with significant coal production, one would expect to have coal producers exerting political pressure on state politicians and regulators to keep coal plants open. We do not find any evidence of this form of regulatory capture, though we cannot rule out the role of other local preferences and priorities that are not related to in-state coal and gas production.

Our paper complements recent research on electricity markets. Gowrisankaran et al. (2025a) builds a structural model of rate-of-return regulation during an energy transition. In their model, utilities balance lowering operating costs with maintaining coal capacity.[1] Our paper provides empirical corroboration for their modeling approach. In other related work, Rebecca Davis and coauthors use U.S. coal plant retirements 2009–2017 to estimate a real options model of power plant decisions, and simulate retirements until 2035 under various counterfactuals (Davis et al., 2022).

Our paper is also related to studies that have examined the determinants of U.S. power plant closures. Linn and McCormack (2019), for example, find that low natural gas prices and weak demand for electricity explain 80% of coal plant retirements in the U.S. eastern interconnection between 2005 and 2015, whereas nitrogen oxides emissions caps and the Mercury and Air Toxic Standards (MATS) had relatively little effect.[2] Our paper implicitly controls for these other factors using region-by-

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[1] Further afield, Borrero et al. (2023) provides a new approach for estimating ramping and operations costs for coal and other power plants and Gowrisankaran et al. (2025b) estimates a dynamic oligopoly model for coal plants that recovers owners' beliefs and uncertainty about future MATS enforcement. There are also several papers that examine the short-run relationship between natural gas prices, coal plant generation, and carbon emissions. Cullen and Mansur (2017), for example, finds that a \$6 per mmBTU decrease in natural gas prices causes a 10% decline in carbon emissions, almost entirely through reduced coal plant generation. Fell and Kaffine (2018) finds that natural gas prices and wind generation jointly explain most of the decline in U.S. electricity generation from coal between 2007 and 2013.

[2] Relatedly, Coglianese et al. (2020) finds that 92% of the decline in U.S. coal production 2008 to 2016 can be explained by low natural gas prices, with environmental regulations explaining an

year fixed effects.

Finally, our paper contributes to the literature on the effects of electricity market deregulation. Previous studies have examined market power (Wolfram, 1999; Borenstein et al., 2002; Bushnell et al., 2008), operating efficiency (Fabrizio et al., 2007; Davis and Wolfram, 2012; Chan et al., 2017; Demirer and Karaduman, 2024), procurement practices (Cicala, 2015), and allocation of production between plants (Mansur and White, 2012; Cicala, 2022). The effect of deregulation on plant exit decisions has received little attention.

2 Background

In this section, we discuss: (1) how regulation works, (2) the economic incentives for regulated plants, (3) deregulated markets, (4) the economic incentives for unregulated plants, and (5) public ownership.

2.1 How Regulation Works

Under rate-of-return regulation, the regulated firm is granted the exclusive right to operate in a particular geographic area, but, in exchange, the regulator sets rates based on the regulated firm's costs. Rate-of-return regulation is widely used in U.S. electricity markets including electricity generation in most states, as well as electricity transmission and distribution. Rate-of-return regulation is also widely used in other markets, including pipelines for natural gas, crude oil, and refined petroleum

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additional 6%.

products, as well as in water distribution, sewage, trash, and recycling.

The regulator's objective is to set rates so that the regulated firm exactly breaks even, including the opportunity cost of capital investments. The first step for the regulator is to determine the firm's total costs (i.e. the "revenue requirement"), including operating expenses and capital costs. For power plants, operating expenses include fuel costs, salaries, taxes, and insurance. Capital costs include depreciation and the opportunity cost of capital. Whereas operating expenses are observed and relatively straightforward to calculate and put into rates, capital costs are more complicated.

A central concept in rate-of-return regulation is the "rate base", i.e. the current value of the firm's capital investments. As the regulated firm makes capital investments, these investments enter the rate base. Then, over time, these investments are assumed to depreciate according to some multiple-year schedule determined by the regulator. The amount that any particular investment counts toward the rate base decreases every year until, eventually, the investment is "fully depreciated" at which point the investment no longer appears in the rate base.

A stylized example is helpful. Suppose a regulated firm makes a $1 billion capital investment in a new power plant. During the first year of operation, the $1 billion enters the rate base.[3] If the firm's allowed rate of return is 10%, then rates are

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[3] A related concept in rate-of-return regulation is the "used and useful rule". In an effort to approximate what happens in unregulated markets, this is the idea that a capital investment enters the rate base only once that investment is operational. Even if it takes a decade to complete a new power plant, for example, those capital costs (including financing) do not enter the rate base until the plant begins operation. The "useful" refers to the capital investment serving some public purpose. Although it is relatively rare in practice, the regulator can decide to "disallow" a capital

increased so that the firm receives an additional $100 million in the first year. If the regulator uses 20-year straight-line depreciation, then $50 million of the plant's value is depreciated in each year, and the rate base would decline to $950 million in year 2, $900 million in year 3, and so on.

2.2 Incentives For Regulated Plants

Under rate-of-return regulation, the owners of regulated power plants are largely insulated from market conditions. When operating costs increase, for example, these costs are passed along to ratepayers, with no implications for shareholders. The regulated firm also bears little risk with regard to capital investments. Whether broader economic conditions end up favorable or unfavorable, the regulated firm continues to receive a guaranteed rate-of-return.

This insulation from market conditions means that owners of regulated plants face little urgency with regard to exit decisions. Suppose that market conditions end up being unfavorable for a particular power plant because, for example, fuel costs have gone up. These unfavorable market conditions simply do not matter to the owner of the regulated plant, as they simply pass along these higher costs to ratepayers.

Firms subject to rate-of-return regulation also have a strong incentive to make and maintain capital-intensive investments. Probably the single hardest job of the regulator is to determine the firm's allowed rate-of-return on capital investments. In practice, the rate-of-return is typically set higher than the firm's cost of capital, cre-

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investment if it is not deemed "useful".

ating a distortion and biasing the firm towards capital-intensive technologies (Averch and Johnson, 1962).

The literature has mostly focused on how this regulatory distortion affects new investments. But this same regulator distortion also impacts exit decisions. When a plant is closed, this capital investment leaves the rate base and is immediately depreciated. This is undesirable from the perspective of the regulated firm because it stops receiving the guaranteed rate-of-return on the capital investment.

Once a plant is fully depreciated, the regulated firm no longer has an incentive to keep it open. At that point, the regulated firm might actually want to close the plant so that it can build something else and start this process over again with a new capital investment in the rate base. But outcomes in this case are uncertain. A regulator might decide that no replacement plant is necessary. Or, the regulator might decide that it will be an unregulated firm, not the regulated firm, that makes this new capital investment.

Another consideration is recurring capital costs. Over time, plant equipment wears out and must be replaced, requiring additional capital investments. For a regulated firm, this goes into the rate base on which the firm earns a guaranteed rate-of-return. Thus, for a regulated firm, recurring capital costs do not hurt profits and may even provide an incentive to keep the plant open. Indeed, if there are enough recurring capital costs, then a plant is unlikely to ever become fully depreciated.

Largely insulated from traditional economic factors, regulated firms are instead subject to the preferences and priorities of local regulators. For example, reporting from

West Virginia Public Broadcasting describes the "unwavering support" for coal in West Virginia at all levels of state government including the governor, state legislature, and state public service commission.[4] The coal industry has a long history in West Virginia and Appalachian Power (a regulated company) has long-term contracts with coal plants in the state.

2.3 Deregulated Markets

Since at least the 1980s, economists have articulated a competitive vision for electricity markets (Joskow and Schmalensee, 1988). The standard prescription was to deregulate generation while keeping transmission and distribution regulated. Beginning in the late 1990s, hundreds of power plants in about a dozen states were sold from regulated companies to unregulated companies, also known as "independent power producers" or "merchant generators". Wholesale markets were established at the same time, with electricity buyers required to participate in these markets.

The hope was that a competitive generation market would lead to greater efficiency, both in the short-run and long-run. In the short-run, competition would create an incentive for firms to operate power plants efficiently and, through the newly established wholesale markets, to allocate production to low-cost plants. In the long-run, competition would impose market discipline on new investments and eliminate the regulatory distortion towards capital expenditures.

U.S. deregulation efforts were stalled by the California Electricity Crisis in 2000 and

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[4] "West Virginia Relies Mostly on Coal for Its Electricity. Customers Are Paying a Heavy Price" WBUR Radio, September 25, 2025.

