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Policy makers have long favored command-and-control (CAC) methods to tackle environmental damage. The number of CAC policies devoted to environmental protection has increased steadily since the 1950s and have been a large part of the overall portfolio of environmental laws and regulation in the industrialized world. Schmitt and Schulze (2011) document that between 1970 and 2011 the two most prevalent EU air-pollution control instruments were CAC in nature. Over 50% of the policy instruments were of the CAC type (regulatory, interventionist, and top-down), with emission limits and technical requirements playing the role of the top two. In China and India, most of the environmental legislation also take the form of explicit directives that levy restrictions on both mobile (vehicular) and stationary sources (factories and combustion plants) of pollution (see Tanaka 2014, Greenstone and Hanna 2014).

In the last two decades, there has been a notable increase in research evaluating policy and programs for environmental protection. The design of empirical studies emphasizes causal inference by comparing group of regulated (treated) firms with a comparable control group of firms that were not subject to the treatment. As a result, we now have an improved perspective on the causal effects of environmental policy instruments that address industrial pollution. This review discusses some of the implementation details of prominent CAC type regulations and highlights the lessons learned from the empirical evaluation of these initiatives.

Introduction

Critical environmental legislation in the 20th century began as early as 1906 in the United Kingdom with the Alkali Works Regulation Act – directly controlling specific air pollutants at industrial source. The Act levied limits on emissions using the concept of "best practicable means" from the heavy chemicals industries, electricity generation, coal carbonization, iron and steel works, non-ferrous metals and mineral processing works (Longhurst, 2009). The United States of America (US) established the Environmental Protection Agency (EPA) to monitor and control pollution via the Clean Air Acts (CAA) of 1963 and 1970, and subsequently the Clean Water Act (CWA) of 1972. Starting in 1973, at the EU level the Environmental Action Programme (EAP) was adopted to guide environmental policy. In Japan, the Basic Law for Environmental Pollution Control was legislated in 1967 and the Environmental Agency established in 1971. The degree of environmental regulation has increased significantly since then and now environmental protection is of interest worldwide, most notably in emerging countries like China and India, where key local air pollutants are well above the World Health Organization's (WHO) recommended exposure limits.

The choice of environmental policy instruments has received much attention on both the political and the academic fronts. The set of instruments available at the disposal of a policy maker is divided into two main categories: command-and-control (CAC) instruments and economic incentive (EI) (or market-based) instruments. While EI instruments provide the polluter an economic incentive to abate pollution with the flexibility to do so by any means, CAC instruments are a direct form of regulation in which the regulator specifies a target or a standard that a firm, plant, or locality must achieve – or face non-compliance penalties. Standard economic theory concludes that EI instruments minimize the cost of achieving a certain level of pollution abatement and generate dynamic monetary incentives to comply; in turn, encouraging the development and adoption of cheaper and innovative clean technology (Baumol and Oates, 1988). Accordingly, economists regularly endorse EI instruments (such as carbon taxes, tradeable emissions permit) over conventional CAC policies (such as "prescriptive" technology or performance standards) for environmental protection. The political choices in the United States and Europe, however, are largely at odds with the policy recommendations prescribed in the economic literature.

Effectiveness of CAC in Emissions Control

The design of the US Clean Air Act (CAA) created spatial variation in the implementation of environmental policy across the US. The EPA set the National Ambient Air Quality Standards (NAAQS) in 1971 for six major air pollutants (carbon monoxide, lead, nitrogen oxides, and photochemical oxidants including ozone, particulate matter, and sulfur oxides) in the United States. To help these localities meet the NAAQS, the CAA set federally determined emission rate-based standards for plants, based on reference levels that were achievable through the use "best-available" technologies. The EPA further assigned each county annually to either air-quality "attainment" or "non-attainment" status, where non-attainment status implied that the area had air quality worse than the NAAQS for a given pollutant. The regulation then required plants in "nonattainment" counties to comply with these requirements. Moreover, the stringency of the requirement varied with plant size.

Several studies use this variation to evaluate the effect of air quality regulation under the CAA framework. Chay and Greenstone (2003) demonstrate that total suspended particles (TSPs) pollution fell dramatically in the early 1970s and that these large changes in ambient TSPs concentrations were regulation induced. While Greenstone (2004) shows that by the end of 1970s, most of the US counties complied with the NAAQS for SO2 concentrations; he finds that the SO2 regulation (nonattainment status) under the CAA did not play a major role in the improvement of ambient air quality for sulfur dioxide. On the other hand, Henderson (1996) documents that nonattainment counties successfully reduced ozone concentrations relative to attainment counties. Nevertheless, the regulation may have had unintended and costly consequences due the non-uniform implementation of the environmental regulation across the US. Becker and Henderson (2000) and Henderson (1996) find evidence of a reduction in the number of polluting plants in regulated counties and a shift over time of industrial plants to unregulated counties. The question remains whether the plants under scrutiny in the nonattainment areas (even those that moved) cleaned up source emissions – the intent of the Clean Air Act.

Other regulation categories of the CAA have also been under empirical evaluation. Auffhammer and Kellogg (2011) examine regulations that control the volatile organic compounds (VOCs) content of motor gasoline to reduce ozone pollution. They highlight that federal gasoline regulations (RVP and RFG) were less "prescriptive" in implementation because they gave refineries the ability to choose their own compliance strategy. Consequently, these mandates led to no meaningful abatement of ozone pollution because the refineries chose to remove those volatile organic chemicals (VOCs) that were not highly reactive to produce ozone. In contrast, the more stringent mandate in California (CARB), which allowed less flexibility to oil refineries regarding the chemical composition of gasoline, resulted in effective air quality improvements.

