Policy Evolution Under the Clean Air Act

Faculty Research Working Paper Series

Richard Schmalensee
Massachusetts Institute of Technology

Robert N. Stavins
Harvard Kennedy School

November 2018

RWP18-039

Policy Evolution under the Clean Air Act

Richard Schmalensee and Robert N. Stavins

ABSTRACT

The U.S. Clean Air Act, passed in 1970 with strong bipartisan support, was the first environmental law to give the Federal government a serious regulatory role, established the architecture of the U.S. air pollution control system, and became a model for subsequent environmental laws in the United States and globally. We outline the Act's key provisions, as well as the main changes Congress has made to it over time. We assess the evolution of air pollution control policy under the Clean Air Act, with particular attention to the types of policy instruments used. We provide a generic assessment of the major types of policy instruments, and we trace and assess the historical evolution of EPA's policy instrument use, with particular focus on the increased use of market-based policy instruments, beginning in the 1970s and culminating in the 1990s. Over the past fifty years, air pollution regulation has gradually become much more complex, and over the past twenty years, policy debates have become increasingly partisan and polarized, to the point that it has become impossible to amend the Act or pass other legislation to address the new threat of climate change.

Key Words: Clean Air Act, air pollution, market-based instruments, emissions trading, cap-and-trade, pollution taxes, performance standards, technology standards

JEL Classification Codes: Q540, Q580, Q400, Q480

Policy Evolution under the Clean Air Act

Richard Schmalensee and Robert N. Stavins[1]

Nearly half a century has elapsed since 1970, when the first Earth Day was celebrated, the U.S. Environmental Protection Agency (EPA) was established, and the U.S. Clean Air Act (CAA) was passed with essentially unanimous bipartisan support.[2] It was not the first Federal law to deal with air pollution – that was the Air Pollution Control Act of 1955 – and it was technically only an amendment to the original Clean Air Act of 1963 (Stern 1982). But it was the first environmental law to give the Federal government a serious regulatory role. The 1970 Act established the basic architecture of the U.S. air pollution control system and became a model for many subsequent environmental laws in the United States and abroad.

In this article, we describe and assess the evolution of air pollution control policy under the Clean Air Act with particular attention to the types of policy instruments used. This evolution was driven at various times by the emergence on the policy agenda of new problems, by innovation and experimentation by EPA, and by changes in the Clean Air Act itself. We begin by outlining the key provisions of the 1970 Act and the main changes Congress made to it over time. We then turn to a generic assessment of the major types of policy instruments that have been employed by EPA.

Finally, we trace and assess the historical evolution of EPA's policy instrument use[3]. Until roughly 2000, EPA made increasing use of market-based instruments, enabled in part by major amendments to the CAA in 1977 and 1990 that passed with overwhelming bipartisan support. In more recent years, however, environmental policy has become a partisan battleground. While EPA's interpretation of the CAA has continued to evolve, it has not been possible to amend it to enable an efficient response to climate change or to address other problems.

The Evolution of the Clean Air Act: 1970-1990

The 1970 Act was a response to increased environmental activism and fears that states would compete by lowering their environmental standards, as well as industry worries about facing a multitude of state-level mandates. This short, 24-page law gave the EPA Administrator considerable discretion and authority to set and change regulations and to enforce compliance.[4]

---

[1] Schmalensee is the Howard W. Johnson Professor of Management Emeritus, Professor of Economics Emeritus, and Dean Emeritus of the MIT Sloan School of Management. Stavins is the A. J. Meyer Professor of Energy and Economic Development at the Harvard Kennedy School, a University Fellow of Resources for the Future, and a Research Associate of the National Bureau of Economic Research. They acknowledge valuable comments on a previous version of the manuscript by Dallas Burtraw, Robert Hahn, Amelia Keyes, Alan Krupnick, Al McGartland, and Paul Portney. The authors, who are responsible for all remaining errors, can be reached at rschmal@mit.edu and robert_stavins@harvard.edu.

[2] There was one negative vote in the House of Representatives, none in the Senate.

[3] A systematic study of the evolution of environmental policy instrument use at the state level is beyond the scope of this paper. It is worth noting, however, that some states have made significant use of market-based instruments. The California cap-and-trade system for greenhouse gases is a notable example (Borenstein et al, 2018).

[4] Under the Administrative Procedure Act (APA) of 1946, EPA is required to publish proposals for major changes in regulation and to take public comments into account in the final versions. Its compliance with the CAA and the APA can be reviewed by Federal courts. In addition, because EPA is an Executive Branch agency, since the Reagan Administration its major regulatory proposals have been required to pass a cost-benefit test administered by the

The law contained four key provisions. First, the Administrator was charged with identifying pollutants that are produced by numerous or diverse sources and have "an adverse effect on public health or welfare" and with promulgating a system of National Ambient Air Quality Standards (NAAQS) for these "criteria air pollutants" to protect public health and welfare. The six criteria air pollutants are carbon monoxide, lead, ground-level ozone, nitrogen dioxide, particulate matter, and sulfur dioxide. Second, the states were tasked with developing State Implementation Plans (SIPs), to which the EPA could require modification, to bring areas under their jurisdiction into attainment with the NAAQS.

Third, EPA was to develop national New Source Performance Standards (NSPS) for power plants and other stationary pollution sources, and emissions standards for new motor vehicles. It was empowered but not required to regulate motor vehicle fuels. Fourth and finally, EPA was to develop National Emission Standards for Hazardous Air Pollutants (NESHAPs), such as benzene, also known as air toxics, to protect the public health. Such air toxics are mainly produced by manufacturing plants and other isolated sources.

Imposing strict requirements only on new stationary and mobile sources had the perverse effect of slowing turnover of the capital stock and thereby retarding environmental progress (Stavins 2006), but states retained the authority to regulate existing stationary sources if necessary to bring areas into attainment.

The 112-page 1977 Amendments were passed by a voice vote in the Senate and a vote of 273-109 in the House. They dealt with several important issues that had come into focus since 1970.[5] A regime of Prevention of Significant Deterioration was established that limited the worsening of air quality in areas in attainment with the NAAQS. This regime permitted new stationary sources to be built in non-attainment areas if, through modifications of existing sources, overall emissions were reduced. This regime enabled EPA to extend its experiments with trading, which began in 1974 (and are discussed below). Also, EPA was empowered to issue technology-based control standards for air toxics instead of emissions/performance standards, where the latter were not practicable. Finally, EPA was given authority to regulate substances likely to deplete stratospheric ozone.

In the 1980s, acid rain caused by emissions of sulfur dioxide (SO_2) from coal-fired power plants emerged as a significant problem. In 1988, the U.S. ratified the Montreal Protocol to protect the ozone layer. In response to these developments and others after 1977, Congress passed the 314-page 1990 Amendments, which had four main provisions: (1) the establishment of the path-breaking sulfur dioxide (SO_2) cap and trade program, intended to cut acid rain to half of 1980 levels (Schmalensee, *et al*. 1998; Stavins 1998; Schmalensee and Stavins 2017); (2) regulation of a number of aspects of motor vehicle fuels, including volatility;[6] (3) authority for EPA to ensure that the U.S. would meet its obligations under the Montreal Protocol, and direction to use a cap-and-trade system to do so; and (4) instructions to EPA to issue technology standards for each of 189 listed air toxics, providing the maximum degree of emissions reduction, taking into account costs and non-air-quality effects.[7] The 1990 Amendments were passed by large bipartisan majorities: over 90% of Democrats voted in favor in both Houses of Congress, as did 87% of Republicans.

Office of Management and Budget (OMB); see, e.g., Copeland (2009). A key part of the OMB process is submission of a Regulatory Impact Analysis (RIA) that compares the costs and benefits of the proposal.

[5] The 1977 Amendments stipulated that the NSPS for sulfur dioxide from coal-fired power plants must require that some of the sulfur in the coal burned be removed from the plants' flue gas. This "scrubber" requirement was a political victory for producers of high-sulfur Eastern coal (Ackerman and Hassler 1981).