2001. Since that time, the regulatory status of power plants has been essentially frozen, with little attempt to further deregulate, but also little attempt to regulate those plants that had already deregulated. Thus today's mix of regulated and unregulated power plants in the United States essentially reflects which states deregulated first over 25 years ago. Deregulated plants are mainly found in California, Texas, the Northeast and parts of the Midwest, while most plants in the rest of the country remain regulated (Borenstein and Bushnell, 2015).

White (1996) shows that deregulation tended to occur in states with high electricity prices, where consumers potentially had the most to gain from deregulation. States with low electricity prices, for example, due to abundant low-cost generation resources, were less likely to deregulate. Several previous studies have compared operating behavior and other outcomes between regulated and unregulated plants. See, e.g. Fabrizio et al. (2007); Davis and Wolfram (2012); Cicala (2015); Chan et al. (2017); Cicala (2022).

2.4 Incentives for Unregulated Plants

As we mentioned earlier, owners of unregulated plants make exit decisions based on wholesale electricity prices, operating costs, and other traditional economic factors. These are profit-maximizing firms, so they will close a plant when it ceases to be profitable. How much the plant cost to build originally, or however much the firm paid for the plant is a sunk cost and, therefore, irrelevant. There is no rate base and certainly no guaranteed rate-of-return.

Market conditions tended to be unfavorable for U.S. power plants during our study period. Previous papers have pointed to low natural gas prices, weak electricity demand, and the entry of renewables, among other factors, as hurting the economic prospects for U.S. power plants (Fell and Kaffine, 2018; Linn and McCormack, 2019). Owners of unregulated plants were fully exposed to these unfavorable conditions, so it makes sense that many of these owners made the decision to exit.

Unregulated firms are also fully exposed to recurring capital costs. For the regulated firm, these costs go into the rate base on which the firm earns a guaranteed rate-of-return. In contrast, for an unregulated firm, recurring capital costs come directly from firm profits. Owners of unregulated plants do not like to make this type of capital expenditure and may choose to close the plant to avoid incurring such costs.

2.5 Public Ownership

A third category is public ownership. This includes municipally owned utilities like the Los Angeles Department of Water and Power (LADWP), state-owned utilities like the New York Power Authority (NYPA), and federally owned utilities like the Tennessee Valley Authority (TVA), as well as member-owned electric cooperatives like Old Dominion Electric Cooperative (ODEC), which owns power plants in Virginia and Maryland.

The governance of publicly owned utilities varies widely. LADWP, for example, has a five-member board that is appointed by the mayor of Los Angeles and approved by the Los Angeles city council. NYPA has a nine-member board appointed by the governor of New York and approved by the state Senate. TVA has a nine-member board appointed by the president and approved by the Senate. ODEC has a 10+ member board elected by its members. These boards then select chief executives, financial officers, and other executives to manage operations.

Publicly owned utilities are largely insulated from market conditions. When operating costs increase, for example, these costs are passed along to ratepayers. There are no shareholders, nor are these utilities owned or co-owned by private individuals. The risk of capital investments is borne by the ratepayers. There is no rate base for a publicly owned utility, and thus no regulatory bias toward capital-intensive investments, but also no direct private economic consequences when economic conditions end up unfavorable for a particular capital investment.

Publicly owned utilities make power plant closure decisions based on the needs of the utility but also influenced by local priorities and preferences. For example, a publicly owned utility might value retaining local employment in a way that an unregulated firm is not incentivized to do. Taken together, a publicly owned utility does not have private owners, so the economic consequences of exit decisions are not experienced as acutely as they are with an unregulated firm.

3 Data and Descriptives

3.1 Data Construction

We constructed for this analysis a comprehensive dataset describing U.S. power plants over the period 2010–2023. Our primary source is EIA-860, an annual survey of U.S. power plant operators conducted by the U.S. Department of Energy, Energy Information Administration (EIA). EIA-860 includes generator, plant, and operator-level information about all U.S. power plants over one megawatt capacity. The key variables from EIA-860 for our analysis are regulation type, name of owner, fuel type, capacity (in MW), technology type (e.g. combustion turbine), year opened, and year retired (if retired).

We restrict the analysis to coal and natural gas units. These were the two largest categories of U.S. electricity generation as of 2010, with coal and gas responsible for 45% and 24% of generation, respectively, in that year.[5] The other categories in 2010 were nuclear (20%), conventional hydro (6%), wind, solar, and other renewables (4%), and petroleum/other (1%). We perform all analyses at the generator unit level, rather than at the power plant level, as it is common for units within a plant to open and/or to retire in different years.

We include in the analysis all units that were operating as of 2010. Thus, we exclude units that retired in or before 2010, as well as units that began operation after 2010.

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[5] See EIA "Electric Power Annual 2010", Table 2.1.A Net Generation by Energy Source. Coal and natural gas represented 69% of total U.S. generation in 2010. The third largest category of generation, nuclear, would have been interesting to include, but there are too few total units to support an empirical analysis.

We selected 2010 as the starting point because this is the beginning of a period of low wholesale electricity prices. By 2010, hydraulic fracturing had substantially increased the supply of natural gas, lowering the cost of gas-fired electricity generation, and decreasing wholesale electricity prices (Hausman and Kellogg, 2015). Thus, our analysis should be thought of as describing retirement behavior for U.S. coal and natural gas units that were operating as of 2010.

Regulation type is an important variable in our analysis, so we devote considerable attention to ensuring that this variable is measured as accurately as possible. The key question in EIA-860 is "*What type of entity is the principle owner and/or operator? i) Cooperative, ii) Investor-Owned Utility (IOU), iii) Independent Power Producer (IPP), iv) Municipally-Owned Utility, v) Political Subdivision, vi) Federally-Owned Utility, vii) State-Owned Utility, viii) Industrial (principal business is not electricity generation, ix) Commercial (principal business is not electricity generation).*[6]

We drop units that operate for industrial or commercial purposes (i.e. the last two categories). These are units for which the primary purpose is something other than selling electricity. Instead, these units typically provide electricity or heat (or both) to co-located facilities and face a very different set of constraints and incentives. These industrial and commercial units were less than 4% of capacity in 2010.

The remaining units we categorize as "regulated" or "unregulated". In particular,

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[6] The "entity type" question was not asked in EIA-860 until 2013. In addition, this information is missing for a small number of units in some years during the period 2013–2023. To address both forms of missing information, we impute using information for that same unit in other years. In a small number of cases (<2%), we use additional information about the regulation type available from a related "sector type" question in EIA-860.

we categorize independent power producers (i.e. the third category above) as "unregulated", and all other remaining categories as "regulated". Later in the paper, we further break down this regulated category to distinguish investor-owned utility (i.e. the second category above), from the various types of publicly-owned utilities, cooperative, federal, municipal, municipal marketing authority, political subdivision, and state (i.e. the first, fourth, fifth, sixth, and seventh categories above).

For our analysis, we characterize units based on their regulation type as of the first available year in which that information is available. As mentioned earlier, there has been little effort anywhere in the U.S. during our study period toward deregulation, but also little effort to regulate again those units that were deregulated during earlier decades. There are a small number of cases for which the EIA-860 data show changes in regulation type over time. Some of these may be reporting errors. Moreover, it is not completely clear how to treat time-series variation in regulation type in the context of retirement. For example, would a unit sale from a regulated to unregulated company constitute a retirement for the regulated company? We instead choose to frame our analysis as describing the retirement choices of the fleet as it appears in the beginning of our study period.

We apply this same approach to other unit characteristics, describing units based on their fuel type and capacity as of the first available year in which that information is available. For inherently cross-sectional characteristics such as year opened and year retired for which different values across years reflect data errors or misreporting and not time series variation, we use the most recent data, under the assumption that reporting should improve over time. With retirements, this also likely reflects units that were expected to retire but ended up not retiring until the following year.

A notable trend during our study period was the conversion of units from coal to gas. Between 2011 and 2023, 15% of the coal units in the 2010 fleet, and close to 9% of coal capacity was converted from coal to gas. We do not treat these as retirements. Consistent with our approach of studying units based on their characteristics at the beginning of the study period, these units remain in our sample with the fuel type as measured in 2010. Although potentially interesting, our view is that these conversions are quite different from retirements. For an investor-owned utility, for example, a conversion allows the company to maintain or even increase the amount of capital included in the rate base. We leave this related question of fuel switching for future research.

3.2 Summary Statistics

The U.S. electricity generation market has several features that make it particularly suited for an empirical analysis of regulatory distortions. Most importantly, the U.S. has a mix of regulated and unregulated units, with hundreds of units in each category.

Table 1 reports summary statistics. Panel (A) describes all units operating as of 2010. An advantage of our national-level study of the United States is the large sample size, with thousands of coal and gas units in our dataset. There are more total natural gas units than coal units , but coal units tend to be larger and older.

