Policy Evolution under the Clean Air Act

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Nearly half a century has elapsed since 1970, when the first Earth Day was celebrated, the US Environmental Protection Agency (EPA) was established, and the US Clean Air Act passed with unanimous bipartisan support in the Senate and only a single negative vote in the House of Representatives. 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 the 1970 Clean Air Act established the basic architecture of the US air pollution control system, it was the first environmental law to give the federal government a serious regulatory role, and it became a model for many subsequent environmental laws in the United States and abroad. In this article, we describe the evolution of air pollution control policy under this legislation with particular attention to the types of policy instruments used.

While the Clean Air Act evolved over time, so too did the area of scholarship that came to be known as "environmental economics." For almost a half century after Pigou (1920) advanced the abstract notion of taxing pollution, economists paid very little attention to environmental protection. In the late 1960s, Crocker

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(1966), Dales (1968), Ayres and Kneese (1969), and a few others began serious study of environmental policy, but economists were not engaged in the design of the US Clean Air Act. The *Journal of Environmental Economics and Management* was launched in 1974, and environmental protection received increasing attention from economists throughout the late 1970s and 1980s, leading to the area's emergence as a distinct field during the 1990s. The National Bureau of Economic Research held its first Conference on Economics of the Environment in 1991, and in 2007 it launched its Environment and Energy Economics Program.

We begin our analysis by outlining the key provisions of the 1970 act and its main changes over time. We then turn to our main focus, which is to trace and assess the historical evolution of the policy instruments used by the Environmental Protection Agency in its clean air regulations. This evolution has been driven at various times by the emergence on the policy agenda of new air quality problems, by innovation and experimentation by the agency, and by changes in the Clean Air Act itself. Until roughly 2000, EPA made increasing use of market-based instruments, enabled in part by major amendments to the Clean Air Act in 1977 and 1990 that passed with overwhelming bipartisan support. In recent years, however, environmental policy has become a partisan battleground. So far, it has not been possible to provide an efficient response to climate change or to address other new and evolving air quality problems.

The Evolution of the Clean Air Act: 1970–1990

The 1970 Clean Air Act was a national-level response to environmental concerns. For environmental activists, this national approach addressed the fears that states would compete by lowering their environmental standards. For industries operating across states, it addressed the fear of facing a multitude of state-level mandates. This law, only 24 pages in length, gave the Environmental Protection Agency considerable discretion and authority to set and change regulations and to enforce compliance. Under the Administrative Procedure Act of 1946 (Pub. L. 79-404, 60 Stat. 237), 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 provisions of the Clean Air Act and the Administrative Procedure Act 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 benefit-cost test administered by the Office of Management and Budget (for discussion, see Copeland 2009). A key part of the process is submission of a Regulatory Impact Analysis that compares the benefits and costs of the proposal.

The 1970 law contained four key provisions. First, the Environmental Protection Agency 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 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, states were tasked with developing State Implementation Plans, to which the Environmental Protection Agency could require modification, to bring areas under their jurisdiction into attainment with the National Ambient Air Quality Standards.

Third, the Environmental Protection Agency was to develop national New Source Performance Standards 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. Imposing requirements only on *new* stationary and mobile sources had the perverse effect of encouraging firms to retain their existing capital stock, slowing turnover of the capital stock and thereby retarding environmental progress (Stavins 2006). However, states retained the authority to regulate existing stationary sources if necessary to bring areas into attainment with air quality standards.

Fourth, the Environmental Protection Agency was to develop National Emission Standards for Hazardous Air Pollutants, also known as air toxics, to protect public health. These air toxics, such as benzene, are mainly produced by manufacturing plants and other isolated sources and have localized effects.

The first major set of amendments to the Clean Air Act, 112 pages in length, passed in 1977 by a voice vote in the Senate and a vote of 273–109 in the House of Representatives. A regime of Prevention of Significant Deterioration was established, which limited the worsening of air quality in areas that were already in compliance with the National Ambient Air Quality Standards. This regime permitted new stationary sources of air pollution to be built in nonattainment areas if, through modifications of existing sources, overall emissions were reduced. This regime enabled the Environmental Protection Agency to extend its experiments with emissions trading, which began in 1974 (and are discussed below). Also, EPA was empowered to issue technology-based control standards for air toxics instead of emission or performance standards, where the latter were deemed impractical. Finally, EPA was given authority to regulate substances likely to deplete stratospheric ozone.