[6] The volatility standard was explicitly relaxed if corn-based ethanol were used to meet it. The Republican leader in the Senate represented a large corn-producing state.

[7] This provision reflected the fact that developing harm-based standards for air toxics had proven to be unworkable: only seven such standards had been issued since 1970.

Beginning in the late 1980s, climate change emerged as a significant issue. Then-candidate George H.W. Bush promised in 1988 to use the "White House Effect" to address the emerging problem of the greenhouse effect, and the Senate ratified the U.N. Framework Convention on Climate Change in October, 1992, without a roll-call vote. By the time legislation to deal with climate change received serious consideration in 2009, however, environmental politics had changed dramatically, with Congressional Republicans almost universally opposed to environmental regulation.

In June, 2009, the U.S. House of Representatives passed legislation – H.R. 2454, the American Clean Energy and Security Act of 2009 or the Waxman-Markey bill – that included an economy-wide emissions trading system to cut carbon dioxide (CO_2) emissions linked with global climate change. Despite bipartisan support for emissions trading in the 1990 Amendments, many Republicans (and some coal-state Democrats) attacked the proposed emissions trading system as "cap-and-tax.'' The legislation passed the House by a vote of 219-212, with support from 83 percent of Democrats, but only 4 percent of Republicans. In July, 2010, the Senate abandoned its attempt to pass companion legislation.

This polarization between the two political parties on environmental issues (Shipan and Lowry 2001) was part of a gradually widening gulf between the parties on virtually all issues (Fleisher and Bond 2004). Polarization – the gradual disappearance of moderates – has been taking place for decades (Lowry and Shipan 2002; Theriault 2008), and has shown up in studies by political scientists employing a diverse set of measures (Poole and Rosenthal 1997, 2007). The rise of the Tea Party movement within the Republican Party and the nomination and election in 2016 of Donald Trump are only the most recent episodes in a much longer story.

The Clean Air Act, and federal air pollution legislation generally, ceased to evolve after 1990, although regulatory actions and judicial oversight continued. As we discuss below, the Obama Administration attempted to deal with climate change using the Clean Air Act as it stood after the 1990 Amendments, but the Trump Administration rolled back those attempts.

Policy Instruments used under the Clean Air Act

Three major types of policy instruments have been employed under the authority of the Clean Air Act: technology standards, which specify the equipment or process to be used for compliance; performance standards, which specify the maximum quantity of emissions (typically in rate-based units, such as grams of pollutant per mile driven) or maximum atmospheric concentrations that are allowed; and emissions trading systems, either in the form of emissions-reduction credit (offset) systems or cap-and-trade. In addition, taxes have sometimes been employed, although their use under the Clean Air Act has been peripheral.[8]

As the first panel of Table 1 indicates, three types of instruments have been used for the control of criteria air pollutants. Hazardous air pollutants have only been controlled by standards; emissions trading and taxes have been used to address the protection of stratospheric ozone; and cap-and-trade has been employed to reduce SO_2 emissions as a precursor of acid rain. More recently, the Obama administration proposed a hybrid standard/trading approach to reduce CO_2 emissions in the electricity sector, but the Trump administration has proposed to replace it by a standards regime.

[8] The 1990 Amendments allowed states to tax regulated air pollutants to recover administrative costs of state programs, and allowed areas in extreme non-compliance to charge higher rates. Under this structure, the South Coast Air Quality Management District (SCAQMD) in Los Angeles implemented the highest permit fees in the country (U.S. Congress, Office of Technology Assessment 1995). As we discuss below, Congress imposed a tax, outside the Clean Air Act, on ozone-depleting chemicals that took effect in 1990.

The second panel of Table 1 examines the use of the four types of policy instruments across regulated sectors of the economy: electricity generation, other stationary sources, and mobile sources. The command and control mainstays of the original 1970 Act – technology standards and performance standards – have been used in all domains, while emissions trading has been applied only to stationary sources.

Most economists would agree that economic efficiency — achieved when the difference between benefits and costs is maximized — ought to be one of the fundamental criteria for evaluating environmental protection efforts (Pareto 1896; Kaldor 1939; Hicks 1930).[9] Discussions in the environmental policy realm, however, have more frequently employed a more modest criterion — cost-effectiveness (minimizing the costs of achieving some given objective) — largely because of the challenges of measuring the benefits of environmental protection. Assuming effective enforcement, on which all policy instruments depend for their effectiveness, and the same emissions objective, performance standards are at least as cost-effective as technology standards because they provide greater flexibility to minimize compliance costs.

When emissions from multiple sources are *well-mixed*, so that emissions from all sources produce the same damages per unit of pollution, cost-effectiveness requires that all sources that exercise some degree of emissions control experience the same marginal abatement cost (Baumol and Oates 1988). In principle, governments could employ non-uniform performance standards to bring about the cost-effective allocation of control responsibility among emissions sources with heterogeneous control costs, but to develop such a set of standards, the government would need to know the marginal abatement cost functions of all sources. Costs are generally heterogeneous, and the government rarely, if ever, knows sources' cost functions. As a consequence, command and control methods are rarely, if ever, cost-effective.

There are two ways the government can achieve the cost-effective allocation of control responsibility among pollution sources without detailed information about source-level control costs. For some 40 years prior to Coase (1960), the economic prescription was that emissions should be taxed. In principle, the tax on each unit of pollution should equal the marginal social damages at the efficient level of control (Pigou 1920). Even if damages cannot be measured, imposing the same tax rate on all sources will lead them to reduce emissions to the point where their marginal abatement costs are equal to the common tax rate, thereby satisfying the necessary condition for cost-effectiveness. But such pollution taxes have never been implemented under the Clean Air Act.

Why have Pigouvian taxes not been much used, despite their theoretical advantages (Kneese and Schultz 1975)? First, it is difficult to identify the appropriate tax rate. For efficiency, it should be set equal to the marginal benefits of cleanup at the efficient level of cleanup, but policy makers are more likely to focus on a desired level of cleanup, and they are uncertain about how firms will respond to a given level of taxation. A more important political problem is that tax systems are likely to be more costly than command and control for regulated firms, because firms both incur abatement costs and pay taxes on their residual emissions (Buchanan and Tullock 1975). In practice, some of these costs will be passed on to consumers, but many firms may still be worse off under a tax.

The work of Coase (1960) pointed to a second way the government could achieve its pollution-control targets cost-effectively, without the abatement uncertainty inherent in the tax approach, and without the tax burden on regulated firms. Coase (1960) described the problem of pollution as one of poorly defined property rights. If resources such as clean air could be recognized as a form of property, with corresponding rights that could be traded in a market, private actors could allocate the use of this

[9] This criterion is considered in the companion essay by Janet Currie in this issue.

property in a cost-effective way. Some fifty years ago, Crocker (1966) and Dales (1968) proposed emissions trading systems that could provide such a market solution. Such systems are of two basic types: credit programs and cap-and-trade systems. Under credit programs, credits are assigned (created) when a source reduces emissions below the level required by existing, source-specific limits; these credits can enable the same or another firm to meet its control target.

Under a cap-and-trade system, an allowable overall level of pollution is established and allocated among firms in the form of allowances.[10] Firms that keep their emissions below their allotted level may sell their surplus allowances to other firms or, in many systems, bank them for later use. It is in the interest of each source to carry out abatement up to the point where its marginal control costs are equal to the market-determined price of tradable allowances. Hence, the environmental constraint is satisfied, and marginal abatement costs are equated across sources, satisfying the condition for cost-effectiveness.

Except under unusual conditions, the unique cost-effective equilibrium is achieved independent of the initial allocation of allowances (Montgomery 1972, Hahn and Stavins 2011). This independence property is a key reason why cap-and-trade systems have been employed rather than tax systems in representative democracies. The government can set the overall emissions cap and then allocate the available (and valuable) allowances among regulated sources to maximize support for the initiative without reducing the system's environmental performance or driving up its cost.