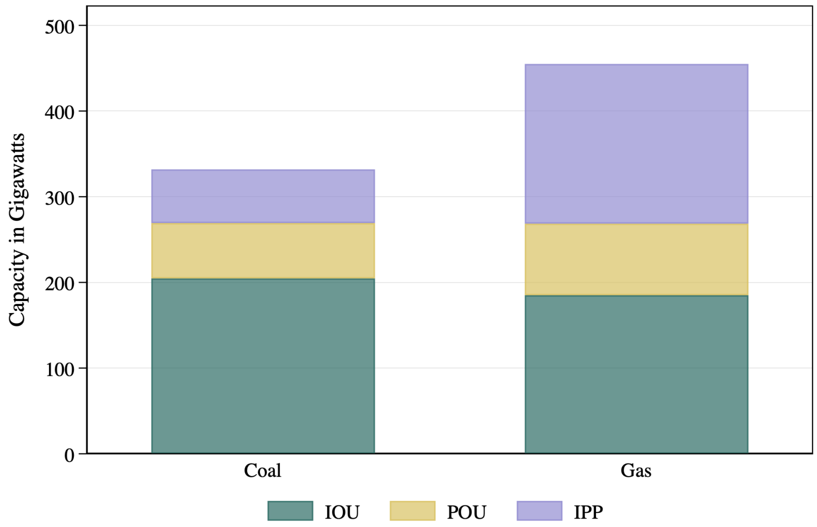
Panel (B) describes the units that retired between 2011 and 2023. In total, more than 1500 units closed during our study period. More gas units closed than coal units, but coal units were much more likely to retire. Of the units operating in 2010, 55% of coal units retired between 2011 and 2023, compared to 18% of gas units. With both coal and gas, the units that retired tended to be older.

Figure 1(A) shows capacity by regulation type. We distinguish between investor-owned utilities (IOU), publicly-owned utilities (POU) and independent power producers (IPP). For coal, IOU units comprise the largest share of capacity, although there are also substantial shares for both POU and IPP. For gas, IOU and IPP have similar total capacity, with POU representing a smaller but still substantial share. Note that on average the capacity of units differs by regulation type. IOU coal units have an average capacity of 339 MW, while the average coal capacity of POU and IPP is 179 and 278 respectively. IOU gas units are also larger on average than POU units with means of 124 and 46 MW respectively, and 112 MW for IPP gas.

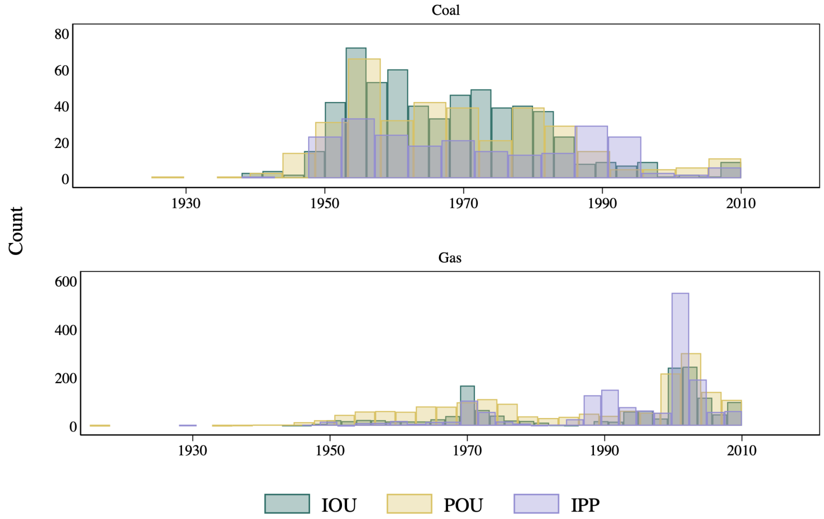
Figure 1(B) shows year opened by regulation type. Since this includes all units operating as of 2010, the year opened effectively illustrates the distribution of units' age as of 2010. Coal units tend to be the oldest, with many units open since the 1950s and 1960s. Some gas units are very old, but most gas units opened after 1970, and there was a large spike in openings in the early 2000s. In terms of regulation type, IPP units tend to have later opening years, for both coal and gas, but there is considerable overlap in the distributions.

Figure 1: U.S. Power Plants by Regulation Type

(A) Capacity as of 2010



(B) Year Opened



Notes: This figure describes U.S. power plants by regulation type as of 2010. We focus on coal and natural gas, the two largest categories of generation as of 2010. Regulation types include investor-owned utilities (IOU), publicly-owned utilities (POU) and independent power producers (IPP).

Table 1: Summary Statistics

	Mean	Std. Dev.	Min	Max
All units:				
Coal (n = 1189, regulated = 964)				
Size (MW)	279.1	272.2	0.4	1,425.6
Year Opened	1968	15	1925	2010
Gas (n = 4960, regulated = 3303)				
Size (MW)	91.7	103.7	0.2	1,027.0
Year Opened	1989	17	1915	2010
Retired units:				
Coal (n = 652, regulated = 506)				
Size (MW)	164.3	182.6	0.4	1,425.6
Year Opened	1962	13	1925	2010
Gas (n = 898, regulated = 600)				
Size (MW)	62.6	110.0	0.2	799.2
Year Opened	1972	17	1928	2010

NOTES: This table reports summary statistics for our dataset of electricity generating units. Panel (A) describes all units in operation as of 2010. Panel (B) describes all units that retired between 2011 and 2023. For each category, we report the total number of units as well as the number of units that are "regulated", defined here as including both investor-owned utilities and publicly-owned utilities. Statistics have been rounded to the nearest integer.

3.3 Retirements 2011–2023

Figure 2 plots U.S. coal capacity (panel A), and cumulative retired capacity (panel B), over our study period. Total coal capacity declined steadily between 2010 and 2023, with total coal retirements reaching 130+ gigawatts by the end of the period.

Panels C and D present the same information for natural gas. Total gas capacity decreased steadily during our study period, but by much less than coal. By the end of our study period, total gas retirements reached 50+ gigawatts.

Table 2 reports the percent retired by fuel type and regulation type. Unregulated coal units were significantly more likely to retire during our sample period – 65% compared to 53% for regulated coal units. The difference is highly statistically significant (p-value .001). For natural gas, the percent retired is almost identical – 18% in both cases – for regulated and unregulated units.

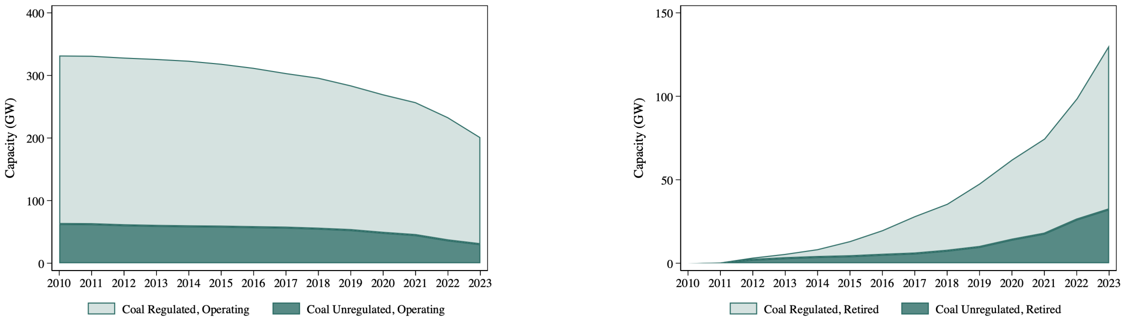
Comparing retirement shares by regulation type is suggestive, but does not fully answer our research question. In particular, we have already seen differences in opening year for regulated and unregulated units. In any given year, we would expect older units to be more likely to retire than younger units. Thus, in the following subsection, we examine the average age at retirement.

