Markets for Clean Air
The U.S. Acid Rain Program

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Contents

Illustrations

Tables

1 A Market-Based Experiment

A STAR IS BORN (?)

More than thirty years ago, Dales (1968) demonstrated that, in theory, an emissions-trading system, in which rights to emit pollution are available in fixed and limited aggregate amount and are freely tradable, would induce rational firms to reduce pollution at the least possible cost. This basic theoretical argument has been refined and elaborated many times since.[1] Over this same period, the alternative command-and-control approach to environmental policy, in which the design or performance of individual pollution sources is specified, has been applied to a wide variety of problems and has generally performed poorly, with excessive costs and, often, failure to achieve environmental objectives. Nonetheless, until quite recently, emissions trading and related approaches (such as emission taxes) attracted little but hostility from noneconomists and were rarely employed in practice.[2]

Then, with relatively little fanfare, Title IV of the 1990 Clean Air Act Amendments (1990 CAAA, Public Law 101–549), the U.S. Acid Rain Program, passed by the U.S. Congress and signed by President George Bush in 1990, established the first large-scale, long-term U.S. environmental program to rely on tradable emission permits (called

1. Notable works in this tradition include Montgomery (1972), Tietenberg (1985), and Baumol and Oates (1988).
2. For discussions of other environmental programs employing various forms of emissions trading, see Tietenberg (1985), Hahn and Hester (1989), and National Economic Research Associates, Inc. (1994, Chapt. 2). Noll (1989, p. 1275) discusses some of the political reasons such programs are rare; see also Stavins (1998).

"allowances" in the legislation) to control emissions. Its target was electric utility emissions of sulfur dioxide (SO_2), the major precursor of acid rain.

Since 1990, policymakers' interest in emissions trading has grown rapidly. This growth accelerated in 1995, when Title IV came into effect. Most observers quickly judged the program to be a great success, largely because the price of emission rights (allowances) was well below expectations.[3] Subsequently, the United States has moved toward implementation of a regional trading program for rights to emit oxides of nitrogen (generally called NO_x, which are important contributors to ozone pollution), and the international community has endorsed, at least in principle, the use of international emissions trading to deal with the threat of global climate change.[4] There seems to be a conference on emissions trading somewhere in the world every day, each accompanied by a raft of papers from universities, think tanks, and government agencies. In less than a decade, emissions trading has gone from being a pariah among policymakers to being a star – everybody's favorite way to deal with pollution problems. As always, when widespread public acclaim for a new approach to an important public policy issue comes so fast and is based on fragments of evidence about performance, at least some will wonder whether such acclaim is truly deserved.

This book provides a comprehensive description, analysis, and evaluation of the source of this widespread public acclaim: the SO_2 emissions-trading program created by Title IV of the 1990 Clean Air Act Amendments. This work is based on the first few years of experience with the program. Our goal is both to deepen understanding of this program in its own right and to make it possible to use experience with Title IV to inform both decisions about the use of emissions trading to control pollution and the design of emissions-trading systems more broadly. We concentrate on political economy, compliance behavior, and abatement cost; an inquiry into the benefits of reduced emissions is beyond the scope of this study.[5] We find that, on

3. Ironically, as we show in Chapter 11, the very low allowance prices in 1995 and 1996 reflected the Acid Rain Program's (perhaps inevitable) imperfections more than its virtues.
4. On these and related developments see, for instance, U.S. Council of Economic Advisers (1998, pp. 156–80).
5. NAPAP (1998) provides a discussion of the effects and benefits of the reduction of SO_2 emissions effected so far by Title IV. In general, the pertinent sections state that a

balance, Title IV has indeed performed well and has thereby proven that emissions trading has considerable potential in practice, as well as in theory. But, as we hope subsequent chapters will demonstrate, there is much more to be learned from careful analysis of this complex and important policy experiment than can be inferred from a cursory examination of allowance price levels.

We turn first to a brief description of the structure of the SO_2 allowance-trading program set up by Title IV and of how it was designed to operate. (More details are given in subsequent chapters as needed.) The final section of this chapter provides an overview of the rest of this book.

THE U.S. ACID RAIN PROGRAM

Acid rain (or, more properly, acid deposition) occurs when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react in the atmosphere to form sulfuric and nitric acids, respectively.[6] These acids then fall to earth, sometimes hundreds of miles downwind from their source, in either wet or dry form. In North America, acid rain is a concern mainly in the northeastern United States, particularly in the Adirondacks and New England, and in southeastern Canada. The motivation for regulatory policies to reduce acid rain is the argument that in this region, acid rain damages aquatic life and harms trees in sensitive forest areas. The dominant precursor of acid rain in the United States is SO_2 from coal-fired and, to a much smaller extent, oil-fired power plants. These emissions are the focus of Title IV of the 1990 Clean Air Act Amendments.[7]

statistically significant reduction in sulfur deposition was observed in 1995 by monitors located in the Northeast and the Ohio River Valley, but similarly significant changes in the acidity of waters or other indicia of ecosystem response have not been observed, because of the longer response times of these complex processes.