Even when the assumption that emissions are well-mixed is only approximately correct, taxes or emissions trading may still be superior to command and control if costs differ substantially across sources. If source-specific damages differ too much, however, command and control may be superior. If sources are relatively isolated, trading may produce "hot spots," areas of unacceptably high concentrations, without further policy protections. In addition, neither taxes nor emissions trading have been used to regulate mobile sources, though tradeable performance standards have been employed, as we discuss below..

The Evolution of Policy Instrument Use

Under the original 1970 Act, all Federal air pollution regulation involved either technology or performance standards. At that time, some environmental advocates argued that implementing greater flexibility through tradable rights to emit pollution would inappropriately legitimize environmental degradation, while others questioned the feasibility of such an approach (Mazmanian and Kraft 2009). But, over time, as the Act was amended and EPA's interpretation of its provisions evolved, air pollution regulation evolved from sole reliance on conventional, command-and-control regulations to greater use of emissions trading.[11] This evolution has come to a halt in the last decade.

EPA's First Experiments with Emissions Trading in the 1970s

Beginning in 1974, EPA experimented with emissions trading among stationary sources through four programs – netting, bubbles, offsets, and banking. Under netting or bubbles, firms that reduced

[10] In some cap-and-trade systems most allowances are auctioned off, notably in the Regional Greenhouse Gas Initiative in the northeast United States (Burtraw et al 2006) and the California cap-and-trade program (California Legislative Analyst's Office, 2017), but auctioning has not played an important role under the Clean Air Act. While abatement is certain under cap-and-trade regimes, allowance prices are not. Weitzman (1974) began a large literature comparing the two approaches under uncertainty.

[11] U.S. Environmental Protection Agency (2001) provides a comprehensive discussion of the use of economic incentives in all U.S. environmental protection programs through 2000, but it must be recognized that command-and-control regulations were still the norm (Hahn 2000).

emissions below the level required by law received credits usable against higher emissions elsewhere within the firm, so long as total, combined emissions did not exceed an aggregate limit (Tietenberg 1985; Hahn 1989; Foster and Hahn 1995). By the mid-1980s, EPA had approved more than 50 bubbles, and states had authorized many more under EPA's framework rules. Estimated compliance cost savings from these bubble programs exceeded $430 million (Korb 1998).

The offset program, which was explicitly authorized by the 1977 Amendments, allowed trades between firms. Firms wishing to establish new sources in areas that were not in compliance with NAAQS could offset their new emissions by reducing existing emissions through internal sources or through agreements with other firms. Finally, under the banking program, firms could store earned emission credits for future use, allowing for either internal expansion or sale of credits to other firms.

EPA codified all four programs in its Emissions Trading Program in 1986, but the programs were never widely used. States were not required to use the programs, and uncertainties about their future course may have made firms reluctant to participate (Liroff 1986). In addition, individual trades were subject to administrative approval, and trades were required to produce significant net emissions reductions, raising transactions costs. Nevertheless, companies such as Armco, DuPont, USX, and 3M traded emissions credits, and a market for transfers developed. Even this limited degree of participation in EPA's post-1974 trading programs may have saved between $5 billion and $12 billion over the life of the programs (Hahn and Hester 1989).

The Leaded Gasoline Phasedown in the 1980s

Lead in gasoline fouls catalytic converters, which were required in new U.S. cars starting with 1975 models to reduce emissions of carbon monoxide and hydrocarbons. To avoid this problem, the EPA required that only unleaded gasoline be used in cars with catalytic converters. In the late 1970s, there was growing concern about the threat of lead emissions to human health, and EPA began to phasedown gasoline lead beginning in 1979. It initially set different performance standards for refineries of different sizes to account for the higher compliance costs of smaller refineries, but smaller refineries still found it difficult to meet the requirements (Newell and Rogers 2007).

In late 1982, EPA launched a trading program aimed at reducing the burden of the phasedown on smaller refineries. Unlike a textbook cap-and-trade program, in which a fixed quantity of allowances is given or sold to compliance entities, there was no explicit allocation of allowances (Hahn 1989). If a refiner produced gasoline with a total lead content that was lower than the amount allowed, it earned lead "credits" that EPA allowed it to trade. This structure is sometimes referred to as a tradable performance standard. When EPA promulgated an accelerated phaseout of lead in 1985, they added a banking provision that allowed lead credits could also be saved for later use. This created an incentive for refineries to make early reductions in lead content to help them meet the lower limits that took effect over time.

Overall, this program, which was terminated at the end of 1987,[12] was successful in meeting its environmental targets (Anderson, Hofmann, and Rusin 1990; Newell and Rogers 2007), and resulted in leaded gasoline being removed from the market faster than anticipated. In each year of the program, more than 60 percent of the lead added to gasoline was associated with traded lead credits (Hahn and Hester 1989). This high level of trading far surpassed levels observed earlier under EPA's Emissions Trading Program in the 1970s. The level of trading and the rate at which the production of leaded gasoline was reduced suggest that the program was relatively cost-effective (Kerr and Maré 1997; Nichols 1997). EPA estimated that from 1985 through 1987, the program resulted in savings of approximately 20 percent relative to approaches that did not include trading (U.S. Environmental Protection Agency, Office

[12] By 1988, when a uniform performance standard was imposed, very little leaded gasoline was produced in the U.S. The 1990 Amendments banned all lead beginning in 1996.

of Policy Analysis 1985). In addition, the program provided significant incentives for cost-saving technology diffusion (Kerr and Newell 2003).

As the first environmental program in which trading played a central role, the lead phasedown program demonstrated that a trading system could be both environmentally effective and economically cost-effective. In addition, in contrast to the Emissions Trading Program, the lead phasedown program demonstrated that transaction costs in such a system could be low enough to permit substantial trade. The lack of a prior approval requirement was an important factor in the success of lead trading (Hahn and Hester 1989). Also, as in later trading programs, the ability to bank credits enabled significant cost savings and early reductions.

Stratospheric Ozone Protection

Following U.S. ratification of the Montreal Protocol in 1988, Congress imposed an excise tax on chemicals that deplete stratospheric ozone. The tax took effect in 1990 (U.S. Congress 1989). Beginning in 1989, EPA set up an emissions trading system for ozone-depleting chemicals (ODCs) that was expanded after the 1990 Amendments (Hahn and McGartland 1989). Producers were required to have adequate allowances. Limits were placed on both the production and use of ODCs by issuing allowances that limited these activities. Different types of ODCs have different effects on ozone depletion, so each ODC was assigned a different weight on the basis of its depletion potential. Through mid-1991, there were 34 participants in the market and 80 trades, but no studies were conducted to estimate cost savings.

The timetable for the phaseout of ODCs was subsequently accelerated, and the tax on CFCs was raised over time (Reitze 2001). It served as a windfall-profits tax, to prevent private industry from retaining scarcity rents created by the quantity restrictions (Merrill and Rousso 1990; U.S. Environmental Protection Agency 2001). The tax may have become the binding instrument, but there was considerable debate regarding which mechanism should be credited with the ultimately successful reduction in the use of these substances, for which U.S. production ceased in 1995 (Cook 1996).

Sulfur Dioxide Allowance Trading

Throughout the 1980s, there was growing concern that acid precipitation – due mainly to emissions of SO_2 from coal-fired power plants – was damaging forests and aquatic ecosystems (Glass, *et al.* 1982). Because costs of reducing these emissions differed dramatically across sources, however, legislative proposals using command-and-control instruments failed to attract sufficient support. That changed with the 1990 Amendments, which addressed this issue by requiring EPA to launch the SO_2 allowance trading program, eventually covering all non-trivial power plants with a declining cap representing a 50 percent reduction from 1980 levels (Ellerman *et al.* 2000).