Table 2: Percent Retired

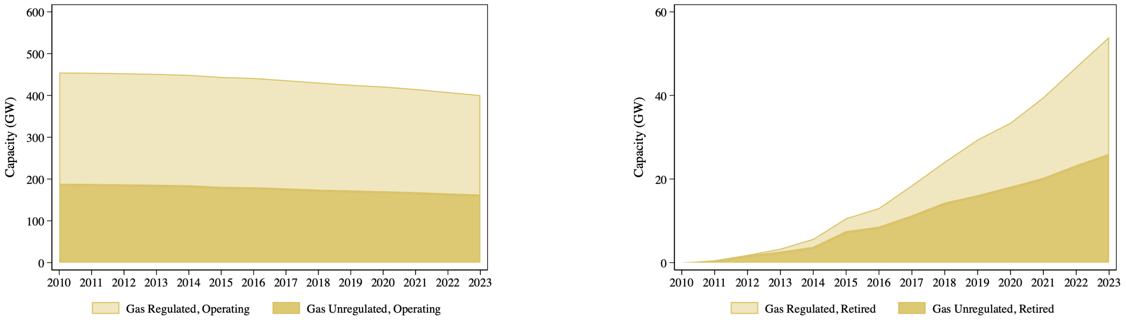
	(1) Regulated Units	(2) Unregulated Units	(3) p-value (1) vs (2)
Coal	52.5%	64.9%	0.001
	(506 of 964)	(146 of 225)	
Gas	18.2%	18.0%	0.876
	(600 of 3,303)	(298 of 1,657)	
All	25.9%	23.6%	0.053
	(1,106 of 4,267)	(444 of 1,882)	

NOTES: This table reports the percent retired by fuel type and regulation type. In each category, the denominator is the number of units operating in 2010, and the numerator is the number of units that retired over the period 2011–2023. The final column reports p-values from a t-test of the null hypothesis that retirement is equally likely for regulated and unregulated units.

Figure 2: U.S. Coal and Gas Electricity Generating Capacity, 2010–2023



(A) Coal Operating (B) Coal Retired



(C) Gas Operating (D) Gas Retired

Notes: This figure was created by the authors using data from EIA Form-860. As discussed in the text, our dataset includes all generating units that were operating in the United States as of 2010. The goal of our research is to understand retirement behavior so we have excluded units that opened after 2010, and the total capacity in the figure does not match aggregate U.S. coal and gas capacity in those years.

3.4 Average Age At Retirement

Table 3 reports the average age at retirement for regulated and unregulated units. Regulated units tend to be considerably older at retirement than unregulated units. Considering both coal and gas, regulated units average 50 years at retirement, compared to only 42 for unregulated units. The difference (8 years) is strongly statistically significant with a p-value < 0.001.

Table 3: Average Age at Retirement

	(1) Regulated Units	(2) Unregulated Units	(3) p-value (1) vs (2)
Coal	55	49	0.000
	(n=506)	(n=146)	
Gas	47	39	0.000
	(n=600)	(n=298)	
All	50	42	0.000
	(n=1106)	(n=444)	

Notes: This table reports the average age at retirement in years for regulated and unregulated units. We calculated these ages using our dataset of U.S. electricity generating units that were operating in 2010 and retired between 2011 and 2023. The final column reports p-values from a t-test of the null hypothesis that the ages at retirement are equal for regulated and unregulated units.

The pattern goes in the same direction for coal and gas. In both cases, regulated units have a considerably higher average age at retirement than unregulated units. In both cases, the differences are strongly statistically significant with p-values < 0.001. It may initially be surprising that this table shows a difference for gas, whereas Table 2 did not, but unregulated gas units tend to be newer than the regulated gas units, so even though the percent retired was similar, the unregulated units were retired earlier.

The magnitude of the difference is economically and statistically significant. The pattern is consistent with owners of regulated units being insulated from traditional economic factors and facing less pressure to exit during unfavorable economic times. In the following section, we turn to a hazard model that allows us to continue to compare regulated and unregulated units, while also controlling for unit capacity, plant technology and vintage, and regional economic trends.

4 Empirical Analysis

4.1 Proportional Hazard Model

In this section, we use a proportional (Cox) hazard model to estimate the impact of regulation on the relative risk of unit exit in a given year. In the parlance of traditional survival analysis, a unit's life begins at its opening year, and the unit continues to "survive" until it exits.

The reason we use a hazard model rather than, for example, linear regression, is that this setting is intrinsically about duration. We want to understand how different factors shift the time until exit and to be able to say how regulation type shifts the expected lifetime for generating units.

The hazard model is specified:

$$\lambda(t; x_i) = \exp(x_i \beta) \lambda_0(t), \tag{1}$$

where t denotes the duration of unit i's operating life (in years), and $\lambda_0(t)$ is the baseline hazard function. We estimate hazard models separately for coal and natural gas, which allows the baseline hazard model $\lambda_0(t)$ to vary by fuel type.[7]

This is called a proportional hazard model because covariates x_i shift this baseline hazard function proportionally. Our covariate of interest is *Regulated*, an indicator equal to one for units owned by regulated companies. Here we include among regulated companies both IOUs and POUs, but later we estimate more flexible models which distinguish between IOUs and POUs.

Among the covariates x_i we also include unit capacity (in MW) and NERC by 5-year fixed effects (2010–2014, 2015–2019, 2020–2023). The fixed effects are included to control for market conditions and other time-varying factors unique to the unit's NERC region. This includes, for example, regional electricity demand and entry of renewables. There are 10 NERC regions (ASCC, FRCC, HICC, MRO, NPCC, RFC, SERC, SPP, TRE, WECC) and 14 years in our study period, so this is a total of 30 fixed effects. We would have liked to include even richer fixed effects, for example NERC by 1-year fixed effects, but there is not enough variation in exit within NERC by 1-year groups for this to be estimated. As an alternative, we estimate a model with 1-year fixed effects and NERC region fixed effects not interacted as a robustness check, with estimates provided in Appendix Table 4.

In some specifications, we also include vintage by technology strata. This is in-

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[7] The covariate vector x_i scales the baseline hazard ratio proportionally by a factor of $\exp(x_i\beta)$, and the ratio of hazard rates between two units i and j can be expressed: $\frac{\lambda(t;x_i)}{\lambda(t;x_j)} = \frac{\lambda_0(t)exp(\beta x_i)}{\lambda_0(t)exp(\beta x_j)} = exp(\beta(x_i - x_j))$. Thus, the relative risk between two units i and j differs by $exp(\beta(x_i - x_j))$ regardless of time.

troduced not as additional covariates, but by allowing the baseline hazard function to differ by strata, which means we estimate separate baseline hazard functions for each vintage by technology group, which are then all shifted by the same proportional $\exp(x_i\beta)$ term. For vintage, we use the decade the unit opened. For technology, we use the unit's technology type – prime mover in EIA-860 data. This richer specification allows, for example, combustion gas turbine units built in the 1940s to have a different baseline hazard function than combined cycle units built in the 2000s.

4.2 Main Results

Table 4 presents our main results. For each of six specifications, we report the hazard ratio and standard error corresponding to *Regulated*, an indicator equal to one for units that are regulated. Columns (1), (3), and (5) control for unit capacity only. Columns (2), (4), and (6) additionally incorporate NERC by 5-year fixed effects and vintage by technology strata. Columns (1) and (2) include coal units only, columns (3) and (4) include gas only, and columns (5) and (6) include all coal and gas units. In column (6), vintage by technology strata are also interacted with fuel type, allowing each vintage by technology by fuel type group to have its own baseline hazard function. The NERC by 5-year fixed effects are also interacted with fuel type in column (6).

Regulated units are much less likely to exit than unregulated units. The table reports estimates of the implied hazard ratio for regulated units compared to unregulated units, which are the exponentiated coefficient estimates from equation (1). Across the six specifications, we estimate hazard ratios ranging from 0.43 to 0.60. As usual, a hazard ratio of 1.0 would indicate equally likely, so regulated units exit at approximately half the rate of unregulated units, controlling for observable factors. In column (6), the estimated hazard ratio of 0.55 implies that regulated coal and gas units are 45% less likely to exit than unregulated units.

Standard errors are clustered at the power plant level in all specifications. Statistical significance is assessed relative to the null hypothesis that the hazard ratio equals 1.0, i.e. that regulated and unregulated units are equally likely to exit. This null is rejected in all six specifications, with p-values below 0.001 in all cases.

The estimated hazard ratios are similar for coal and gas, in both cases indicating lower exit rates for regulated units. The estimated hazard ratios are somewhat larger for coal – 0.59–0.60 – compared to for gas – 0.43–0.53, but the confidence intervals overlap. Thus, the main takeaway from Table 4 is that regulated coal and gas units have been significantly less likely to exit than unregulated units.

Figure 3 shows these results visually. Based on the specification in Table 4 column (5), the figure plots the cumulative retirement probabilities for regulated and unregulated units by age. For example, 60 years after opening 39% of regulated units have exited, compared to 64% of unregulated units. Converting the cumulative probability density functions shown in the figure into their implied probability density functions and computing mean durations across the two groups, we find that the average age at retirement is 8.4 years higher for regulated units compared to unregulated units.