6. NAPAP (1991).
7. Electric utilities accounted for about 70% of 1985 U.S. SO_2 emissions: Coal-fired units accounted for 96% of this total, and oil-fired units accounted for the remainder (EPA, 1994). The other 30% of emissions is accounted for by a wide variety of industrial, commercial, and residential boilers and process sources (including smelters and paper facilities), as well as by the use of diesel fuel for transportation. Aside from certain voluntary opt-in provisions contained in Title IV, including these other sources in the allowance program was not given serious consideration. These sources are generally individually much smaller than utility sources and are much more diverse. Moreover, there were no systematic baseline emissions data available for these sources

Title IV represents a fundamental change in the regulatory framework governing air pollution in the US. Previous air pollution regulations controlled the emissions rates of individual pollution sources (measured in, for instance, pounds of pollutant per unit of fuel burned) or required that individual sources employ designated control technologies. Aggregate emissions (measured in, for instance, tons of pollutant) were not directly controlled. In contrast, the 1990 acid rain law focuses directly on aggregate SO_2 emissions rather than on emissions by individual sources, their emission rates, or the techniques they use to control emissions. It does so by placing an aggregate cap on SO_2 emissions and gives polluters extensive flexibility to choose whether and how to reduce emissions at specific sources. The introduction of emissions trading goes well beyond trading among utilities. Equally importantly, the 1990 law gives utilities with multiple fossil-fired generating units enormous and unprecedented flexibility in complying with emission limits even if they trade no allowances at all with each other.

Title IV was advertised as requiring a 10-million-tons-per-year reduction in SO_2 emissions from 1980 levels by the year 2000. To achieve this goal, the law created a cap on SO_2 emissions from electric generating plants of roughly 9 million tons per year, effective in the year 2000 and beyond. This emissions cap was to be achieved in two phases. During Phase I (1995–1999), the 263 dirtiest large generating units (located in 110 generating plants and accounting for 88 GW^e of electric generating capacity) were required to reduce their emissions by roughly 3.5 million tons per year, beginning in 1995. In Phase II (2000 and beyond), virtually all fossil-fueled electric generating plants become subject to the national cap on aggregate annual SO_2 emissions. (All states had Phase II units except Alaska and Hawaii, which were simply omitted from the program, and Idaho, which had no fossil-fueled generating units.)

The Phase I reductions and Phase II cap are enforced through the annual issuance of tradable emission allowances, each of which permits its holder to emit one ton of SO_2 in a particular year or any subsequent year.[8] Each unit has thirty days after the end of each year

to provide a basis for allocating allowances to incumbents. On this issue, see Kete (1993, pp. 217–21).

8. In fact, these allowances are like checking account deposits, in that they exist only as records in the EPA's computer-based allowance-tracking system. The system, which contains accounts for all affected generating units and for any other parties that want to hold allowances, can be used to transfer allowances from one account to another.

to deliver to the U.S. Environmental Protection Agency (EPA) valid allowances sufficient to cover its emissions during the year. At that time, the EPA cancels the allowances needed to cover emissions. Failure to produce the necessary allowances subjects a utility to substantial financial penalties and requirements to make additional future emission reductions.

Allowances good in any particular year but not needed to cover SO_2 emissions in that year may be "banked" for future use, but allowances can never be borrowed from the future. (As we shall see, this has turned out to be an absolutely critical feature of the program.) Owners of individual units are free to decide what mix of emission reductions and allowance transactions they will employ to meet each year's allowance constraint, and essentially no restrictions are placed on emission reduction techniques. There is also no restriction on who may buy or sell allowances. Brokers have acquired some in hopes of future price increases, for instance, and environmentalists have acquired some in order to reduce emissions more than the law requires.

Phase I (1995–99)

The basic allowance-allocation formula for each unit required to reduce emissions in Phase I (called "Table A units" because they are listed in Table A in the statute) multiplies an emission rate (ER) of 2.5 pounds of SO_2 per million Btus of heat input (2.5 lb/mmBtu, for short) by baseline heat input (generally the unit's 1985–87 average). As discussed in Chapter 3, however, the final bill included significant departures from this formula. The most important of these was designed to favor the use of eastern high-sulfur coal by providing bonus allowances to Phase I units ("extension units") that opted to comply with Title IV via flue-gas desulfurization. This involves installing a relatively expensive facility, generally called a "scrubber," that removes sulfur from the flue gas. The main alternative approach to emission reduction is to switch to coal with a lower sulfur content, which is historically more expensive than high-sulfur coal.