Unsurprisingly, the 1977 legislation included some politically driven provisions. For example, one stipulation was that the New Source Performance Standards 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) over the producers of low-sulfur Western coal, which would otherwise have been favored for meeting standards for reduced sulfur emissions.

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 United States ratified the Montreal Protocol to protect the ozone layer. In response to these developments and others, Congress passed the 314-page 1990 amendments, which included four main provisions: (1) the establishment of the path-breaking sulfur

dioxide cap-and-trade program, intended to cut acid rain to half of 1980 levels (discussed in this journal in Schmalensee et al. 1998; Stavins 1998; Schmalensee and Stavins 2013); (2) regulation of a number of aspects of motor vehicle fuels, including volatility (that is, how easily a fuel vaporizes);[1] (3) authority for the Environmental Protection Agency to ensure that the United States 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. Economists inside and outside the administration were engaged in the design of the acid rain program (G. Chan et al. 2012). This final 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. The 1990 amendments were passed by large bipartisan majorities: over 90 percent of Democrats voted in favor in both houses of Congress, as did 87 percent of Republicans.

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 UN 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 policy had become a partisan issue, and polarization between the parties had increased.

In June 2009, the House of Representatives passed legislation (the American Clean Energy and Security Act of 2009, also known as 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. Five of the eight Republicans who supported the legislation were from heavily Democratic states, where a "nay" vote would have been highly visible and attracted opposition, and 25 of the 44 Democrats who did not support it were from heavily Republican states. The legislation would have had its greatest impact on coal, the most carbon-intensive fossil fuel, and 25 of the 44 Democrats who opposed the legislation were from states in which more than half of electricity was generated from coal. In July 2010, the Senate abandoned its attempt to pass companion legislation.

This polarization between the two political parties in regard to environmental policy—well documented by political scientists (for example, Shipan and Lowry 2001)—was part of a gradually widening gulf between the parties on virtually all

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[1] The volatility standard was explicitly relaxed if corn-based ethanol was used. The Senate minority leader in 1990, Robert Dole (R-Kansas), represented a large, corn-producing state.

issues (Fleisher and Bond 2004).[2] The Clean Air Act, and federal air pollution legislation generally, ceased to evolve after 1990, although regulatory actions authorized by existing legislation and judicial oversight continued.

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.[3]

As panel A of Table 1 indicates, three types of instruments have been used for the control of criteria air pollutants. Hazardous air pollutants have been controlled only 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. As we discuss below, the Obama administration proposed a hybrid standard/trading regulation under the Clean Air Act to reduce CO_2 emissions in the electricity sector, but the Trump administration has proposed replacing it with a standards regime.

Panel B 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 a fundamental criterion for evaluating environmental protection efforts (Pareto 1896; Hicks 1939; Kaldor 1939).[4] However, discussions in the environmental policy realm have frequently employed the criterion of cost effectiveness—that is, minimizing

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[2]Polarization, and a corresponding gradual disappearance of moderates, has been taking place for decades (Lowry and Shipan 2002; Theriault 2008). It 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.

[3]The 1990 amendments to the Clean Air Act allowed states to tax regulated air pollutants to recover administrative costs of state programs, and allowed areas in extreme noncompliance to charge higher rates. Under this structure, the South Coast Air Quality Management District in Los Angeles implemented the highest permit fees in the country (US 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.

[4]This criterion is considered in the companion article by Janet Currie and Reed Walker in this issue.

Table 1

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

	Policy instrument used			
	Technology standards	*Performance standards*	*Emissions trading*	*Taxes*
A: Pollutant categories				
Criteria pollutants	*	*	*	
Toxic/hazardous pollutants	*	*		
Stratospheric ozone depletion			*	*
Acid rain			*	
Greenhouse gases		Proposed	Proposed	
B: Regulated sectors				
Electricity generation	*	*	*	
Other stationary sources	*	*	*	*
Mobile sources	*	*		

the costs of reducing emissions to a specified level. Of course, cost effectiveness is not the same as economic efficiency, but measuring the benefits of environmental protection is challenging. Reducing emissions to a level determined by noneconomic considerations, but at the lowest cost, offers an empirically easier alternative. Using this approach (and assuming equal effectiveness of enforcement), performance standards for reduced emissions are at least as cost effective as technology standards in meeting a given emissions standard, 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 nonuniform 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 the relevant cost functions of pollution sources. As a consequence, such detailed command-and-control methods are rarely, if ever, cost effective.