Could this pattern reflect unregulated companies cutting corners in operations and maintenance (O&M)? Possibly, but neither the academic literature nor the popular press emphasizes equipment deterioration as a major driver of plant exit decisions.[8] Furthermore, it is not clear whether unregulated companies have less incentive than regulated companies to invest in O&M. On the one hand, an unregulated company cannot pass O&M costs along to ratepayers. However, on the other hand, unregulated companies have a strong incentive to keep their plants running.[9] Unregulated companies make profit from selling electricity and therefore do not want operational problems that lead to outages.

Could this pattern reflect that regulated units were less affected by MATS? Fowlie (2010) finds that regulated companies (both IOUs and POUs) are more likely to invest in capital intensive emission equipment for coal plants, which the paper attributes to the Averch-Johnson effect. With more emission equipment already installed, regulated units might then have been less affected by MATS. This may well be part of the mechanism here, but it is worth emphasizing that MATS applies to coal but not gas, so this mechanism cannot explain the estimates in columns (3) and (4). Moreover, as we mentioned before, previous research finds that MATS played only a small role in explaining recent U.S. coal plant retirements (Linn and McCormack,

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[8] For the academic literature see Linn and McCormack (2019) and the other papers cited in the introduction, and for the popular press see: "Power Company Losses Some of Its Appetite for Coal," by Eric Lipton, *New York Times*, December 19, 2012. "Utilities Speed Up Closure of Coal-Fired Power Plants," by Katherine Blunt, *Wall Street Journal*, January 9, 2019. "New York's Last Coal-Fired Power Plant Is Closing," by Anne Barnard, *New York Times*, March 20, 2020.

[9] In related work, Hausman (2014) finds that unregulated nuclear plants are safer than regulated along various observable measures. The paper argues that unregulated companies work hard to improve safety because they have "strong incentives to avoid outages". For an unregulated company, "any outage leads to large losses in operating profits", while a regulated company can pass along the cost of an outage to ratepayers. This incentive to avoid outages is particularly strong for nuclear plants due to their low marginal cost of generation, but is also present for coal and gas plants.

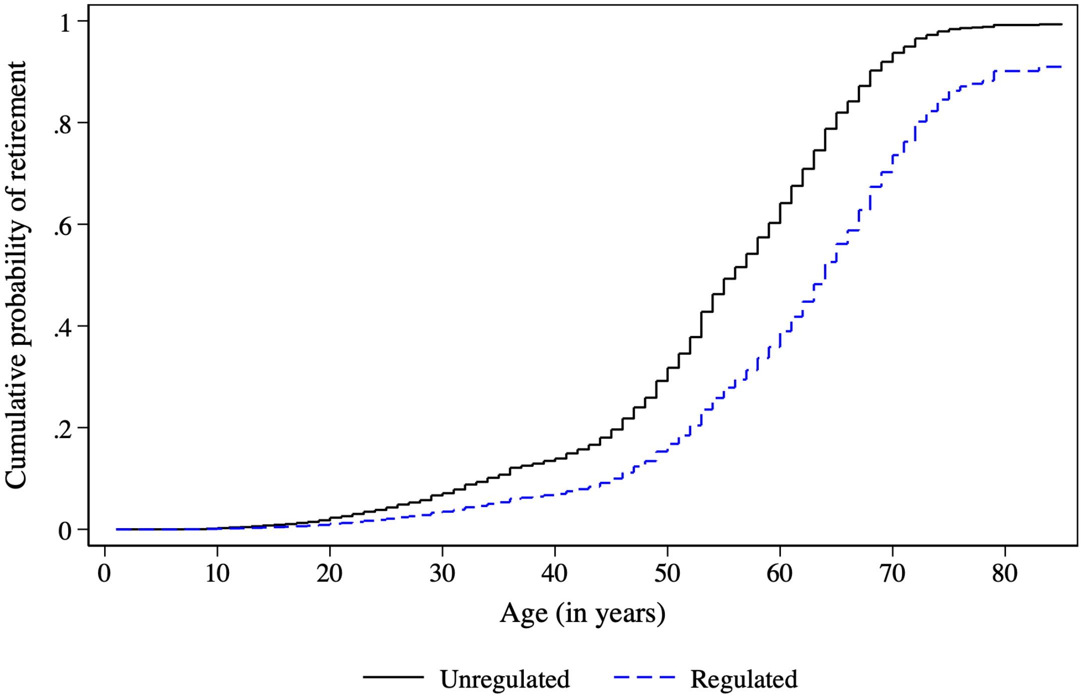
2019).

Table 4: Does Regulation Distort Exit Decisions?

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	0.598***	0.589***	0.432***	0.529***	0.505***	0.554***
	(0.091)	(0.094)	(0.068)	(0.086)	(0.056)	(0.064)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	7,683	6,085	12,213	8,046	21,943	14,142
Observations	14,073	14,073	65,743	65,743	79,816	79,816
Unique units	1,189	1,189	4,960	4,960	6,149	6,149
Number retirements	652	652	898	898	1550	1550

NOTES: This table reports estimated hazard ratios from a proportional hazard (cox) model described in equation (1). The model is estimated using maximum likelihood. The variable *Regulated* equals one for units owned by either an investor-owned utility or a publicly-owned utility. Columns with vintage by technology strata estimate separate baseline hazard functions for each combination of entry decade and prime mover group (e.g. natural gas combined cycle vs natural gas combustion steam turbine). For column (6), the included strata are vintage by technology by fuel type and the included fixed effects are NERC by 5-Year by fuel type. Standard errors are clustered at the power plant level. Statistical significance is assessed relative to the null hypothesis that the hazard ratio equals one.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 3: Does Regulation Distort Exit Decisions?



Notes: This figure plots cumulative retirement probabilities for regulated and unregulated units by age. For example, 60 years after opening 39% of regulated units have exited, compared to 64% of unregulated units. The estimates imply that the average age at retirement is 8.4 years higher for regulated units. Cumulative retirement probabilities are estimated using a Breslow estimator to recover the baseline hazard function after estimating the Cox model specification in Table 4 column (5).

4.3 IOU versus POU

We next estimate more flexible models that distinguish between investor-owned utilities (IOUs) and publicly-owned utilities (POUs). The results in the previous subsection combine both IOUs and POUs into a single category "regulated", but here we break down the regulated units into two categories.

Table 5 reports the estimated hazard ratios for IOUs and POUs. The structure of the table is identical to our main results in Table 4, except that we replace the variable *Regulated* in all specifications with two variables *Investor Owned Utility* and *Public Owned Utility*, which are indicators for IOU and POU units, respectively. The excluded category continues to be units owned by unregulated companies.

Both IOU and POU units are less likely to exit than unregulated units. In the full specification in column (6), the estimated hazard ratios are 0.62 and 0.44, indicating that IOU and POU units are 38% and 56% less likely to exit than unregulated units, respectively. The estimated hazard ratios are similar across columns, and twelve of the twelve estimated hazard ratios are statistically significant with p-values below 0.001. The table also reports in the last row p-values for tests of equality for the two estimated hazard ratios. The differences are statistically significant in some, but not all cases.

These results are consistent with both IOUs and POUs being less exposed to economic conditions. For IOUs, the lower exit rate also reflects that these companies, in some cases, have an incentive to continue operating capital-intensive equipment. With POUs, there is this same insulation from market conditions, but no regulatory bias toward capital-intensive investments. Instead, POUs are influenced by local priorities and preferences. As mentioned earlier, a POU might value, for example, retaining local employment or simply have strong preferences toward maintaining the status quo.

Table 5: Does Regulation Distort Exit Decisions? IOU versus POU

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Investor Owned Utility	0.608***	0.645**	0.584***	0.598***	0.592***	0.620***
	(0.096)	(0.111)	(0.100)	(0.115)	(0.069)	(0.080)
Public Owned Utility	0.550***	0.453***	0.319***	0.429***	0.405***	0.439***
	(0.114)	(0.098)	(0.059)	(0.085)	(0.055)	(0.063)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	7,636	6,005	12,137	7,961	21,839	13,953
Observations	14,073	14,073	65,743	65,743	79,816	79,816
Unique units	1,189	1,189	4,960	4,960	6,149	6,149
Number retirements	652	652	898	898	1550	1550
P-value: IOU vs POU	0.552	0.042	0.000	0.067	0.001	0.005

NOTES: This table is identical to our main results in Table 4 except that we replace in all specifications the variable *Regulated* with two variables *Investor Owned Utility* and *Public Owned Utility* which are indicators for IOU and POU units, respectively. The table has also been augmented with a new last row which reports the p-value for a Wald test of equality for the two estimated hazard ratios.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.4 Market Power

An additional consideration for unregulated companies is market power. Based on a structural oligopoly model, Myatt (2018) concludes that there has been too much coal exit in two major U.S. electricity markets (MISO and PJM), relative to the optimal choices of a hypothetical least-cost planner. The paper interprets these exits as a strategic reduction in capacity by unregulated companies to increase electricity prices for the remaining units owned by the same companies. Thus, market power might provide an alternative explanation for why unregulated units would have exited at higher rates than regulated units.