The government freely allocated allowances to power plants to emit specific quantities of SO_2, based primarily on actual fuel use during the 1985-1987 period.[13] If annual emissions at a regulated facility exceeded its allowance allocation, the owner could comply by buying additional allowances or reducing emissions – by installing pollution controls, shifting to a fuel mix with less sulfur, or reducing production. If emissions at a regulated facility were below its allowance allocation, the facility owner could sell the extra allowances or bank them for future use.

Although government auctioning of allowances would have generated revenue that could have been used – in principle – to reduce distortionary taxes, thereby reducing the program's social cost

[13] In addition, the statute required EPA to withhold about 2.8% of all allowance allocations each year, sell them at an annual auction, and return the proceeds in proportion to firms from which allowances had been withheld (Ellerman *et al* 2000).

(Goulder 1995), this efficiency argument was not advanced at the time. Because the entire investor-owned electric utility industry was subject to cost-of-service regulation in 1990, it was assumed that the value of free allowances would be passed on to consumers and thus not generate windfall profits for utilities. Just as important, the ability to allocate *free* allowances helped to build significant political support for the program (Joskow and Schmalensee 1998). Because of the independence property associated with cap-and-trade systems, the initial allocation of allowances could be designed to maximize political support without compromising the system's environmental performance or raising its cost.

The program performed well, with SO_2 emissions from electric power plants decreasing 36 percent between 1990 and 2004 (U.S. Environmental Protection Agency 2011), even though electricity generation from coal-fired power plants *increased* 25 percent over the same period (U.S. Energy Information Administration 2012). The program delivered emissions reductions more quickly than expected, as utilities made substantial use of the ability to bank allowances for future use. With continuous emissions monitoring and a $2,000/ton statutory fine for any excess emissions, enforcement was exceptionally stringent, and compliance was nearly perfect (Burtraw and Szambelan 2010).

Because emissions were not well-mixed and emissions from different power plants had different impacts, some worried that trading might produce "hot spots" of unacceptably high SO_2 concentrations. Computer models had predicted that plants that had the most impact on ecosystems had the lowest costs of reducing emissions, however. Subsequently, the pattern of emissions reductions was found to be broadly consistent with those predictions. No significant hot spots emerged (Ellerman et al. 2000; Swift 2004).[14]

The cost of the program was significantly reduced by the substantial deregulation of railroads in 1980, which caused rail rates to fall and thus reduced the cost of burning low-sulfur Western coal in the East (Keohane 2003; Ellerman and Montero 1998; Schmalensee and Stavins 2013). A command-and-control policy would not have provided the flexibility to take advantage of the fall in rail rates. That said, cost savings overall were at least 15 percent and perhaps as great as 90 percent of the costs of various alternative command and control policies (Carlson *et al*. 2000; Ellerman et al. 2000; Keohane 2003). Furthermore, the program may have reduced costs over time by providing incentives for innovation (Ellerman *et al*. 2000; Popp 2003; Bellas and Lange 2011).

Although the program's costs were likely not as low as they ideally could have been (Schmalensee and Stavins 2013), costs were much lower than they would have been under comparable command-and-control regulation. The emission reductions goals were achieved with less litigation (and thus less uncertainty) than was typical for environmental programs, because firms that found it particularly costly to reduce emissions had the option to buy allowances instead. Moreover, firms could not complain about EPA's exercise of administrative discretion, because the law gave EPA very little discretion.

The SO_2 reductions achieved benefits that were a substantial multiple of the program's costs (Burtraw, *et al*. 1998; Chestnut and Mills 2005), although the program's benefits were due mainly to what have been termed "co-benefits", in this case human health impacts of decreased local SO_2 and small particulate concentrations, not the ecological benefits of reduced acid deposition that motivated the program's establishment (Schmalensee and Stavins 2013).

Although subsequent regulatory actions, court decisions, and regulatory responses led to the virtual elimination of the SO_2 allowance market by 2010 (Schmalensee and Stavins 2013), the SO_2 trading program is still often celebrated. A key feature was putting final rules in place well before the

[14] Chan et al (2018) argue that the actual SO_2 emissions had worse health impacts than emissions under a hypothetical uniform performance standard with the same total emissions. Of course, that hypothetical program had been a political non-starter.

beginning of the first compliance period, which provided regulated entities with some degree of certainty, thereby facilitating their planning and limiting allowance price volatility in early years. As with the lead trading program, the absence of requirements for prior approval of trades contributed to low transaction costs and substantial trading (Rico 1995). Banking of allowances was again important, accounting for more than half of the program's cost savings (Carlson *et al*. 2000; Ellerman *et al*. 2000).

Regional Programs under Clean Air Act Authority

Two other programs that merit attention were not Federal programs *per se*, but rather regional programs executed under Clean Air Act authority: the Regional Clean Air Incentives Market (RECLAIM) in the Los Angeles area, and NO_x trading in the East.

First, the South Coast Air Quality Management District, which is responsible for controlling emissions in a four-county area of southern California, launched the Regional Clean Air Incentives Market (RECLAIM) in 1993 to reduce emissions of nitrogen oxides (NO_x) and in 1994 to reduce SO_2 emissions from 350 affected sources, including power plants and industrial sources in the Los Angeles area, replacing command-and-control regulations (Ellerman, Joskow, and Harrison 2003). RECLAIM Trading Credits (RTCs) were allocated for free, with the NO_x and SO_2 caps declining annually until 2003, when the market reached its overall goal of a 70% emissions reduction (Ellerman, Joskow, and Harrison 2003). The compliance period was a single year, and banking was not allowed. A unique aspect of this program's design was its zonal nature: trades were not permitted from downwind to upwind sources, reflecting differences in marginal source-specific damages.

The program was predicted to achieve significant cost savings via trade (Johnson and Pekelney 1996; Anderson 1997), and by June 1996, 353 program participants had traded more than 100,000 tons of RTCs, with a value of over $10 million (South Coast Air Quality Management District 2018). Emissions at RECLAIM facilities were some 20 percent lower than at facilities regulated with parallel command-and-control regulations, hotspots did not appear, and substantial cost savings were achieved (Burtraw and Szambelan 2010; Fowlie, Holland, and Mansur 2012).

In the program's early years, allowance prices remained in the expected range of $500 to $1,000 per ton of NO_X. During California's electricity crisis in 2000-2001, however, some sources of electricity were eliminated, which required dramatic increases in generation at some RECLAIM facilities. This caused emissions to exceed permit allocations at those facilities, and, in the absence of a pool of banked allowances, resulted in a dramatic spike in allowance prices -- to more than $60,000/ton in 2001 (Fowlie, Holland, and Mansur 2012). The program was temporarily suspended. Prices returned to normal levels (about $2,000/ton) by 2002, with all sources rejoining the program by 2007. As of July 2018, the twelve-month moving average of NO_X prices was $2,530/ton (South Coast Air Quality Management District 2018).

The other regional program of interest is NO_x trading in the eastern United States. Under EPA guidance, and enabled by the 1990 Amendments, in 1999 eleven northeastern states and the District of Columbia developed and implemented the NO_x Budget Program, a regional NO_X cap-and-trade system. Given the significant adverse health effects of ground-level ozone (smog formed by the interaction of NO_x and volatile organic compounds in the presence of sunlight), the goal of the program was to reduce summertime ground-level ozone by more than 50% relative to 1990 levels (U.S. Environmental Protection Agency 2004). Some 1,000 electric generating and industrial units were required to demonstrate compliance each year during the summer ozone season.

The region covered by the program was divided into upwind and downwind zones, reflecting differences in source-specific damages, and allowances were given to states to distribute to in-state sources. Sources could buy, sell, and bank allowances within limits reflecting the seasonal nature of the ozone problem. Upwind states were given less generous allowance allocations as percentages of 1990 emissions. However, trading across zones was permitted on a one-for-one basis, and the two zones made similar reductions from baseline emissions levels (Ozone Transport Commission 2003).