In principle, government has two methods for achieving the cost-effective reduction of pollution across sources when it lacks detailed information about source-level control costs: a tax on pollutant emissions and an emissions trading system. In theory, 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. Although for efficiency the tax should be set equal to the marginal benefits of cleanup at the efficient level of cleanup, policymakers are much more likely to focus on a desired level of cleanup, and there is uncertainty 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 for regulated firms than command and control, 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 an alternative way that 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 described the issue of how to address pollution as a problem 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 property in a cost-effective way.

Not long after Coase's work appeared, Crocker (1966) and Dales (1968) proposed emissions trading systems based on property rights. Such systems are of two basic types: credit programs and cap-and-trade systems. Under credit programs, credits are assigned (or 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. 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. Each source has an incentive to abate emissions 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. Although the specified overall level of pollution abatement is certain under cap-and-trade regimes, the price at which pollution allowances will be traded is not assured in advance.

Under a cap-and-trade system, the unique cost-effective equilibrium can usually be 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 preferred to pollution 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 either reducing the system's environmental performance or driving up its cost. In some cap-and-trade systems, most allowances are auctioned off, notably in the Regional Greenhouse Gas Initiative in the northeastern United States (Burtraw, Kahn, and Palmer 2006) and the California cap-and-trade program

(California Legislative Analyst's Office 2017), but auctioning of allowances has not played an important role under the Clean Air Act.

Even when the assumption that emissions are well mixed is only approximately correct, taxes or emissions trading may be more cost effective than command and control if marginal abatement 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. Further, neither taxes nor emissions trading has been used to regulate mobile sources, although tradable performance standards have been employed, as we discuss below.

The Evolution of Air Quality Policy Instruments

Under the original 1970 Clean Air Act, all federal air pollution regulation involved either technology standards 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 Clean Air Act was amended and as the interpretation of its provisions by the Environmental Protection Agency evolved, air pollution regulation evolved from sole reliance on conventional, command-and-control regulations to greater use of emissions trading.[5] This evolution has come to a halt in the past decade.

First Experiments with Emissions Trading in the 1970s

Beginning in 1974, the Environmental Protection Agency experimented with emissions trading among stationary sources through four programs: netting, bubbles, offsets, and banking. Under netting or bubbles, firms that reduced 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). Bubbles allowed firms to treat multiple sources within a plant as a single source, whereas netting extended the practice to multiple firms. These may be thought of as basic forms of intrafirm and interfirm emissions trading, respectively. 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, as explicitly authorized by the 1977 amendments, allowed trades between firms. Firms wishing to establish new sources in areas that were not in compliance with National Ambient

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[5]A report from the Environmental Protection Agency (2001) provides a comprehensive discussion of the use of economic incentives in all US environmental protection programs through 2000, but command-and-control regulations were still the norm (Hahn 2000).

Air Quality Standards 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.

The Environmental Protection Agency codified all four programs in its Emissions Trading Program in 1986, but the programs were not 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 between firms were subject to administrative approval, and trades were required to produce significant net emissions reductions, all of which raised transactions costs. Nevertheless, companies such as Armco, DuPont, USX, and 3M did trade 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

Starting in 1975, new US car models were required to be built with catalytic converters to reduce emissions of carbon monoxide and hydrocarbons. However, lead in gasoline fouls catalytic converters, so the Environmental Protection Agency required that only unleaded gasoline could be used in new cars.

There was also concern about the threat of lead emissions to human health, and the Environmental Protection Agency began to set rules for reducing the quantity of lead in gasoline beginning in 1979. However, smaller refineries found it difficult to meet the requirements, even though the rules for reducing lead were less stringent for smaller operations (Newell and Rogers 2007). In late 1982, EPA launched a lead emissions trading program aimed at reducing the burden of the phasedown on the smaller refineries. Unlike a textbook cap-and-trade program, in which a fixed quantity of allowances is given or sold to potential emitters, there was no explicit allocation of allowances (Hahn 1989). Instead, 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 called a "tradable performance standard." In 1985, EPA promulgated rules for an accelerated phaseout of lead. These new rules included a "banking" provision, so that lead credits could be saved for later use. This created an incentive for refineries to make early reductions in lead content, which in turn would help them meet the lower limits that took effect over time.