In this subsection, we test for market power. We identify the potential to exercise market power using each unregulated company's total 2010 U.S. capacity. From EIA-860, we observe the operator name for each unit using the variable "Utility Name". Given that many parent companies have unique LLCs for different power plants (e.g. Calpine Bethlehem LLC and Calpine Bosque Energy Center LLC; AES Alamitos LLC and AES Beaver Valley), we extract the first word of the operator name and sum 2010 capacity based on that name. For example, we sum capacity for all units with an operator name that starts with the word Calpine, AES, Dynegy, and so on. This generates 481 unique operators for 1882 unregulated units at 574 power plants. Appendix Table 7 provides a list of the twenty largest operators.

Table 6 reports the results of this market power test. This table is identical to our main results in Table 4 except that we replace in all specifications the variable *Regulated* with three variables which are indicators for units operated by independent power producers (i.e., unregulated) with different total portfolio sizes.

The estimated hazard ratios are all above 1.0, consistent with our previous results. Notice that for this table, we have flipped the excluded category. Whereas in the previous tables the excluded category was unregulated units, the excluded category now is regulated units. Thus, hazard ratios above 1.0 in this table are equivalent to hazard ratios less than one in the previous tables, in both cases indicating that regulated units are *less* likely to exit relative to unregulated units.

If market power was driving exit behavior, then we would expect to see larger hazard ratios for large portfolios. Estimates vary between specifications, but, in general, this is not what we find. Medium-sized portfolios tend to have the largest hazard ratios, with smaller hazard ratios for large-sized portfolios. In addition, most of the differences are not statistically significant. The three bottom rows in the table report p-values for tests of equality and, in almost all cases, the differences are not significant.

It is also notable that the estimated hazard ratios are considerably higher than 1.0 even for smaller operators. This is not what we would expect with market power. The motivation for companies in this setting is that in retiring one unit, this pushes up prices for remaining units. But in this case, these operators are small enough that this strategy becomes unprofitable because there are not enough other units to benefit.

Thus, these results suggest that market power is not driving our main results. Estimated hazard ratios vary widely, but there is no consistent evidence of higher exit rates among larger operators, nor do we find significantly lower exit rates among the smallest operators. Market power motivations may well be a factor in retirement decisions, but they do not seem to be the dominant factor, nor does it seem that market power can explain the patterns observed in Tables 4 and 5.

Table 6: Does Regulation Distort Exit Decisions? Market Power Test

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Unregulated, Operator < 3 GW	2.121**	1.820***	2.420***	1.616**	2.337***	1.662***
	(0.627)	(0.397)	(0.508)	(0.368)	(0.381)	(0.271)
Unregulated, Operator 3–11 GW	1.786***	2.344***	2.404***	2.383***	1.921***	2.342***
	(0.264)	(0.406)	(0.678)	(0.591)	(0.361)	(0.371)
Unregulated, Operator > 11 GW	1.069	1.022	2.081***	1.994***	1.570***	1.576**
	(0.305)	(0.377)	(0.439)	(0.434)	(0.274)	(0.311)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	7,676	6,089	12,216	8,045	21,935	14,123
Observations	14,073	14,073	65,743	65,743	79,816	79,816
Unique units	1189	1189	4960	4960	6149	6149
Number retirements	652	652	898	898	1550	1550
P-value: Small vs. Medium	0.589	0.337	0.983	0.215	0.406	0.110
P-value: Small vs. Large	0.085	0.167	0.564	0.433	0.076	0.818
P-value: Medium vs Large	0.090	0.031	0.645	0.560	0.398	0.098

NOTES: This table is identical to our main results in Table 4 except we replace in all specifications the variable *Regulated* with three variables which are indicators for units operated by independent power producers (i.e. unregulated) with different total portfolio sizes. The table has also been augmented with three new rows at the bottom which reports p-values for Wald tests of equality for the various estimated hazard ratios.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.5 Local Priorities

As discussed earlier, regulated firms are subject to the preferences and priorities of local regulators. In this subsection, we study one form that these local priorities can take and test a potential mechanism related to regulatory capture.

Cicala (2015) compares procurement behavior by U.S. coal plants before and after deregulation. Using difference-in-differences, the paper finds that deregulation reduced the price paid for coal by 12 percent, primarily because unregulated plants became more willing to source coal from out of state. The paper attributes this pattern to regulatory capture in the spirit of Stigler (1971) and Peltzman (1976), with coal producers exerting political pressure on state politicians and regulators.

We hypothesize that this same mechanism could also affect exit behavior. In states with large amounts of coal and gas production, we would expect more political pressure to keep regulated coal and gas plants operating. To test this hypothesis, we compile additional data and identify states that are "large" producers of these inputs. We define "large" producing states as the ten states with the highest cumulative production of coal and gas, respectively, over the period 2011–2023. These "large" producing states account of 88% and 90% of total cumulative production of coal and gas, respectively during that period.[10]

Table 7 reports the results of this test of regulatory capture. This table is similar to our main results in Table 4 except that we replace in all specifications the variable *Regulated* with two variables that indicate regulated units in states with or without large in-state production of coal and natural gas, respectively. Our hypothesis is about coal producers influencing coal plants and natural gas producers influencing gas plants, so we do not estimate a "stacked" specification for all units.

We find no evidence of regulatory capture along this dimension. Regulated units are again less likely to exit than unregulated units. The estimated hazard ratios are all well below one and are all highly statistically significant. But we see no difference in exit behavior for units located in states with or without large in-state

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[10] These calculations were made using state-by-year data from U.S. Department of Energy, Energy Information Administration, State Energy Data System. `https://www.eia.gov/state/seds/`. The top ten states for coal are Wyoming, West Virginia, Kentucky, Pennsylvania, Illinois, Indiana, Montana, Texas, North Dakota, and Colorado. The top ten states for gas are Texas, Pennsylvania, Louisiana, Oklahoma, Colorado, West Virginia, New Mexico, Wyoming, Ohio, and North Dakota.

production. Perhaps this is unsurprising for natural gas. Cicala (2015) finds little evidence that deregulation changed procurement behavior for natural gas, which the paper attributes to gas being a “homogeneous commodity traded in regional markets with transparent prices”. Natural gas markets are sufficiently transparent and regional that it may simply not be worth lobbying to keep in-state gas plants operating.

In contrast, coal is more heterogeneous. Local coal plants are often tuned to the specific characteristics of locally produced coal, and there is more asymmetric information with coal contracts (Joskow, 1987; Cicala, 2015). Given this, it is somewhat surprising that units in states with large coal production do not exhibit lower exit rates. However, there could be other counteracting differences between states with and without large coal production, and/or the magnitude of the effect could be too small to detect. Moreover, it is worth emphasizing that this is only one of many forms that local priorities and preferences could take, so these results should not be interpreted as providing evidence against all forms of local priorities and preferences.

Table 7: Does Regulation Distort Exit Decisions? Local Priorities

	Coal		Gas	
	(1)	(2)	(3)	(4)
Regulated x Large coal production	0.571***	0.538***		
	(0.116)	(0.107)		
Regulated x Small coal production	0.608***	0.616***		
	(0.095)	(0.105)		
Regulated x Large gas production			0.396***	0.527***
			(0.072)	(0.102)
Regulated x Small gas production			0.444***	0.530***
			(0.075)	(0.093)
Size (MW)	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes
AIC	7,684	6,093	12,214	8,048
Observations	14,073	14,073	65,743	65,743
Unique units	1,189	1,189	4,960	4,960
Number retirements	652	652	898	898

NOTES: This table is identical to our main results in Table 4 except we replace the variable *Regulated* with two variables that indicate regulated units in states with or without large in-state production of coal and natural gas, respectively. Large producing states are the ten states with the highest cumulative production of coal and gas, respectively, over the period 2011–2023.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.6 Sensitivity Analyses

This subsection describes the results of various sensitivity analyses. Overall, the results are robust and quite similar in alternative specifications.

First, we explore specifications which exclude smaller units. As we mentioned earlier, a nice feature of EIA-860 is that it includes all U.S. power plants over one megawatt of capacity. These data thus include many units that are quite small, just a fraction of the capacity of, for example, the average coal and gas unit in our sample. However, we find that estimates are quite similar when we estimate the model including only units 50 megawatts and larger. Some of the estimated hazard ratios are modestly larger for coal and modestly smaller for gas, but overall quite similar both in magnitude and statistical significance. See Appendix Tables 2 and 3.

