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Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act

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1. Introduction

There has been considerable debate over the costs and effectiveness of energy efficiency investments, such as improving fuel economy of passenger vehicles or retrofitting buildings with better-insulated windows. On the one hand, many estimates suggest that low-cost and even negative cost opportunities exist across the economy, where the market value of the energy savings outweighs the investment cost. On the other hand, many analysts are skeptical of these assertions, arguing that if such opportunities were available, firms and consumers would take advantage of them.

Many of the optimistic estimates are based on case studies or engineering assessments of particular technologies. Previous analysis has identified several reasons why such assessments may be incomplete. First, there may be costs that the analyst does not observe and that hinder adoption. Second, technologies, particularly new ones, may be less effective than expected or not used as expected. Third, missing data on the extent to which the technologies have already entered the market may cause an overestimate of available efficiency opportunities. Fourth, there may be a rebound effect, in which adopting energy-efficient technology reduces its cost of operation and increases its use. Underestimating the rebound effect could lead to an overestimate of emissions reductions caused by technology adoption. For the most part, however, there is little direct evidence on these possibilities, and the controversy remains.

Recent policy developments heighten this debate. Since a legislative approach to climate policy stalled in the US Congress, the Clean Air Act (CAA) has assumed the central role in the development of regulations that will reduce greenhouse gas (GHG) emissions. The US Environmental Protection Agency (EPA) has been developing emissions rate standards for sectors of the economy including passenger vehicles and new industrial sources. EPA also is expected to introduce performance standards for existing stationary sources, such as electricity generators and industrial facilities—an approach that is nearly unprecedented. Such standards raise the possibility of achieving carbon dioxide (CO_2) emissions reductions rapidly due to the low capital costs of the measures being contemplated, which is particularly important given the US commitment to reduce emissions under the 2009 Copenhagen Accord.

Coal-fired electricity generators account for about one-third of annual US CO_2 emissions. EPA estimates that 2 to 5 percent efficiency improvements may be achieved on average at these facilities,[1] yielding annual emissions reductions comparable to those expected from efficiency standards for new passenger vehicles sold from 2012 through 2016.[2] The novelty and potential of these electricity sector standards raise two questions: (1) what are the available abatement opportunities; and (2) what are the costs of reducing emissions? Answering these questions requires addressing each of the issues above: estimating technological potential, technology costs, and the rebound effect.

This course focuses on existing coal-fired electricity generation units. We analyze the actual efficiency of the entire fleet of coal units in the United States, where efficiency is measured as electricity generated per unit of heat input. We assess abatement opportunities and costs by observing how market and regulatory incentives affect the energy efficiency of coal plants. We use the results to compare the cost-effectiveness of alternative energy efficiency policies.

We make two contributions to the literature. First, other studies, for example Metcalf and Hassett (1999) and Linn (2008), have analyzed the effect of fuel prices on energy efficiency in other sectors, but this is the first study on the electricity sector. Second, previous research has shown that heterogeneous abatement costs and opportunities and the rebound effect cause flexible standards to be more cost effective than traditional standards, and cause emissions prices to be more cost effective than flexible standards (a traditional standard requires all units to meet the target whereas a flexible standard allows units to exceed the standard and sell credits to units that do not meet the standard) (Holland et al. 2009). This course is the first to study the electricity sector using econometric techniques and the first to estimate abatement costs, the rebound effect, and heterogeneity parameters in an internally consistent manner and compare the alternative policies.

We first assess abatement opportunities from efficiency improvements by examining heterogeneity in the efficiency of existing coal units. The analysis is performed using a unique panel data set of coal-fired generation units for the years 1985–2009. The data include monthly fuel input, generation, and coal prices by generation unit for nearly all US coal plants, and the units in the sample account for 95 to 98 percent of total coal generation in each year. We use a generation unit's heat rate (the ratio of heat input to electricity generated) to measure efficiency; heat rate is approximately proportional to the rate of CO_2 emissions per unit of electricity generation.

We show that there is considerable heterogeneity and a substantial right-hand (positive) tail in the heat rate distribution. Specific technical factors help explain heterogeneity across units, including boiler design, size, and vintage, and features such as pollution control equipment and cogeneration. After controlling for these factors, fleetwide emissions rate reductions of up to 6 percent may be technically feasible by improving performance up to a 90th percentile emissions-rate benchmark. This estimate does not account for costs, and we consider it an upper bound, given current technology.

To compare the costs of alternative policies, we specify and estimate the key parameters in an electricity sector model. In principle, several types of policies could be used to incentivize heat rate improvements, and the costs may vary across the alternative policies. We compare the costs of four policy alternatives: a traditional (inflexible) performance standard, a flexible performance standard, an emissions tax and a fuel tax. To make this comparison we observe that (1) cost-effectiveness depends largely on potentially heterogeneous abatement costs and the rebound effect; and (2) coal prices mimic the incentives created by a CO_2 emissions price (i.e., an emissions cap or tax) or some types of performance standards. Demonstrating the first point requires a brief description of the policies.