Taken together, these tradable and bankable lead "credits" resulted in leaded gasoline being removed from the market faster than anticipated (Anderson, Hofmann, and Rusin 1990; Newell and Rogers 2007). In each year of the program before it was terminated in 1987, 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 the 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). The program resulted in savings of approximately 20 percent relative to approaches that did not include trading (Environmental Protection Agency 1985). In addition, the program provided significant incentives for diffusion of cost-saving technology (Kerr and Newell 2003). By 1988, when uniform performance standards were imposed for reductions in lead at oil refineries of all sizes, very little leaded gasoline was produced in the United States. The 1990 amendments to the Clean Air Act banned all leaded gasoline beginning in 1996.

The phasedown of leaded gasoline was the first environmental program in which trading played a central role, and it demonstrated that a trading system could reduce emissions in an economically cost-effective manner. Moreover, it demonstrated that transaction costs in such a system could be low enough to permit substantial trade. The lack of a prior approval requirement, as had existed in the preceding Emissions Trading Program, was an important factor in the success of lead trading (Hahn and Hester 1989). Also, the ability to bank credits enabled significant cost savings and early reductions.

Stratospheric Ozone Protection

Following US ratification of the Montreal Protocol in 1988, Congress imposed an excise tax on chemicals that deplete stratospheric ozone that took effect in 1990 (Omnibus Budget Reconciliation Act of 1989, Pub. L. 101-239, 103 Stat. 2106, § 7506 [1989]). Beginning in 1989, the Environmental Protection Agency set up an emissions trading system for ozone-depleting chemicals, which was then expanded after the 1990 amendments (Hahn and McGartland 1989). Limits were placed on both the production and the use of ozone-depleting chemicals by issuing allowances to producers. Different types of ozone-depleting chemicals have different effects on ozone depletion, and each ozone-depleting chemical was assigned a weight on the basis of its depletion potential. Through mid-1991, there were 34 participants in the market and 80 trades, but we are not aware of any studies that estimate cost savings.

The timetable for the phaseout of ozone-depleting chemicals was subsequently accelerated, and the tax on ozone-depleting chemicals was raised over time (Reitze 2001). It effectively served as a windfall-profits tax, to prevent firms that held emissions permits benefitting from higher prices created by the quantity restrictions (Merrill and Rousso 1990; Environmental Protection Agency 2001). There was considerable debate regarding the extent to which the pollution taxes or the emissions trading system should be credited with the ultimately successful reduction in the use of ozone-depleting chemicals, for which US production ceased in 1995 (Cook 1996).

Sulfur Dioxide Allowance Trading

There was concern starting in the early 1980s (for example, see Glass et al. 1982) that emissions of SO_2 from coal-fired power plants leading to greater acidity in precipitation was damaging forests and aquatic ecosystems. Because costs of reducing these emissions differed dramatically across sources, command-and-control instruments for specifying levels of emissions failed to attract congressional support.

However, the path-breaking 1990 amendments to the Clean Air Act required the Environmental Protection Agency to launch the SO_2 allowance trading program, eventually covering all nontrivial power plants with a declining cap achieving a 50 percent reduction below 1980 levels (Ellerman et al. 2000).

The government allocated allowances to power plants to emit specific quantities of SO_2 at zero cost, based primarily on actual fuel use during the 1985–1987 period. In addition, because of concerns about barriers to entry for new generating plants, the statute required the Environmental Protection Agency to withhold about 2.8 percent of all allowance allocations each year, sell them at an annual auction, and return the proceeds to firms from which allowances had been withheld (Ellerman et al. 2000). If annual emissions at a regulated facility exceeded its allowance allocation, the owner could comply by buying additional allowances or reducing emissions—which in turn could be accomplished 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 (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 increasing its cost.

The program performed well, with SO_2 emissions from electric power plants decreasing 36 percent between 1990 and 2004 (Environmental Protection Agency 2011), even though electricity generation from coal-fired power plants *increased* 25 percent over the same period (Table 8.2a in 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. Although the program's costs, at least initially, were likely not as low as they ideally could have been (Schmalensee and Stavins 2013), cost savings overall were eventually 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).