Second, we estimate alternative specifications with an alternative set of time fixed effects that capture richer variation over calendar years. Our main results include NERC by 5-year fixed effects, which allows for three separate fixed effects for each NERC region. In this alternative specification, we control separately for NERC fixed effects and year fixed effects. This allows for more richness over time, for example 2021 and 2022 have separate fixed effects, but these two variables are not interacted, so this allows for less cross-NERC flexibility. As it turns out, the estimates in this alternative specification are also very similar, so the results are not unduly sensitive to exactly how we construct these fixed effects. See Appendix Table 4.

Third, we estimate alternative specifications which exclude units for which there is some disagreement in the EIA-860 about regulation type. In our main results, we measure regulation type using the response to the "entity type" question. This question provides the most complete information, including the distinction between IOU and POU. But there is also a "sector type" question which does not have as much detail, but does distinguish between regulated and unregulated companies. In 7% of the cases there is disagreement between the two questions, and in this alternative specification we exclude those observations. The results are very similar and, if anything, indicate somewhat stronger differences in behavior between regulated and unregulated companies. See Appendix Table 5.

Finally, we estimate an alternative cross-sectional model using least squares. The hazard model is a better match for our setting, but makes strong functional form assumptions. In this alternative specification, we collapse our dataset to a single observation per unit and estimate a linear probability model in which the outcome is an indicator equal to one if the unit exited at any point during 2011–2023. Some specifications control for capacity, age, NERC fixed effects, vintage fixed effects, and technology fixed effects. In our preferred binary regulatory status specification in column (2), regulated coal units are 13.2 percentage points less likely to exit, compared to a base of 54.8%, while in column (5) regulated gas units are 6.1 percentage points less likely to exit, compared to a base of 18.1%. Thus, in both cases, the probability of exit decreases by about one third. Both effects are statistically significant at the 1% level. Distinguishing between IOU and POU in columns (3) and (6) the point estimates for IOU are negative but smaller and less statistically significant, and the effects for POU are negative, large, and statistically significant. See Appendix Table 6.

5 Conclusion

U.S. power companies made the decision to retire more than 180 gigawatts of coal and natural gas between 2011 and 2023. In this paper, we focus on the role that regulation plays in these decisions. Using generator-level data, we show that units owned by regulated companies were 45% less likely to exit than units owned by unregulated companies. This difference remains after controlling for unit characteristics and region-by-time fixed effects, is large and statistically significant for both coal and natural gas plants, and holds for both investor-owned utilities and publicly-owned utilities.

In the paper, we argue that this behavior reflects incentives. Unregulated companies were exposed to unfavorable market conditions during this period, so many decided to exit. Regulated companies, on the contrary, were insulated from economic conditions and therefore less likely to exit. For investor-owned utilities, there is also a well-known regulatory distortion which created a strong incentive to continue operating capital-intensive equipment.

Since 2024, the fortunes for U.S. power companies have changed dramatically. The increased demand for electricity from data centers shifted the market overnight from surplus to shortage and left companies scrambling to add new capacity, and, in a few cases, even to bring back capacity that had been recently closed. One of the implications of this dramatic reversal is that units that did not exit in 2011–2023 are now more likely to remain open for the foreseeable future.

Moving forward incentives will continue to matter. More exposed to the positive economic conditions, we would expect unregulated units to be *less* likely to exit than regulated units. There will also be pressure to keep regulated units operating, but it remains to be seen whether this pressure will be as strong as the profit motive for unregulated units. The broader point is that the effect of regulation on exit decisions can be either positive or negative, but that we should expect regulated companies to be insulated from whatever current economic conditions may be.

References

Averch, Harvey and Leland L Johnson, "Behavior of the Firm Under Regulatory Constraint," *American Economic Review*, 1962, *52* (5), 1052–1069.

Borenstein, Severin, "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster," *Journal of Economic Perspectives*, 2002, *16* (1), 191–211.

_ **and James Bushnell**, "The U.S. Electricity Industry After 20 Years of Restructuring," *Annual Review of Economics*, 2015, *7* (1), 437–463.

_ **, James B Bushnell, and Frank A Wolak**, "Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market," *American Economic Review*, 2002, *92* (5), 1376–1405.

Borrero, Miguel, Gautam Gowrisankaran, and Ashley Langer, "Ramping Costs and Coal Generator Exit," *Working Paper*, 2023.

Bushnell, James B, Erin T Mansur, and Celeste Saravia, "Vertical Arrangements, Market Structure, and Competition: An Analysis of Restructured U.S. Electricity Markets," *American Economic Review*, 2008, *98* (1), 237–266.

Chan, H Ron, Harrison Fell, Ian Lange, and Shanjun Li, "Efficiency and Environmental Impacts of Electricity Restructuring on Coal-Fired Power Plants," *Journal of Environmental Economics and Management*, 2017, *81*, 1–18.

Cicala, Steve, "When Does Regulation Distort Costs? Lessons from Fuel Procurement in US Electricity Generation," *American Economic Review*, 2015, *105* (1), 411–444.

_ , "Imperfect Markets Versus Imperfect Regulation in US Electricity Generation," *American Economic Review*, 2022, *112* (2), 409–441.

_ , "Restructuring the Rate Base," *AEA Papers and Proceedings*, 2025, *115*, 363–368.

Coglianese, John, Todd D Gerarden, and James H Stock, "The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008-2016," *Energy Journal*, 2020, *41* (1), 55–82.

Cullen, Joseph A and Erin T Mansur, "Inferring Carbon Abatement Costs in Electricity Markets: A Revealed Preference Approach Using the Shale Revolution," *American Economic Journal: Economic Policy*, 2017, *9* (3), 106–133.

Davis, Lucas W and Catherine Wolfram, "Deregulation, Consolidation, and Efficiency: Evidence from US Nuclear Power," *American Economic Journal: Applied Economics*, 2012, *4* (4), 194–225.

Davis, Rebecca J, J Scott Holladay, and Charles Sims, "Coal-Fired Power Plant Retirements in the United States," *NBER Environmental and Energy Policy and the Economy*, 2022, *3* (1), 4–36.

Demirer, Mert and Ömer Karaduman, "Do Mergers and Acquisitions Improve Efficiency? Evidence from Power Plants," *Working Paper*, 2024.

Dunkle Werner, Karl and Stephen Jarvis, "Rate of Return Regulation Revisited," *Energy Institute Working Paper, UC Berkeley*, 2025.

EIA, U.S. Energy Information Administration, "Electricity Data Browser," 2024.

EIA, U.S. Energy Information Administration U.S., "Hydraulically Fractured Horizontal Wells Account for Most New Oil and Natural Gas Wells," January 2018.

Fabrizio, Kira R, Nancy L Rose, and Catherine D Wolfram, "Do Markets Reduce Costs? Assessing the Impact of Regulatory Restructuring on US Electric Generation Efficiency," *American Economic Review*, 2007, *97* (4), 1250–1277.

Fell, Harrison and Daniel T Kaffine, "The Fall of Coal: Joint Impacts of Fuel Prices and Renewables on Generation and Emissions," *American Economic Journal: Economic Policy*, 2018, *10* (2), 90–116.

Fowlie, Meredith, "Emissions Trading, Electricity Restructuring, and Investment in Pollution Abatement," *American Economic Review*, 2010, *100* (3), 837–869.

Gowrisankaran, Gautam, Ashley Langer, and Mar Reguant, "Energy Transitions in Regulated Markets," *Working Paper*, 2025.

_ , _ , and Wendan Zhang, "Policy Uncertainty in the Market for Coal Electricity: The Case of Air Toxics Standards," *Journal of Political Economy*, 2025, *133* (6), 1757–1795.

Hausman, Catherine, "Corporate Incentives and Nuclear Safety," *American Economic Journal: Economic Policy*, 2014, *6* (3), 178–206.

_ and Ryan Kellogg, "Welfare and Distributional Implications of Shale Gas," *Brookings Papers on Economic Activity*, 2015, pp. 71–125.

Holland, Stephen P, Erin T Mansur, Nicholas Z Muller, and Andrew J Yates, "Decompositions and Policy Consequences of an Extraordinary Decline in Air Pollution from Electricity Generation," *American Economic Journal: Economic Policy*, 2020, *12* (4), 244–274.

Joskow, Paul L, "Contract Duration and Relationship-Specific Investments: Empirical Evidence from Coal Markets," *American Economic Review*, 1987, pp. 168–185.