A traditional standard requires improvements at all units with emissions rates in excess of a target without regard to relative cost effectiveness. However, units that decrease heat rates to meet a traditional standard also experience a rebound effect because the lower heat rate reduces the marginal cost of generating electricity.[3] In contrast, a flexible emissions rate standard sets a benchmark emissions rate and allows firms to over-comply and sell credits to firms that under-comply, thus it promotes the lowest-cost efficiency improvements rather than requiring improvements at all units initially exceeding the target. The flexible standard has two effects on generation: it imposes an opportunity cost on heat rates by effectively adding to the cost of fuel, and it provides an output subsidy through the allocation of credits based on generation. The opportunity cost provides a disincentive for generation while the output subsidy provides an incentive to increase generation. Hence, unlike the traditional standard the flexible standard creates incentives to adopt energy efficiency technology at all units. Moreover, unlike the traditional standard the effect of the flexible standard on generation is ambiguous.

A CO_2 emissions or fuel tax raises the cost of using fuel, thereby creating an incentive to adopt energy efficient technology. By raising fuel costs, they also create an incentive for firms to reduce generation so they create the smallest rebound effect; hence, the emissions or fuel tax would require the smallest overall reduction in heat rates to achieve a given emissions target. In short, the relative cost-effectiveness of the policies depends on the cost of improving heat rates and the magnitude of the rebound effect.

Because data on energy efficiency technology adoption are not available, we focus on the response of heat rates to changes in coal prices. A simple model demonstrates that we can estimate the cost of adopting technology by examining the empirical relationship between coal prices and heat rates. We show that, conditional on the utilization of the unit, there is a one-to-one correspondence between the level of energy efficiency technology and the unit's heat rate. Similar to the CO_2 policies, an increase in the price of coal increases the opportunity cost for heat rates, conditional on utilization. Using the same panel data set as for the analysis of abatement opportunities, we find that a 10 percent coal price increase, corresponding to a tax on CO_2 emissions of about \$1.64 per ton, reduces heat rates by 0.2 to 0.5 percent, depending on the estimation procedure. A change in coal prices commensurate with a \$10 per ton tax on CO_2 emissions (representing a coal price increase of about 60 percent) would stimulate a 1 to 2 percent heat rate reduction (holding fixed utilization). This range of estimates encompasses the estimates suggested in the engineering literature but includes the possibility of somewhat lower costs than have been estimated. We note that the overall efficiency improvements of 2 to 5 percent discussed in the engineering literature correspond to the change in heat rate resulting from an increase in coal prices of more than two standard deviations—that is, out of sample. We also obtain a significant relationship between coal prices and utilization. A 10 percent increase in coal prices reduces utilization by 2 to 6 percent.

We use a stylized model of the electricity sector to simulate the effects of four energy efficiency policies: a traditional emissions rate standard, a flexible standard, a coal Btu tax (roughly equivalent to a coal emissions tax), and a fossil fuel emissions tax. We find that because of the narrower focus of the performance standards and the greater rebound effect, more investment in heat rate technology is required under the performance standards than the taxes to achieve a given emissions reduction. This raises the relative costs of the standards, but overall, the costs approximate the engineering estimates.

This course is organized as follows. Section 2 provides a brief background on the regulation of existing coal units under the CAA. Section 3 discusses the operation of coal-fired units in the US electricity system. Section 4 describes the data and summarizes heterogeneity in the heat rates across individual units. Section 5 describes the electricity sector model and motivates the empirical focus on the effects of coal prices on heat rates and utilization. Section 6 presents the empirical strategy and Section 7 presents the estimation results. Section 8 uses the estimation results to compare cost-effectiveness across policies, and Section 9 concludes.

2. The Clean Air Act

The modern CAA was passed in 1970 and conveys broad authority to EPA to develop regulations to mitigate harm from air pollution. In 2007 the Supreme Court affirmed this authority with respect to the regulation of GHGs *(Massachusetts v. EPA)*.[4] Subsequently, the agency made a formal, science-based determination that GHGs are dangerous to human health and the environment. This “endangerment finding” compelled the agency to mitigate that harm.

In 2011 EPA implemented regulations affecting CO_2 emissions from passenger vehicles, medium-duty trucks, and heavy-duty trucks.[5] The agency also implemented regulations for construction permitting (New Source Review, NSR) for major new and modified sources, such as power plants and industrial facilities.[6] The third anticipated EPA regulatory action is the development of performance standards for GHGs affecting the *operation* of stationary facilities.[7] EPA has a long history of setting performance standards for new sources, but performance standards for existing sources are nearly unprecedented.[8] The first standards, expected in 2013, will target new steam boilers at power plants fueled with coal, oil, and natural gas. Subsequently