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 these 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—rather than primarily arising from the ecological benefits of reduced acid deposition that motivated the program's establishment (Schmalensee and Stavins 2013).

One concern was that trading might produce "hot spots" of unacceptably high SO_2 concentrations. However, computer models had predicted that plants that had the most impact on ecosystems had the lowest costs of reducing emissions. The pattern of emissions reductions was broadly consistent with those predictions, and no significant hot spots emerged (Ellerman et al. 2000; Swift 2004).[6]

In retrospect, there are number of reasons this program worked so well. First, a key feature was putting final rules in place well before the 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 (Schmalensee and Stavins 2017). Second, 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). Third, 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). Fourth, the program may have reduced costs over time by providing incentives for technology innovation (Ellerman et al. 2000; Popp 2003; Bellas and Lange 2011). Fifth, the emissions reduction 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. Sixth, with continuous emissions monitoring and a $2,000 per ton statutory fine for any excess emissions, enforcement was stringent and compliance was nearly perfect (Burtraw and Szambelan 2010).

Finally, the cost of the SO_2 reduction program was significantly reduced by an external factor: 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 (Ellerman and Montero 1998; Keohane 2003; Schmalensee and Stavins 2013). A command-and-control policy that required the use of certain technologies to reduce sulfur dioxide emissions would not have provided the flexibility to take advantage of the fall in rail rates (Schmalensee and Stavins 2017).

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 widely regarded as a success story of cost-effective environmental regulation.

Regional Programs under Clean Air Act Authority

Two other market-oriented environmental programs that merit attention were regional programs executed under the authority of the Environmental Protection Agency and the Clean Air Act: the Regional Clean Air Incentives Market in the Los Angeles area, and NO_x trading among eastern states.[7]

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[6]H. 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, given very heterogeneous costs of compliance, that hypothetical program had been a political nonstarter.

[7]A systematic study of the evolution of environmental policy instrument use at the state level is beyond the scope of this article. It is worth noting, however, that some states have made significant use

The Regional Clean Air Incentives Market (RECLAIM) was launched in 1993 by the South Coast Air Quality Management District, which is responsible for controlling emissions in a four-county area of Southern California. It sought to replace command-and-control regulations and find a more cost-effective way of reducing emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) from 350 sources, including power plants and industrial sources in the Los Angeles area. RECLAIM Trading Credits 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 percent reduction in emissions (Ellerman, Joskow, and Harrison 2003). Banking of unused credits from one year to the next was not allowed. A unique aspect of this program's design was that 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). By June 1996, 353 program participants had traded more than 100,000 tons of credits, with a value of over $10 million (South Coast Air Quality Management District 2018). Emissions at facilities covered by the program were some 20 percent lower than at facilities regulated with parallel command-and-control regulations, hot spots 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 taken offline, 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, it resulted in a dramatic spike in allowance prices—to more than $60,000 per ton in 2001 (Fowlie, Holland, and Mansur 2012). The program was temporarily suspended. Prices returned to normal levels (about $2,000 per 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 per ton (South Coast Air Quality Management District 2018).

Another regional program of particular interest is NO_x trading in the eastern United States, which was enabled by the 1990 Clean Air Act 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. The goal of the program was to reduce summertime ground-level ozone—that is, smog formed by the interaction of NO_x and volatile organic compounds in the presence of sunlight—by more than 50 percent relative to 1990 levels (Environmental Protection Agency 2004). Some 1,000 electric generating and industrial units were required to demonstrate compliance each year during the summer ozone season.

of market-based instruments. The California cap-and-trade system for greenhouse gases is a notable example (Borenstein et al. 2018).

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. However, trading across zones was permitted on a one-for-one basis, and the upwind and downwind zones made similar reductions from baseline emissions levels (Ozone Transport Commission 2003).

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). For the 1999–2003 period, abatement cost savings were estimated at 40 to 47 percent relative to conventional regulation that did not include trading or banking (Farrell 2000).

In 1998, the Environmental Protection Agency had issued a call for State Implementation Plans, which required 21 eastern states to submit plans to reduce their NO_x emissions from more than 2,500 sources. The result was an interstate cap-and-trade program, known as the NO_x Budget Trading Program, which went into effect in 2003, replacing the earlier NO_x Budget Program. 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 percent compliance (Butler et al. 2011; Deschenes, Greenstone, and Shapiro 2017).