In 1998, EPA had issued a SIP Call, which required 21 eastern states to submit plans to reduce their NO_x emissions from more than 2,500 sources. The Call created an interstate cap-and-trade program, known as the NO_x Budget Trading Program, which went into effect in 2003, replacing the NO_x Budget Program. In 2005, the NO_X Budget Trading Program was effectively replaced by the Clean Air Interstate Rule (CAIR), which reduced allowance allocations under the acid rain program. In July 2008, however, an Appeals Court ruled that the Clean Air Act did not give EPA authority to amend the acid rain program. Finally, in 2015, CAIR was replaced by the Cross State Air Pollution Rule (CSAPR), which does not allow interstate trading.

At the outset, the NO_X Budget Program market was characterized by uncertainty because some trading rules were not in place when trading commenced. This resulted in high price volatility during the program's first year, although prices stabilized by the program's second year (Farrell 2000). Overall, under the NO_X Budget Program and the NO_X Budget Trading Program, NO_X emissions declined from about 1.9 million tons in 1990 to less than 500,000 tons by 2006, with 99% compliance (Butler, *et al.* 2011; Deschenes, Greenstone, and Shapiro 2017). For the 1999-2003 period, abatement cost savings were estimated at 40 to 47 percent relative to conventional regulation, which did not include trading or banking (Farrell 2000).

This experience demonstrated that in order to avoid unnecessary price volatility all of the components of an emissions trading program should be in place well before the program takes effect, and that a well-designed multi-state process with Federal guidance could be effective in coordinating what were legally state-level goals.

Obama Administration Climate Policies

When attempts to address climate change via new legislation failed in 2010, attention turned to the possibility of regulatory approaches under existing provisions of the Clean Air Act. In response to a lawsuit brought by 12 states and several cities, the U.S. Supreme Court ruled that if EPA were to find that emissions of greenhouse gases (GHGs) endanger public health or welfare, it would be obliged (based on authority in the 1970 Act) to regulate those emissions.[15] In December, 2009, the Obama EPA issued its "Endangerment Finding," which found that current and projected levels of six GHGs endangered public health and welfare. EPA then proceeded to issue regulations covering GHG emissions from mobile and then stationary sources.

The administration first finalized a rule jointly proposed by the U.S. Department of Transportation and the EPA in September, 2009, to increase fuel efficiency under the Corporate Average Fuel Economy (CAFE) program and establish national GHG emissions standards under the Clean Air Act (Broder 2009). The rule increased the required average fuel efficiency in model year 2016 to 35.5 miles per gallon (mpg), with a second phase announced in 2012 increasing the standard to 54.5 mpg for model year 2025. Notably, this rule enabled manufacturers for the first time to earn, bank, and trade credits for exceeding these performance standards (Leard and McConnell 2017)

The second part of the Obama administration's regulatory action on climate change was announced in June, 2014: the Clean Power Plan (CPP), a rule that would reduce CO_2 emissions from existing sources in the electricity-generating sector (U.S. Environmental Protection Agency 2014a).[16]

[15] Massachusetts et al v. Environmental Protection Agency et al, 549 U.S. 497 (2007).
[16] The administration had already proposed in 2013 an NSPS to limit CO_2 emissions from all new coal and natural-gas power plants built in the United States. The proposed rules would essentially have made it impossible to build

EPA's proposal listed specific targets for each state, but gave the states many ways to meet their targets, including: increasing the efficiency of fossil-fuel power plants; switching electricity generation from coal-fired plants to natural gas-fired plants; developing new low-emissions generation (including renewable and nuclear generation), and more efficient end-use of electricity. States were also given flexibility to employ any of a wide variety of policy instruments, including market-based trading systems. Furthermore, states could work together to submit multi-state plans. The regulation was to be finalized in June, 2015 and implemented in 2020.

The state-by-state approach in the CPP did not guarantee cost-effectiveness, because under the formula employed, marginal abatement costs would vary greatly across states. However, encouragement was given to states to employ cap-and-trade systems, and EPA emphasized its willingness to consider multi-state implementation plans. Although EPA was not guaranteeing cost-effectiveness, it was certainly allowing for it, indeed attempting to facilitate it.

Because GHGs are well-mixed globally, climate change is particularly well suited to the use of market-based instruments. But this also means that global damages are unaffected by the location of emissions. Thus any jurisdiction taking action will incur the direct costs of its actions, but the direct climate benefits will be distributed globally. Hence, the direct climate benefits a jurisdiction reaps from its actions will almost certainly be less than the costs it incurs, even if global climate benefits are much greater than global costs. Despite this logic, the central estimate of annual net benefits (benefits minus costs) of the CPP in 2030 in EPA's Regulatory Impact Analysis (RIA) was $67 billion (U.S. Environmental Protection Agency 2014b).[17] How could this be?

Table 2 shows the two answers. First, EPA did not limit its estimate of climate benefits to those received by the United States, but used an estimate of global climate benefits. Second, EPA also quantified and included (the much larger) benefits of human-health impacts associated with reductions in correlated, non-GHG air pollutants.

It would certainly be inappropriate to use a global measure of benefits in analysis of all U.S. regulations (Gayer and Viscusi 2016). Doing so could imply that a labor policy that increased U.S. employment but cut employment in competitor economies would have zero benefits! On the other hand, it can be argued that counting only domestic benefits is not appropriate for a global commons problem (U.S. National Academy of Sciences 2017).

Suppose a domestic U.S climate benefits number were used in the RIA, rather than a global number. EPA estimated global climate benefits of the rule in 2030 using a mid-range 3% discount rate to be $31 billion. According to the Obama administration's Interagency Working Group on the Social Cost of Carbon (2010), U.S. benefits from reducing GHG emissions would be, on average, about 7 to 10 percent of global benefits. If U.S. benefits were thus 8.5% of global benefits, they would amount to about $2.6 billion, considerably less than the RIA's estimated total annual compliance costs of $8.8 billion. This validates the intuition that for virtually any jurisdiction, the direct climate benefits it reaps from reducing GHG emissions will be less than the costs it incurs.[18]

---

new traditional coal plants, but since there were no new coal plants planned or likely to be built, due to the relative prices of coal and natural gas, the rule had no real impacts and was not particularly controversial.

[17] See note 3, above, for the role of RIAs in the regulatory process.

[18] There are abundant caveats to this simple analysis. One is that if the proposed U.S. policy increased the probability of other countries taking climate policy actions, then the impacts on U.S. territory of such foreign policy actions would merit inclusion even in a traditional U.S.-only benefit-cost analysis. Trying to quantify this effect would be speculative at best.

Importantly, in addition to counting climate benefits outside the U.S., the Obama EPA counted health benefits from reductions of other pollutants, the emissions of which are correlated with those of CO_2. The CPP was expected to reduce the burning of coal, leading to decreased emissions of sulfur dioxide (SO_2), nitrogen oxides (NOx), particulate matter, and mercury. These pollutants – especially particulate matter less than 2.5 microns across – have very significant human health impacts, and the estimated benefits from reducing their emissions dwarf the domestic climate benefits. According to the RIA, whereas the U.S. climate change benefits from CO_2 reductions due to the proposed rule in 2030 would probably be less than \$3 billion per year, the domestic health benefits from reduced concentrations of correlated (non-CO_2) air pollutants would amount to some \$45 billion/year![19]

This completely changes the picture. Domestic climate benefits (\$3 billion) plus domestic health benefits (\$45 billion) from reduced coal use greatly exceed the estimated compliance costs of \$9 billion/year, for positive net benefits of \$39 billion/year in 2030. This is the key argument that the CPP increases U.S. welfare. If EPA's global estimate of climate benefits (\$31 billion/year) is employed instead, then the rule looks even better, with total annual benefits of \$76 billion, leading to EPA's bottom-line estimate of positive net benefits of \$67 billion per year in 2030. The Obama Administration's proposed regulation had the potential to be cost-effective, and if you accept these numbers, it could also have been welfare-enhancing.