Harrison et al. (2015) investigate the effectiveness of the Indian Supreme Court Action Plans (CAC regulation) and price incentives (via fuel taxes) to reduce coal use and promote SO_2 pollution abatement technology. Using a comprehensive industrial plant-level dataset, they find that higher coal prices led to a significant reduction in coal use as an input into production across plants. However, the Action Plan were only successful in targeting large highly polluting installations. Greenstone and Hanna (2014) use city-level data to evaluate the impact of the Supreme Court Action Plans (SCAP) and the Mandated Catalytic Converters. They provide evidence that even in India, a setting with weak institutions, CAC air pollution regulation resulted in observable improvements in air quality.

Wätzold (2004) assesses the success of the highly ambitious and stringent goals of the GFA-VO (Ordinance on Large Combustion Plants in 1983) in Germany. This traditional CAC regulation came about against the backdrop of great political pressure on regulators and industry to reduce SO_2 pollution, considered the main cause of Waldsterben ("death of forest") at the time in Germany. Along with the regulatory provisions of the GFA-VO, the government of North Rhein Westfalen (NRW, the largest German state) was able to negotiate a voluntary agreement with the electricity suppliers in NRW to limit SO_2 and NO_x emissions from new and existing plants. Wätzold documents that these policy initiatives led to the installation of FGD (flue-gas desulfurization) technology in the entire fleet of combustion plants regulated in Germany. That, is the policy was successful in the quick and uniform diffusion of state-of-the-art abatement technology. Wätzold argues that the CAC approach was necessary to achieve the policy aims and a more lenient policy, would have fallen short of the target and of the creation of new groundbreaking technologies.

For the purposes of policy design, a potential risk arising from conventional source-specific CAC regulation for policymakers is the "old-plant" effect (Ellerman, 1998). If emission-rate or technology standards for regulated pollutants are far more stringent for new rather than existing polluting sources, there is a concern that such a policy exemption rule, often referred to as "grandfathering," could encourage the operation of plants that are older and dirtier over the longer run. Two such policies are the New Source Performance Standards (NSPS) introduced under the 1970 Clean Air Act in the US and the Large Combustion Plants (LCP) directive in the European Union. The NSPS featured emission-based standards for only new sources and, starting 1978, it mandated up to a 90% reduction in SO_2 emissions from previous pre-regulated levels. Note that the NSPS were followed by another grandfathered policy called the New Source Review (NSR) that applied to both new plants and existing plants undergoing major modifications. It was not until Title IV of the 1990 Clean Air Act amendment that existing sources came under emissions restrictions corresponding to specific abatement technologies. Since the policy did not apply to all plants that came into operation before 1978, it was ineffective in controlling emissions from existing polluting sources. In fact, empirical studies validate that the mandated investment in scrubbers increased operation costs of new plants, which led the operators to utilize older unregulated plants at higher capacity (Stavins, 2006) and delayed re-investment in existing plants to avoid triggering the Clean Air Act requirements (Bushnell and Wolfram 2012).

Similarly, the EU LCP directive to limit emissions of SO_2, NO_x, and particle dust from large combustion plants came into force starting 1988 and imposed stricter provisions for newer plants. Existing power stations (older than 1987) could "opt-in" and be subject to lenient emission standards or "opt-out" and instead reduce their operation hours and eventually shutdown. Note that there were comparable national programs (GFA-VO 1983 in Germany, and Dutch Bees WLV 1987 in Netherlands) in place before the LCP directive which were typical CAC policies and less flexible than the LCP directive for existing plants. Meyer and Pac (2017) are the first to explore the consequences of the LCP policy in the EU. Their results suggest that the coal or lignite power plants were less likely to be opted out of the stricter emission standards—implying that the necessary FGD technology were either newly installed or already in operation. Perhaps the new European LCPD provisions were not strict enough to contribute to the further clean-up of coal electricity generation as compared to pre-existing national regulations.

Policy Lessons Thus Far

The empirical evidence discussed in this review suggests that command-and-control regulations have proven to be quite effective in emissions abatement worldwide. It is nevertheless difficult to gauge conclusively whether a different policy instrument would have performed significantly better and at lower cost, given the country-specific institutions, targets (medium or large-scale), and market structure of regulated industries. Moreover, the conditions in the now highly industrialized nations have changed – broader regional coverage of regulation has increased the value of flexibility that is achievable under market-based instruments. However, policy makers continue to find conventional CAC instruments attractive for many reasons – reasons that may diverge from those held by economists. In particular, legislators are concerned about the distributional aspects of costs and benefits that arise from environmental regulation – such outcomes are more uncertain when designing and evaluating EI policy instruments but can be stated explicitly using conventional CAC methods. Arguably, the cost-efficiency of a policy instrument may be less of a concern for the political world.

CAC instruments were initially the norm and now increasingly combined with market-based instruments to achieve climate targets comprehensively. Even though market-based instruments (at least in the United States) have been considered largely successful for diffusion of existing technologies (Stavins and Schmalensee, 2015) that were previously developed in the context of CAC regimes, and are increasingly popular choices, there does not seem to be a one-fits-all policy recommendation to limit emissions. As argued by Harrington et al. (2004) and Goulder (2008), no single policy instrument seems to trump all other alternatives to achieve environmental objectives. Specifically, a policy portfolio that combines a diverse mix of instruments can effectively speed up the realization of climate policy goals, whether it is to improve ambient air quality, limit or ban the use of harmful chemicals, or reduce source-specific pollution.

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