Overall, 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 multistate process with federal guidance could be effective in coordinating what were legally state-level goals.

In 2005, the NO_x Budget Trading Program was effectively replaced by the Clean Air Interstate Rule, 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 authority to the Environmental Protection Agency to amend the acid rain program (*North Carolina v. Environmental Protection Agency*, No. 05-1244), while an appellate court decision in December of the same year left the policy in place while EPA developed a new approach. In 2015, the Clean Air Interstate Rule was replaced by the Cross State Air Pollution Rule, which does not allow interstate trading.

Climate Change Policies

The single greatest air pollutant emissions issue facing the United States and the world is the emissions of greenhouse gases. For a time, it was unclear whether this topic fell under the purview of the Clean Air Act. Early in the 2000s, the Environmental Protection Agency considered whether it had the authority to regulate emissions of carbon dioxide and other greenhouse gases, noting that during the

major amendments to the Clean Air Act in 1990, Congress had not specified that such emissions should be treated as a pollutant.

Obama Administration Climate Policies

In response to a lawsuit brought by twelve states and several cities, the US Supreme Court ruled in *Massachusetts et al. v. Environmental Protection Agency et al.* (549 US 497 [2007]) that if the Environmental Protection Agency was to find that emissions of greenhouse gases endanger public health or welfare, it would be obligated (on the basis of authority in the 1970 act) to regulate those emissions. In December 2009, the Obama administration EPA issued an "Endangerment Finding," which found that current and projected levels of six greenhouse gases endangered public health and welfare. When attempts to address climate change via new legislation (the American Clean Energy and Security Act of 2009, commonly known as the Waxman–Markey bill) failed in 2010, the focus of addressing greenhouse gas emissions thus turned to the possibility of regulatory approaches under existing authority of the Clean Air Act. EPA proceeded to issue regulations covering greenhouse gas emissions from mobile and then stationary sources. Treating CO_2 as a criteria air pollutant under the Clean Air Act may have been cumbersome and represented a "stretch," but it was a stretch the administration was essentially required to make by the 2007 Supreme Court decision combined with the administration's 2009 Endangerment Finding.

In September 2009, the Obama administration finalized a rule with two main steps: to increase fuel efficiency under the Corporate Average Fuel Economy (CAFE) program and to establish national greenhouse gas 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, with a second phase announced in 2012 increasing the standard to 54.5 miles per gallon 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 began quietly in 2013, with a proposal for New Source Performance Standards to limit CO_2 emissions from all new coal and natural gas power plants built in the United States. The proposed rule would essentially have made it impossible to build 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.

However, a subsequent rule—the Clean Power Plan—announced in June 2014 had considerably more bite. This rule sought to reduce CO_2 emissions from existing sources in the electricity-generating sector. The proposal listed specific targets for each state but gave the states many ways to meet their targets: 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), fostering more efficient end-use of electricity, and others. 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 multistate plans. The regulation was to be finalized in June 2015 and implemented in 2020.

The state-by-state approach in the Clean Power Plan did not guarantee cost effectiveness, because marginal abatement costs would vary greatly across states. However, encouragement was given to states to employ cap-and-trade systems, and the Environmental Protection Agency emphasized its willingness to consider and facilitate multistate implementation plans. EPA was not guaranteeing cost effectiveness, but it was allowing for it and, indeed, attempting to facilitate it.

A difficult challenge for climate change policies is 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 from emissions reductions are much greater than global costs. Despite this logic, the central estimate of annual net benefits (benefits minus costs) of the Clean Power Plan in 2030 in the Environmental Protection Agency's Regulatory Impact Analysis submitted to the Office of Management and Budget was $67 billion (Environmental Protection Agency 2014). How could this be?

Table 2 emphasizes two key underlying assumptions. First, the estimate of climate benefits was not limited to benefits received by the United States, but rather was an estimate of global climate benefits. Second, the estimate of benefits included (the much larger) benefits of human health impacts associated with reductions in correlated air pollutants that were not themselves greenhouse gases.