Trump Administration Climate Policies

Both Obama administration regulatory initiatives – the CAFE standards for motor vehicles and the Clean Power Plan for the electricity sector – were reversed by the Trump administration. In August, 2018, EPA, together with the National Highway Traffic Safety Administration, proposed a rule that would have the Federal government abandon the fuel economy standards for passenger cars and light trucks developed by the Obama administration for 2022-2025 and freeze the standards at their 2020 levels (U.S. Environmental Protection Agency 2018a).

When the final version of the Clean Power Plan was published in October, 2015 (U.S. Environmental Protection Agency 2015), it was immediately subject to lawsuits from a number of states. They argued, among other things, that the Clean Air Act only gave EPA authority to issue technical and performance standards for power plants (some argued that only the states could regulate *existing* plants), and that by allowing flexibility the CPP went well beyond that authority. In February, 2016, the U.S. Supreme Court halted implementation of the CPP while that litigation proceeded (Liptak and Davenport 2016).

In October, 2017, the EPA proposed to repeal the CPP because it exceeded the Agency's authority. And in August, 2018, with implementation of the CPP still suspended, the Trump Administration announced the Affordable Clean Energy (ACE) rule as a replacement for the CPP (Friedman 2018, U.S. Environmental Protection Agency 2018c).[20] The ACE instructs the states to set standards for efficiency improvements in existing coal-fired power plants, subject to EPA guidance regarding technologies to be used and to EPA approval. (It seems that states could require no improvements if EPA agreed.) It does not provide incentives for changing the generating mix or even allow such methods of compliance.[21] Therefore, there is no possibility of cost-effectiveness.

[19]These benefits are driven heavily by predicted reductions in morbidity and mortality, and those in turn are driven by the dose-response assumptions EPA employs.

[20] By issuing the revised regulation, the Trump administration implicitly accepted EPA's 2009 GHG endangerment finding (Friedman 2018).

[21] It also changes the rules on what constitutes a new source, subject to very strict standards, so that old plants can increase efficiency without becoming subject to new source standards.

The RIA for the ACE rule compares it to the CPP and finds it superior (U.S. Environmental Protection Agency 2018d). It would have lower costs, greater coal use, greater GHG emissions, and greater adverse health effects.[22] In this RIA, the EPA uses a U.S.-only social cost of carbon to value those emissions increases. Whereas with a 3% discount rate, the global social cost of carbon in 2030 used by the Obama administration was $50/ton, the U.S.-only cost used by the Trump administration was $7.[23] In several tables that take the loss of health benefits into account, the ACE is found to have lower net benefits than the CPP. But the presentation in the RIA emphasizes "net benefits associated with the targeted pollutant (CO2)." On that metric, considering only domestic climate benefits, the cost savings from moving from the CPP to the ACE outweigh the foregone benefits.

Conclusions

Those who supported passage of the 1970 Clean Air Act no doubt hoped that it would produce major environmental benefits, and it has done so. Despite the fact that real U.S. GDP more than tripled between 1970 and 2017, aggregate emissions of the six criteria pollutants declined by 73 percent (U.S. Environmental Protection Agency 2013b). Most likely, many also expected the bipartisan approach to environmental policy that had led to the Act's passage to persist, and for the first thirty years or so, it did. On the other hand, it is difficult to imagine that any of the supporters of the 24-page 1970 Act imagined how complex air pollution regulation would become over the subsequent half century.

We expect that the evolution toward more intensive use of market-based environmental policy would also have been a surprise to those involved in passage of the 1970 Act. Had they known such an evolution would occur, however, because of the Republican party's historic pro-market orientation, it would not have been a surprise that Republicans led it. President Ronald Reagan's EPA put in place a trading program to phase out leaded gasoline; President George H. W. Bush successfully proposed the use of cap-and-trade to cut U.S. SO_2 emissions; and President George W. Bush's EPA issued the Clean Air Interstate Rule, which would have used cap-and-trade to achieve further reductions in SO_2 emissions.

But those involved in passage of the 1970 Act would surely be disappointed that environmental policy has become a partisan battleground. It has become impossible to amend the Act or to pass other legislation to address climate change in a serious and economically efficient manner. The climate effects of CO_2 emissions are predicted to last for many centuries (Intergovernmental Panel on Climate Change 2013), so if this paralysis persists and U.S. inaction slows global reductions of emissions, the damage will likely be both profound and extremely long lasting.

[22] It is not clear how fully this analysis takes into account the so-called rebound effect: if coal-fired power plants are made more efficient, their marginal costs will be reduced, and it will be economic to use them more intensively. The impact of this effect on human health may be substantial (Keyes et al 2018).

[23] With a 7% discount rate, the U.S.-only social cost of carbon was $1. The same U.S.-only social costs of carbon were also used in the RIA for the Trump Administration's revised CAFE standards.

Table 1:
Major Categories of Pollutants and Sectors Regulated by the Clean Air Act

		Policy Instrument Used			
		Technology Standard	Performance Standard	Emissions Trading	Taxes
Pollutant Category	Criteria Pollutants	*	*	*	
	Toxic / Hazardous Pollutants	*	*		
	Stratospheric Ozone Depletion			*	*
	Acid Rain			*	
	Greenhouse Gases		Proposed	Proposed	

		Policy Instrument Used			
		Technology Standard	Performance Standard	Emissions Trading	Taxes
Regulated Sector	Electricity Generation	*	*	*	
	Other Stationary Sources	*	*	*	*
	Mobile Sources	*	*		

Table 2:
Estimated Benefits and Costs of Clean Power Plan Rule in 2030
(EPA's Regulatory Impact Analysis, Mid-Point Estimates, Billions of Dollars)

	Climate Change Impacts from CO_2		Domestic Health Impacts from Correlated Pollutants *plus* …	
	Domestic	Global	Domestic Climate Impacts	Global Climate Impacts
Benefits				
Climate Change	$3	$ 31	$3	$31
Health Co-Benefits	--	--	$45	$45
Total Benefits	$3	$ 31	$48	$76
Total Compliance Costs	$9	$ 9	$ 9	$ 9
Net Benefits (Benefits – Costs)	- $6	$ 22	$ 39	$ 67

SOURCE: Authors' calculations, based on Table ES-7 (page ES-19) and Table ES-10 (page ES23) of June, 2014, Regulatory Impact Analysis of proposed Clean Power Plan rule (U.S. Environmental Protection Agency 2014b), adopting mid-point estimates, using 3% discount rate, and domestic shares of global climate benefits from the Interagency Working Group on Social Cost of Carbon (2010).

REFERENCES

Ackerman, Bruce A., and William T. Hassler. (1981). *Clean Coal / Dirty Air*. New Haven: Yale University Press.

Anderson, Robert. (1997). *The U.S. Experience with Economic Incentives in Environmental Pollution Control Policy*. Environmental Law Institute, Washington, D.C.

Anderson, Robert C., Lisa A. Hofmann, and Michael Rusin. (1990). "The Use of Economic Incentive Mechanisms in Environmental Management." Research Paper 51, American Petroleum Institute, Washington, D.C.

Baumol, William J., and Wallace E. Oates. (1988). *The Theory of Environmental Policy*. Cambridge, United Kingdom: Cambridge University Press.

Bellas, Allen S., and Ian Lange. (2011). "Evidence of Innovation and Diffusion under Tradable Permit Programs." *International Review of Environmental and Resource Economics* 5(1): 1–22.

Borenstein, Severin, James Bushnell, Frank A. Wolak, and Matthew Zaragoza-Watkins. (2018). "Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design." University of California, Berkeley, Energy Institute at Haas Working Paper 274, June.

Broder, John. (2009). "Obama to Toughen Rules on Emissions and Mileage." *New York Times*, May 18, page A1.

