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Adoption of SO_2 emission control technologies - An application of survival analysis

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HIGHLIGHTS

- Contributing factors affecting investment decisions on emission control devices.
- A survival analysis framework is applied in estimation.
- Data cover over 300 coal-fired electric utility power plants, 2002–2012.
- Still-regulated power plants are more likely to install FGD than deregulated ones.
- State-level inspection frequency leads to more FGD installation.

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ABSTRACT

Using data on coal-fired electric power plants, this article investigates the contributing factors affecting the investment decisions on flue-gas desulfurization (FGD), a capital-intensive emission control technology. The paper makes two contributions to the literature. First, the public regulatory status of electric power plants is found to have a strong influence on whether FGD investment is made. Compared to deregulated power plants, those that are still under rate-of-return regulations by Public Utility Commissions are more likely to install FGD. Second, a higher rate of inspections of polluting facilities (not just electric utility power plants) in a state in the previous year is associated with a higher probability of power plants adopting FGD this year. In addition, sulfur content of coal and plant size are both positively associated with the likelihood of FGD installation. The service length of boilers is negatively associated with the likelihood.

1. Introduction

A large share of air pollution in the US is generated in the energy sector, especially by fossil-fired electric power plants. According to a 2012 report by the Environmental Protection Agency (EPA), about two thirds of all SO_2 and 40 percent of all NO_x come from coal-fired electric power plants. The most important piece of environmental regulation on SO_2 emissions has been the Acid Rain Program, established by Title IV of the 1990 Clean Air Act Amendments to address the issue of acid rain caused by emissions. The primary goal of the Acid Rain Program is to reduce annual SO_2 emissions to 10 million tons below 1980 levels, mainly via emission monitoring and compliance enforcement. To monitor emissions, all plants regulated by the Acid Rain Program installed Continuous Emission Monitoring systems and report emissions to the EPA every quarter. Enforcement, on the other hand, is performed by the delegated state and local environmental agencies, which report to Environmental Protection Agency's Air Facility System.

Power plants have a number of ways to reach compliance: installing flue-gas desulfurization (FGD, also called scrubbers), switching to low-sulfur coal or natural gas, or adopting renewable energy. For an established electric power plant, it is not always easy to switch from coal to natural gas. For new power plants, the options of using renewable energy are predetermined by location and the availability of renewable energy sources such as solar and wind. For all these reasons, FGD stands as a relatively practical option to reduce emission.

In the 1990s and 2000s, emissions of sulfur dioxide and nitrogen oxides declined continuously.[1] The achievement was most

Abbreviations: AFS, Air Facility System; EIA, Energy Information Agency; EPA, Environmental Protection Agency; FGD, Flue-gas desulfurization; MACT, Maximum Achievable Control Technology; PUC, Public Utility Commission; TVA, Tennessee Valley Authority; SO_2, Sulfur dioxide; NO_x, Nitrogen oxides

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[1] On the contrary, greenhouse gas emissions from electricity have increased by about 11% since 1990, and accounted for 32% of US total greenhouse gas emissions in 2012 (EIA, 2013).

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noticeable in the electric power sector, where total SO_2 emissions decreased from close to 16 million short tons in 1990, to 11 million short tons in 2000, to under 4 million short tons in 2012. The US Energy Information Administration (EIA) attributes such attainment to the increasing number of coal-fired units retrofitted with FGD, among a few other reasons.

FGD is a type of control device that removes SO_2 emissions from large electric coal-fired utility boilers.[2] Traditional FGD systems use an alkaline reagent to produce a solid compound to enhance the absorption of acid gases (EPA-APTI, 2014). Though effective – the reduction efficiency is between 50% and 98% – FGD involves substantial capital cost and the operation and maintenance costs. According to EPA (2003), the capital cost for a wet scrubber installed on unit size greater than 400 MW was between 100 and 250 dollars per kW in 2001. The operation and maintenance costs were about 2–8 dollars per kW. The capital cost increased substantially throughout the 2000s. The wet FGD capital cost for a 500 MW unit retrofit during 2004–2006 increased from $342 to $407 per kW, meaning the average capital cost for a 500 MW unit is about 187 million US dollars (Cichanowicz, 2010). FGD is an important technology in reducing SO_2 emissions, and yet, its installation and maintenance impose a substantial financial burden on power plants. Their decision to adopt is hardly a trivial one. It is important, as well as interesting, to understand the leading factors affecting coal-fired electric power plants' decisions on adopting this device. Among others, we are particularly interested in the impact of policy variables such as electric utility industry restructuring and environmental regulations.