It would certainly be inappropriate to use a global measure of benefits in analysis of all US regulations (Gayer and Viscusi 2016). Doing so could imply that a labor policy that increased US employment, but led to lower 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 (National Academy of Sciences 2017). In a global commons problem, every jurisdiction will find itself in a situation where the benefits of its actions spill over to other jurisdictions, and the direct climate benefits it reaps from reducing greenhouse gas emissions within its own jurisdiction will be less than the costs it incurs. One can also imagine trying to argue that a US climate policy would increase the probability of other countries taking similar actions, but trying to quantify this effect would be speculative at best.

In addition to counting climate benefits outside the United States, the Environmental Protection Agency under President Obama counted health benefits from reductions of other pollutants, the emissions of which are correlated with those of CO_2. For example, the Clean Power Plan was expected to reduce the burning of coal, leading to decreased emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter, and mercury. These pollutants—especially particulate matter less than 2.5 microns across—have very significant human health impacts; indeed, the estimated benefits from reducing their emissions dwarf the domestic climate

Table 2

Estimated Benefits and Costs of Clean Power Plan Rule in 2030

(Environmental Protection Agency's Regulatory Impact Analysis, midpoint 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*
Climate change benefits	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 minus costs)	−6	22	39	67

Source: Authors' calculations, based on table ES-7 (p. ES-19) and table ES-10 (p. ES-23) of June 2014 Regulatory Impact Analysis of proposed Clean Power Plan Rule (Environmental Protection Agency 2014), adopting midpoint estimates, using 3 percent discount rate, and domestic shares of global climate benefits from the Interagency Working Group on Social Cost of Carbon (2010).

benefits. According to the Regulatory Impact Analysis, whereas the US climate change benefits from CO_2 reductions due to the proposed rule in 2030 would probably be less than $3 billion per year,[8] the domestic health benefits from reduced concentrations of correlated non–greenhouse gas air pollutants would amount to some $45 billion per year! Thus, 94 percent of estimated domestic benefits of this climate policy were due to reductions of non–greenhouse gas air pollutants. In turn, these estimates of health benefits are driven heavily by predicted reductions in morbidity and mortality, and those in turn are driven by the dose-response assumptions EPA employs.

The inclusion of these human health co-benefits is the key argument that climate policies provide a near-term or medium-term increase in US welfare. If the global estimate of climate benefits ($31 billion per year) is employed instead, then the Clean Power Plan Rule looks even better, with total annual benefits of $76 billion, leading to the Environmental Protection Agency's bottom-line estimate of positive net benefits of $67 billion per year in 2030. The Obama administration's proposed Clean Power Plan thus offered the flexibility to be cost effective, and if one accepts the estimates of benefits and costs, it could also have been welfare enhancing.

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[8] Suppose a domestic US climate benefits number were used in this analysis, rather than a global number. EPA estimated global climate benefits of the rule in 2030 using a midrange 3 percent discount rate to be $31 billion. According to the Obama administration's Interagency Working Group on Social Cost of Carbon (2010), US benefits from reducing greenhouse gas emissions would be, on average, about 7 to 10 percent of global benefits. If benefits within the United States were thus 8.5 percent of global benefits, they would amount to about $2.6 billion, considerably less than the $8.8 billion in total annual compliance costs estimated by the Regulatory Impact Analysis.

Trump Administration Climate Policies

Both of the main Obama administration climate change regulatory initiatives—the Corporate Auto Fuel Economy standards for motor vehicles and the Clean Power Plan for the electricity sector—were reversed by the Trump administration. In August 2018, the Environmental Protection Agency and the National Highway Traffic Safety Administration proposed a rule that would have the federal government freeze the motor vehicle standards at their 2020 levels going forward (Environmental Protection Agency 2018a).

When the final version of the Clean Power Plan was published in October 2015 (40 C.F.R. 60), it immediately faced lawsuits from a number of states. They argued, among other things, that the Clean Air Act gave authority to the Environmental Protection Agency only 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 Clean Power Plan went well beyond that authority. In February 2016, the US Supreme Court issued a stay in the implementation of the Clean Power Plan while that litigation proceeded (Liptak and Davenport 2016).