__ **and Richard Schmalensee**, "Markets for Power: An Analysis of Electrical Utility Deregulation," *MIT Press Books*, 1988.

Linn, Joshua and Kristen McCormack, "The Roles of Energy Markets and Environmental Regulation in Reducing Coal-Fired Plant Profits and Electricity Sector Emissions," *RAND Journal of Economics*, 2019, *50* (4), 733–767.

Mansur, Erin T and Matthew White, "Market Organization and Efficiency in Electricity Markets," *Working Paper*, 2012.

Myatt, James, "Market Power and Long-Run Technology Choice in the U.S. Electricity Industry," *Northwestern University Department of Economics Working Paper*, 2018.

Peltzman, Sam, "Toward a More General Theory of Regulation," *Journal of Law and Economics*, 1976, *19* (2), 211–240.

Peng, Jing, Jesse Buchsbaum, Catherine Hausman, and Johanna L Mathieu, "Power System Decarbonization: A Comparison Between Carbon Taxes and Forcing Coal Power Plant Retirements," *IEEE Transactions on Sustainable Energy*, 2024.

Stigler, George J, "The Theory of Economic Regulation," *The Bell Journal of Economics and Management Science*, 1971, pp. 3–21.

Warner, Cody, Duncan Callaway, and Meredith Fowlie, "Risk-Cost Tradeoffs in Power Sector Wildfire Prevention," *Energy Institute Working Paper, UC Berkeley*, 2024.

White, Matthew W, "Power Struggles: Explaining Deregulatory Reforms in Electricity Markets," *Brookings Papers on Economic Activity*, 1996, *1996*, 201–267.

Wolfram, Catherine D, "Measuring Duopoly Power in the British Electricity Spot Market," *American Economic Review*, 1999, *89* (4), 805–826.

Online Appendix

Appendix Table 1: Balance of Covariates

	(1) Regulated Units	(2) Unregulated Units	(3) P-value (1) vs. (2)
A. Coal			
Size (MW)	279	278	0.961
	(273.8)	(266.6)	
Year Opened (MW)	1968	1972	0.000
	(14)	(16)	
B. Gas			
Size (MW)	81	112	0.000
	(97.8)	(111.7)	
Year Opened (MW)	1987	1993	0.000
	(19)	(14)	
Combined Cycle	0.24	0.47	0.000
Combustion Gas Turbine	0.43	0.36	0.000
Combustion Steam Turbine	0.12	0.07	0.000
Other	0.22	0.11	0.000

NOTES: This table reports summary statistics for our dataset of electricity generating units by fuel type and regulatory status. Panel (A) describes all coal units in operation in 2010 and panel (B) describes all gas units. Mean capacity and opening year is reported, with standard deviations in parenthesis. Unit technology shares are reported for gas units; "Other" includes internal combustion, combined cycle units that operate with a single shaft, and units with energy storage. The final column reports p-values from a t-test of the null hypothesis that values in the two columns are equal for regulated and unregulated units.

Appendix Table 2: Does Regulation Distort Exit Decisions? Alternative Specification Including Only Units 50MW and Larger

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	0.644***	0.676**	0.520***	0.390***	0.625***	0.557***
	(0.108)	(0.111)	(0.118)	(0.105)	(0.084)	(0.079)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	5,844	4,632	2,827	2,047	9,620	6,687
Observations	11,524	11,524	36,797	36,797	48,321	48,321
Unique units	958	958	2,709	2,709	3,667	3,667
Number retirements	518	518	255	255	773	773

NOTES: This table reports an alternative specification which is identical to the specification used for Table 4, except we exclude units smaller than 50MW.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix Table 3: Does Regulation Distort Exit Decisions? IOU vs POU Alternative Specification Including Only Units 50MW and Larger

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Investor Owned Utility	0.645**	0.678**	0.523***	0.429***	0.623***	0.574***
	(0.110)	(0.121)	(0.124)	(0.123)	(0.086)	(0.088)
Public Owned Utility	0.599*	0.602**	0.496**	0.270***	0.606**	0.450***
	(0.166)	(0.150)	(0.160)	(0.101)	(0.131)	(0.093)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year	No	Yes	No	Yes	No	Yes
Vintage x Technology	No	Yes	No	Yes	No	Yes
AIC	5,801	4,564	2,816	2,030	9,567	6,596
Observations	11,524	11,524	36,797	36,797	48,321	48,321
Unique units	958	958	2,709	2,709	3,667	3,667
Retirements	518	518	255	255	773	773
P-value: IOU vs POU	0.764	0.592	0.850	0.119	0.888	0.172

NOTES: This table reports an alternative specification which is identical to the specification used for Table 5, except we exclude units smaller than 50MW.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix Table 4: Does Regulation Distort Exit Decisions? Alternative Specification Using Richer Time Fixed Effects

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	0.598***	0.588***	0.432***	0.525***	0.505***	0.556***
	(0.091)	(0.098)	(0.068)	(0.086)	(0.056)	(0.066)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC FE	No	Yes	No	Yes	No	Yes
Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	7,683	5,993	12,213	7,936	21,943	13,940
Observations	14,073	14,073	65,743	65,743	79,816	79,816
Unique units	1,189	1,189	4,960	4,960	6,149	6,149
Number retirements	652	652	898	898	1550	1550

NOTES: This table reports an alternative specification which is identical to the specification used for Table 4, except that annual (1 year) fixed effects are included, as well as separate (non-interacted) fixed effects for NERC regions.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix Table 5: Does Regulation Distort Exit Decisions? Sample Restricted to Units with Aligned Sector and Entity Type Designations

	Coal		Gas		All	
	(1)	(2)	(3)	(4)	(5)	(6)
Regulated	0.592***	0.545***	0.405***	0.487***	0.481***	0.509***
	(0.093)	(0.093)	(0.065)	(0.083)	(0.054)	(0.062)
Size (MW)	Yes	Yes	Yes	Yes	Yes	Yes
NERC x 5-Year FE	No	Yes	No	Yes	No	Yes
Vintage x Technology Strata	No	Yes	No	Yes	No	Yes
AIC	6,992	5,509	11,622	7,633	20,532	13,143
Observations	13,306	13,306	60,451	60,451	73,757	73,757
Unique units	1,117	1,117	4,575	4,575	5,692	5,692
Number retirements	600	600	862	862	1462	1462

NOTES: This table reports an alternative specification which is identical to the specification used for Table 4, except we exclude units whose sector classification is inconsistent with their reported entity type in the EIA-860 data

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix Table 6: Does Regulation Distort Exit Decisions? Cross Sectional Model

	Coal			Gas			All		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Regulated	-0.124**	-0.132***		-0.0260	-0.0619***		0.0175	-0.0733***	
	(0.0486)	(0.0474)		(0.0252)	(0.0214)		(0.0245)	(0.0195)	
IOU			-0.0856*			-0.0175			-0.0312
			(0.0500)			(0.0253)			(0.0227)
POU			-0.204***			-0.111***			-0.123***
			(0.0612)			(0.0247)			(0.0229)
Size (MW) Quadratic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age Quadratic	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
NERC FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Vintage FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Technology FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Dependent var. mean	0.548	0.548	0.548	0.181	0.181	0.181	0.252	0.252	0.252
R-squared	0.112	0.243	0.252	0.049	0.274	0.282	0.005	0.341	0.347
Observations	1,189	1,189	1,189	4,960	4,960	4,960	6,149	6,149	6,149

NOTES: This table reports the estimates from a cross-sectional model of retirement estimated using least squares. For this regression, we collapse the data so that there is one observation per unit. The outcome variable equals one if the unit was retired at any point during 2011–2023 and zero otherwise. A similar set of covariates are included as in the main analysis in Table 4, with some modifications as not all interacted fixed effects can be estimated in this cross section.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix Table 7: Large Operators

Operator	Capacity (GW)	Coal Units	Gas Units
GenOn	24.06	38	84
Luminant	17.52	11	40
Calpine	16.19	2	104
NRG	15.52	7	93
PSEG	9.47	4	71
Dynegy	9.06	12	32
Midwest	8.33	15	5
AES	7.20	11	18
Ameren	5.42	13	10
Tenaska	4.69		20
New	3.84		24
CAMS	3.66		23
Dominion	3.38	5	9
PPL	3.23	5	17
Louisiana	2.57	3	13
TC	2.55		21
Gila	2.48		12
TPF	2.47		25
Union	2.43		12
Constellation	2.40	6	1

NOTES: This table lists the top 20 operators by 2010 capacity of unregulated units. Unique operators are identified from the EIA-860 data using the first word of the identified operator name.