Buchanan, James, and Gordon Tullock (1975). "Polluters Profits and Political Response: Direct Controls versus Taxes." *American Economic Review*, 65 (1): 139-147.

Burtraw, Dallas, Danny Kahn, and Karen Palmer. (2006). "CO_2 Allowance Allocation in the Regional Greenhouse Gas Initiative and the Effect on Electricity Investors." *Electricity Journal* 19 (2): 79-90.

Burtraw, Dallas, Alan J. Krupnick, Erin Mansur, David Austin, and Alan Farrell. (1998). "The Costs and Benefits of Reducing Air Pollution Related to Acid Rain." *Contemporary Economic Policy* 16: 379-400.

Burtraw, Dallas, and Sarah Jo Szambelan. (2010). "U.S. Emissions Trading Markets for SO_2 and NO_x." *Permit Trading in Different Applications*, Bernd Hansjürgens (ed.), New York: Routledge.

Butler, T. J., Vermeylen, F. M., Rury, M., Likens, G. E., Lee, B., Bowker, G. E., & McCluney, L. (2011). "Response of Ozone and Nitrate to Stationary Source NO_x Emission Reductions in the Eastern USA." *Atmospheric Environment*, *45*5, 1084-1094.

California Legislative Analyst's Office (2017). "The 2017-18 Budget: Cap-and-Trade." February. Available at https://lao.ca.gov/reports/2017/3553/cap-and-trade-021317.pdf.

Carlson, Curtis, Dallas Burtraw, Maureen Cropper, and Karen Palmer. (2000). "SO_2 Control by Electric Utilities: What Are the Gains from Trade?" *Journal of Political Economy* 108: 1292-326.

Chan, H. Ron, B. Andrew Chupp, Maureen L. Cropper, and Nicholas Z. Muller. (2018). "The Impact of Trading on the Costs and Benefits of the Acid Rain Program." *Journal of Environmental Economics and Management*, 88: 180-209.

Chestnut, Lauraine G., and David M. Mills. (2005). "A Fresh Look at the Benefits and Costs of the US Acid Rain Program." *Journal of Environmental Management*, 77(3): 252-266.

Coase, Ronald. **(**1960). "The Problem of Social Cost." *Journal of Law and Economics* 3: 1-44.

Cook, Elizabeth, ed. (1996). *Ozone Protection in the United States: Elements of Success*. Washington, D.C.: World Resources Institute.

Copeland, Curtis W. (2009). "Federal Rulemaking: The Role of the Office of Information and Regulatory Affairs." Congressional Research Service Report for Congress RL32397, June 9.

Crocker, Thomas D. (1966). "The Structuring of Atmospheric Pollution Control Systems." In *The Economics of Air Pollution*, ed.. H. Wolozin, pp. 61-86. New York: W. W. Norton and Company, Inc.

Dales, J. H. (1968). "Land, Water, Ownership." *Canadian Journal of Economics* 1: 791-804.

Deschenes, Olivier, Michael Greenstone, and Joseph S. Shapiro. (2017). "Defensive Investments and the Demand for Air Quality: Evidence from the NO_x Budget Program." *American Economic Review* 107(10): 2958-2989.

Ellerman, A. Denny, Paul L. Joskow, and David Harrison. (2003). *Emissions Trading in the U.S.: Experience, Lessons and Considerations for Greenhouse Gases.* Prepared for the Pew Center on Global Climate Change.

Ellerman, A. Denny, Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth M. Bailey. (2000). *Markets for Clean Air: The U.S. Acid Rain Program*. Cambridge, UK: Cambridge University Press.

Ellerman, A. Denny, and Juan-Pablo Montero. (1998). "The Declining Trend in Sulfur Dioxide Emissions: Implications for Allowance Prices," *Journal of Environmental Economics and Management* 36: 26-45.

Farrell, Alan. (2000). "The NO_x Budget: A Look at the First Year." *The Electricity Journal*, 13(2), 83-93.

Fleisher, Richard, and John R. Bond. (2004). "The Shrinking Middle in the U.S. Congress." *British Journal of Political Science*, 34(3): 429–451.

Foster, Vincent and Robert W. Hahn. (1995). "Designing More Efficient Markets: Lessons from Los Angeles Smog Control." *Journal of Law and Economics* 38: 19-48.

Fowlie, Meredith, Stephen P. Holland, and Erin T. Mansur. (2012). "What Do Emissions Markets Deliver and to Whom? Evidence from Southern California's NO_x Trading Program." *American Economic Review*, Vol. 102, No. 2 (April), pp. 965-993.

Friedman, Lisa. (2018). "Trump's Plan for Coal Emissions: Let Coal States Regulate Them." *New York Times*, August 18, page 1A.

Gayer, Ted, and W. Kip Viscusi. (2016). "Determining the Proper Scope of Climate Change Policy Benefits in U.S. Regulatory Analyses: Domestic versus Global Approaches." *Review of Environmental Economics and Policy* 10(2): 245–263.

Glass, Norman R., *et al*. (1982). "Effects of Acid Precipitation." *Environmental Science and Technology*, Vol. 16, No. 3, pp. 162A-169A.

Goulder, Lawrence H. (1995). "Environmental Taxation and the 'Double Dividend': A Reader's Guide." *International Tax and Public Finance* 2(2):157-183.

Hahn, Robert W. (1989). "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders." *Journal of Economic Perspectives* 3:95-114.

Hahn, Robert W. (2000). "The Impact of Economics on Environmental Policy." *Journal of Environmental Economics and Management* 39(3): 375-399.

Hahn, Robert W., and Gordon L. Hester. (1989). "Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program." *Yale Journal of Regulation* 6: 109-153.

Hahn, Robert W., and Albert M. McGartland. (1989). "Political Economy of Instrumental Choice: An Examination of the U.S. Role in Implementing the Montreal Protocol." *Northwestern University Law Review* 83:592-611.

Hahn, Robert W., and Robert N. Stavins. (2011). "The Effect of Allowance Allocations on Cap-and-Trade System Performance." *Journal of Law and Economics* 54(4), 2011, pp. S267-S294.

Hicks, John R. (1939). "The Foundations of Welfare Economics." *The Economic Journal* 49: 696-712.

Interagency Working Group on Social Cost of Carbon, United States Government. (2010). "Technical Support Document, Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866" (February).

Intergovernmental Panel on Climate Change. (2013). *Climate Change 2013: The Physical Science Basis.* Cambridge, U.K.: Cambridge University Press.

Johnson, Scott Lee, and David M. Pekelney. (1996). "Economic Assessment of the Regional Clean Air Incentives Market: A New Emissions Trading Program for Los Angeles." *Land Economics* Vol. 72, No. 3, pp. 277-297.

Joskow, Paul L., and Richard Schmalensee. (1998). "The Political Economy of Market-Based Environmental Policy: The U.S. Acid Rain Program." *Journal of Law and Economics* 41(1): 37–83.

Kaldor, Nicholas. (1939). "Welfare Propositions of Economics and Interpersonal Comparisons of Utility." *Economic Journal* 49: 549-552.

Keohane, Nathaniel O. (2003). "What Did the Market Buy? Cost Savings under the U.S. Tradeable Permits Program for Sulfur Dioxide." Working Paper YCELP-01-11-2003, Yale Center for Environmental Law and Policy.

Kerr, Suzi, and David Maré. (1997). "Efficient Regulation Through Tradeable Permit Markets: The United States Lead Phasedown." Department of Agricultural and Resource Economics, University of Maryland, College Park, Working Paper 96-06 (January).

Kerr, Suzi, and Richard Newell. (2003). "Policy-Induced Technology Adoption: Evidence from the U.S. Lead Phasedown." *Journal of Industrial Economics*, 51(3), pp. 317-343.