In August 2018, with implementation of the Clean Power Plan still suspended, the Trump administration announced the Affordable Clean Energy Rule as a replacement for the Clean Power Plan Rule (Friedman 2018; Environmental Protection Agency 2018c). The new rule instructs the states to set standards for efficiency improvements in existing coal-fired power plants, subject to guidance from the Environmental Protection Agency regarding technologies to be used as well as EPA approval. (It seems that states could require no improvements at all, if EPA agreed.) 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. It does not provide incentives for changing the mix of methods used for generating electricity or even allow such methods for compliance. Without such flexibility, there is no possibility of cost effectiveness in reducing air pollution. However, it is interesting to note that by issuing the revised regulation, the Trump administration implicitly accepted the 2009 finding by EPA that greenhouse gas emissions do cause harm (Friedman 2018).

The Regulatory Impact Analysis for the Affordable Clean Energy Rule compares it with the Clean Power Plan and finds it superior (Environmental Protection Agency 2018d), although the same report estimates that it would have lower costs, greater coal use, greater greenhouse gas emissions, and greater adverse health effects.[9] The different conclusion is based on different underlying assumptions. This Regulatory Impact Analysis uses a US-only social cost of carbon to value those emissions increases. Whereas, with a 3 percent discount rate, the global social cost of carbon

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[9] It is not clear how fully this analysis of the Affordable Clean Energy Rule 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. 2019).

in 2030 used by the Obama administration was $50 per ton, the US-only cost used by the Trump administration was $7 per ton. With a 7 percent discount rate, the US-only social cost for a ton of carbon emissions was $1 per ton.

The same US-only social cost of carbon was also used in the Regulatory Impact Analysis for the Trump Administration's revised CAFE standards. In several tables that take the loss of health benefits into account, the Affordable Clean Energy Rule is found to have lower net benefits than the Clean Power Plan. But the presentation in the Regulatory Impact Analysis de-emphasizes these health co-benefits and focuses on "net benefits associated with the targeted pollutant (CO_2)." On that metric, and considering only domestic climate benefits, the cost savings from moving from the Clean Power Plan to the Affordable Clean Energy Rule outweigh the foregone benefits.

Conclusions

The supporters of the 1970 Clean Air Act no doubt hoped that it would produce major environmental benefits. They would surely be pleased that despite the fact that real US GDP more than tripled between 1970 and 2017, aggregate emissions of the six criteria pollutants declined by 73 percent (Environmental Protection Agency 2018a). On the other hand, the original supporters of the 1970 Clean Air Act might well be surprised by some of the twists and turns of clean air regulation since then. For example, 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. In addition, we suspect 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.

But those involved in the strongly bipartisan passage of the 1970 Clean Air Act would surely be disappointed that environmental policy has become a partisan battleground. It has seemingly become impossible to amend the Clean Air Act or to pass other legislation to address climate change in a serious and economically efficient manner. Regulation under the Clean Air Act has not ceased, but addressing new problems such as climate change has become exceedingly difficult, partly because the existing legislation provides no simple vehicle for doing so. The climate effects of CO_2 emissions are predicted to last for many centuries (Stocker et al. 2013). If US inaction slows global reductions of greenhouse gas emissions, the environmental damage is likely to be both profound and long lasting.

A great deal has been learned over the 50 years since the Clean Air Act was signed into law in 1970. The 1977 and 1990 amendments reflect some of that learning, including the practical difficulty of regulating a myriad of air toxics. Much has also been learned about the design and implementation of emissions trading systems (Schmalensee and Stavins 2017). Most importantly, we now know from experience that cap-and-trade systems can be environmentally effective and economically cost effective. Provisions for the banking of permits have proven to be

very important for achieving maximum gains from trade, and the absence of such provisions has led to price spikes and market collapses.

Another implication of these five decades of experience may be that policies to address climate change and other new environmental problems should be designed to make them more acceptable in the real world of politics. This could mean, for example, giving greater attention to suboptimal, second-best designs of carbon-pricing regimes (Stavins 2019). Examples might include earmarking revenues from taxes or allowance auctions to finance additional climate mitigation, rather than optimizing the system via cuts in distortionary taxes, and/or using such revenues for fairness purposes, such as with lump-sum rebates or rebates targeted to low-income and other particularly burdened constituencies (Goulder and Hafstead 2017; Stavins 2019). Economists might also be more effective by sometimes working to catch up with the political world by examining better design of second-best nonpricing climate policy instruments, such as clean energy standards, subsidies for green technologies, and other approaches. At some point the politics may change, of course, which is why ongoing economic research on climate policy instruments of all kinds is important.

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