Using data between 2002 and 2012, this paper applies survival analysis framework to estimate the effects of environmental regulations and electricity market restructuring as well as firm size, fuel costs, quality of coal, on the likelihood of FGD installation. The estimation unit is boiler. A total of 327 coal-fired power plants and their 917 boilers are included in the sample. The study makes two contributions to the literature. First, we show that electricity market restructuring is strongly associated with the power plants' adoption of FGD. Although plenty of research has been written about the influence of electricity market restructuring on power plants, none of them directly estimates the relationship between restructuring and FGD installation. We find that still-regulated power plants are much more likely to install the emission control device compared to their deregulated counterparts. Second, the environmental regulatory stringency has a strong impact on power plants' propensity to install FGD. Inspections by state and local agencies, whether carried out in the electric utility industry or not, have a strong influence on FGD adoption by power plants. A one percentage point increase in the state-level inspection rate of all polluters in the previous year increases the probability of FGD installation this year by about 1.3–2.7%. Additionally, the empirical results find a strong positive influence of plant size on the propensity to invest in this emission control technology. Boiler age, on the other hand, is negative associated with the technology adoption.

The paper is organized as follows. Section two provides background information on the literature and relevant regulations. Section three outlines the empirical model. Section four describes the data and summary statistics. Section five presents the empirical results. Section six contains our conclusions.

[2] FGD systems are also used in process plants such as refineries and pulp and paper mills.

2. Literature and regulatory background

Closely related to this paper are two strands of research, focusing on restructuring of the electric utility industry and environmental protection regulations respectively.

Restructuring of the electric utility industry. In the US, restructuring of the electric utility industry mainly took the form of deregulation in terms of ownership, rate-making, cost recovery, and entry of new competitors into the market. The restructuring movement was not nationwide in that, to this day, 15 states have restructured their electricity industry, 27 states are still regulated, and the rest have once started but then suspended restructuring. Even in states that undertook the reform, restructuring does not mean complete deregulation, as the government continues to regulate some services of the industry.

In still-regulated states, utilities continue to be able to seek the recovery of prudently incurred operating costs from Public Utility Commissions (PUCs) and receive rate-of-return on capital investments. In contrast, utilities in states that completed restructuring can no longer resort to such cost recovery. For a more detailed discussion of the regulatory history of electricity market restructuring, refer to White (1996), Joskow (1997), EIA (2000), Borenstein and Bushnell (2000), Wolfram (2005), and EPA (2011).

Most studies in this field examine the impact of rate-or-return regulations or deregulations on two things: cost savings and the pricing of electricity output. First, deregulated power plants appear to be more capable of cutting expenses on labor, fuel, and operations. Fuel efficiency at plants following restructuring improved by about 2% during the sample period of 1997–2003 (Bushnell and Wolfram, 2005). Power plants in restructured states reduced labor and non-fuel expenses by roughly 5% or more relative to plants unaffected by restructuring incentives (Wolfram, 2005; Fabrizio et al., 2007). Procurement cost of coal input drops by 12% at deregulated plants relative to matched plants that were not subject to any regulatory change (Cicala, 2015). Other studies contributing to the impact on cost savings include Rose and Joskow (1990), Newbery and Pollitt (1997), Joskow (1997), and Bellas and Lange (2008). Second, the electricity output price tends to be higher in regulated states than that in deregulated ones, and new entrants can consistently underprice the projects proposed by regulated power plants (White, 1996). The higher rates were attributed to historical reasons that regulators forced utilities to purchase power from high-cost independent suppliers under the Public Utilities Regulatory Policy Act of 1978, as well as the industry's expensive foray into nuclear power.

So far, no research has directly measured the relationship between regulatory status and the installation of capital-intensive emission control devices like FGD.[3] Whether such relationship is positive or negative is unknown a priori. On one hand, regulated power plants may be more inclined to install FGD because (i) rate-of-return regulations incentivize plants to expand their capital stock (Averch and Johnson, 1962); and (ii) regulated units may be able to recover the investment cost of emission control device, if the investment is deemed prudent by the local PUC. On the other hand, regulated power plants may be less likely to install FGD because in regulated states, PUCs require power plants to obtain pre-approvals prior to installation of control technologies. As shown in Fig. A1, regulated power plants generally resort to pre-approvals (more frequently) or periodic rate adjustments when seeking cost recovery. Such pre-approvals create hurdles for

[3] With one exception, Cicala (2015), which touched on sulfur compliance strategy by regulated and deregulated power plants. The main results of Cicala (2015) show the effect of deregulation on fuel procurement price and import status, both of which are convincing. However, for FGD adoption, his results are unsatisfactory with R^2 as low as 0.017.