Keyes, Amelia T., Kathleen F. Lambert, Dallas Burtraw, Jonathan J. Buonocore, Johathan I. Levy, and Charles T. Driscoll. (2018). "The Affordable Clean Energy Rule and the Impact of Emissions Rebound on Carbon Dioxide and Criteria Air Pollutant Emissions." Washington, D.C., Resources for the Future, Working Paper 18-20.

Kneese, Allen V. and Charles L. Schultz. (1975). *Pollution, Prices, and Public Policy*. Washington, D.C.: The Brookings Institution.

Korb, Barry. (1998). "U.S. Experience with Economic Incentives for Emissions Trading", in: Organization for Economic Cooperation and Development, *Applying Market-Based Instruments to Environmental Policies in China and OECD Countries* (OECD, Paris): 99-115.

Leard, Benjamin, and Virginia McConnell. (2017). "New Markets for Credit Trading under US Automobile Greenhouse Gas and Fuel Economy Standards." Washington: Resources for the Future, August.

Liptak, Adam, and Coral Davenport. (2016). "Supreme Court Deals Blow to Obama's Efforts to Regulate Coal Emissions." *New York Times*, February 10, page A1.

Liroff, Richard A. (1986). *Reforming Air Pollution Regulations: The Toil and Trouble of EPA's Bubble* Washington, D.C.: Conservation Foundation.

Lowry, William R., and Charles R. Shipan. (2002). "Party Differentiation in Congress." *Legislative Studies Quarterly* 27: 33-60.

Mazmanian, Daniel A., and Michael E. Kraft. (2009). "The Three Epochs of the Environmental Movement," D. A. Mazmanian and M. E. Kraft, *Toward Sustainable Communities: Transition and Transformations in Environmental Policy*, pp. 3-32. Cambridge, Massachusetts: The MIT Press.

Merrill, P. R., and A. S. Rousso. (1990). "Federal Environmental Taxation." Paper presented at the Eighty-third Annual Conference of the National Tax Association, San Francisco, California (November 13).

Montgomery, David W. (1972). "Markets in Licenses and Efficient Pollution Control Programs." *Journal of Economic Theory* 5: 395-418.

Newell, Richard G., and Kenneth Rogers. (2007). "The Market-Based Lead Phasedown." *Moving to Markets in Environmental Regulation: Lessons from Twenty Years of Experience*, pp. 173-193. Edited by Jody Freeman and Charles Kolstad. Oxford: Oxford University Press.

Nichols, Albert L. (1997). "Lead in Gasoline." Richard D. Morgenstern, ed., *Economic Analyses at EPA: Assessing Regulatory Impact*, pp. 49-86. Washington, D.C.: Resources for the Future.

Ozone Transport Commission. (2003). *NO_X Budget Program: 1999-2002 Progress Report*. See: http://www2.epa.gov/sites/production/files/2015-08/documents/otcreport.pdf

Pareto, Vilfredo. (1896). Cours d'Economie Politique, Volume 2 (Lausanne).

Pigou, Arthur C. (1920). *The Economics of Welfare*. London: Macmillan.

Poole, Keith T., and Howard Rosenthal. (1997). *Congress: A Political-Economic History of Roll Call Voting*. New York: Oxford University Press.

Poole, Keith T., and Howard Rosenthal. (2007). *Ideology and Congress*. New Brunswick: Transaction Publishers.

Popp, David. (2003). "Pollution Control Innovations and the Clean Air Act of 1990." *Journal of Policy Analysis and Management* 22(4): 641– 60.

Reitze, Arnold W. Jr. (2001). *Air Pollution Control Law: Compliance and Enforcement*. Washington, DC, Environmental Law Institute, ch. 13.

Rico, Renee. (1995). "The U.S. Allowance Trading System for Sulfur Dioxide: An Update of Market Experience." *Environmental and Resource Economics* 5(2): 115-129.

Schmalensee, Richard, Paul L. Joskow, A. Denny Ellerman, Juan-Pablo Montero, and Elizabeth M. Bailey. (1998). "An Interim Evaluation of Sulfur Dioxide Emissions Trading." *Journal of Economic Perspectives*, 12(3): 53-68.

Schmalensee, Richard, and Robert N. Stavins. (2013). "The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment." *Journal of Economic Perspectives*, Volume 27, Number 1, Winter, pp. 103-122.

Shipan, Charles R., and William R. Lowry. (2001). "Environmental Policy and Party Divergence in Congress." *Political Research Quarterly* 54: 245-263.

South Coast Air Quality Management District. (2018). "July 2018 Quarterly Report to Stationary Source Committee." Diamond Bar, California.

Stavins, Robert N. (1998). "What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading." *Journal of Economic Perspectives*, 12(3): 69–88.

Stavins, Robert N. (2006). "Vintage-Differentiated Environmental Regulation." *Stanford Environmental Law Journal*, 25 (1): 29-63.

Stern, Arthur C. (1982). "History of Air Pollution Legislation in the United States." Journal of the Air Pollution Control Association, 32(1): 44-61.

Swift, Byron. (2004). "Emissions Trading and Hot Spots: A Review of the Major Programs." *Environment Reporter* 35(19): 1–16.

Theriault, Sean M. (2008). *Party Polarization in the Congress*. New York: Cambridge University Press.

Tietenberg, Tom. (1985). *Emissions Trading: An Exercise in Reforming Pollution Policy*. Washington, D.C.: Resources for the Future.

U.S. Congress. (1989). "Omnibus Budget Reconciliation Act of 1989." 101st Congress, 1st session, P.L. 101-239, Sec. 7506, "Excise Tax on the Sale of Chemicals Which Deplete the Ozone Layer and of Products Containing Such Chemicals" (19 December).

U.S. Congress, Office of Technology Assessment. (1995). *Environmental Policy Tools: A Users Guide*. Washington, D.C.

U.S. Energy Information Administration. (2012). "Electricity Net Generation: Total (All Sectors), 1949–2011." Table 8.2a, *Annual Energy Review 2011*. Washington, D.C.

U.S. Environmental Protection Agency. (1985). "Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis." Office of Policy Analysis, Washington, D.C.

U.S. Environmental Protection Agency, (2001). "The United States Experience with Economic Incentives for Protecting the Environment." National Center for Environmental Economics, Report EPA-240-R-01-001, January.

U.S. Environmental Protection Agency. (2004). "Evaluating Ozone Control Programs in the Eastern United States: Focus on the NO_x Budget Trading Program." Washington, D.C.

U.S. Environmental Protection Agency. (2011). *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data: 1970–2011*. Washington, D.C.

U.S. Environmental Protection Agency. (2014a). "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units." 40 CFR Part 60 (June 18).

U.S. Environmental Protection Agency. (2014b). "Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants." EPA-452/R-14-002 (June).

U.S. Environmental Protection Agency. (2015). "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Final Rule." 40 CFR Part 60 (October 23).

U.S. Environmental Protection Agency. (2018a). "The Safer and Affordable Fuel Efficient Vehicles Proposed Rule for Model Years 2021-2026." https://www.epa.gov/regulations-emissions-vehicles-and-engines/safer-and-affordable-fuel-efficient-vehicles-proposed.

U.S. Environmental Protection Agency. (2018b). "Air Pollution Trends Show Cleaner Air, Growing Economy."https://www.epa.gov/newsreleases/air-pollution-trends-show-cleaner-air-growing-economy

U.S. Environmental Protection Agency. (2018c). "Proposal: Affordable Clean Energy (ACE) Rule," August 21. https://www.epa.gov/stationary-sources-air-pollution/proposal-affordable-clean-energy-ace-rule

U.S. Environmental Protection Agency. (2018d). "Regulatory Impact Analysis for the Proposed Emissions Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review Program." EPA-453/R-18-006.

U.S. National Academy of Sciences. (2017). *Valuing Climate Dam*ages. Washington, D.C.: National Academies Press.

Weitzman, Martin. (1974). "Prices vs. Quantities." *Review of Economic Studies*, 41(4): 477-491.