Title IV also contains provisions designed to give utilities additional flexibility in complying with Phase I emission-reduction obligations:

- The "substitution" provision permits utilities to substitute other units for Table A units. Non-Table A units that have been sub-

stituted for Table A units then receive allocations of allowances approximately equal to their historic emissions and, for all intents and purposes, are treated as Table A units.

- The "compensation" provision allows utilities to reduce generation in Table A units in a way that does not simply involve shifting electricity production and the associated SO_2 emissions from a Phase I unit to units not affected by Phase I.

Collectively, these provisions are often referred to as the "voluntary compliance program." As we discuss in Chapter 8, the substitution provision has been much more important than anyone had anticipated, while the compensation provision has been little used.[9]

Phase II (2000 and Beyond)

During Phase II, each fossil-fuel-based generating unit exceeding 25 MW^e generating capacity is allocated a specific number of SO_2 allowances per year, and additional reductions in aggregate emissions are required. The Phase II allocation rules for the years 2000–09, which we analyze in detail in Chapter 3, are specified in about thirty statutory provisions. The provisions for 2010 and subsequent years are only slightly less complex. As in Phase I, utilities can cover their emissions with the allowances they were allocated, and buy, sell, or bank allowances for future use. Any individual or firm is free to buy and sell allowances, as well.

Annual EPA Auctions

In addition to allocating allowances to each generating unit, the EPA has been required by Title IV to conduct small annual revenue-neutral allowance auctions since 1993. Auctioned allowances are acquired by the EPA's holding back approximately 2.8% of the allowances issued to each unit; each unit in turn receives a pro rata share of the auction proceeds. The auction is "revenue neutral" in the sense that the EPA takes allowances from each affected source (i.e., each generating unit that must use allowances to cover its emissions) and then pays the source for these allowances based on the market

9. Title IV also established a voluntary program applicable to industrial sources that allowed such sources to "opt in" to the program. However, like the compensation provisions, the voluntary industry-source program has also been little used.

value they fetch at auction. The auction provision was a response to concerns expressed by independent power producers and rapidly growing utilities that an active market for allowances would not emerge, concerns strengthened by assertions during debates on the 1990 Clean Air Act Amendments that utilities would hoard their initial allocations and refuse to sell at any price.[10]

Measuring Emissions

Any effective "cap and trade" system such as that embodied in Title IV requires an accurate method for measuring emissions and tracking allowances. Title IV requires utilities to install continuous emission monitoring (CEM) equipment, and EPA regulations contain powerful financial incentives to ensure that these monitors are operationally accurate. In addition, the EPA created a comprehensive computer database that allows owners of affected units, as well as the EPA and third parties, to track the number of allowances in each unit's "account" at a particular point in time. The system also allows each unit's authorized representative to record transfers of allowances between generating units under common ownership as well as between generating units with different owners. While the terms and conditions of allowance market transactions are not reported to the EPA, any allowances that are bought and sold must eventually appear in the EPA's allowance-tracking system if they are to be used for compliance purposes.

OVERVIEW OF THE BOOK

Like it or not, environmental policies are outputs of political processes. Understanding the political process that drove the design and enactment of Title IV can inform thinking about future uses of emissions trading. Chapter 2 describes the evolution of acid rain control policy in the United States over the last three decades, and the long political process that culminated in the passage of Title IV

10. For several years, some allowances were also held back each year for sale at a fixed price (which turned out to be well above market prices); any excess supply was auctioned the following year. Hausker (1992) discusses the political economy of these institutions; see also Joskow, Schmalensee, and Bailey (1998) and Chapter 7 of this book.

in 1990. Since allowances to emit SO_2 are valuable, it should be no surprise that interest groups affected by the program desired to gain title to as many allowances as possible. Moreover, the economic impact on key actors – utilities, coal-mine owners, coal miners, and electricity consumers – of a program designed to reduce SO_2 emissions significantly varied widely from one region of the country to another. There was similar variation in the political influence of the groups affected in each region and of their legislative representatives. In Chapter 3, we examine Congress's ultimate allocation of SO_2 allowances among electric generating units located in different regions of the United States from a political economy perspective, focusing on the role of key interest groups and their supporters in Congress.

With this background, we then turn to a multidimensional analysis of the effects of Title IV on SO_2 emissions, of compliance strategies adopted by the owners of affected generating units, of the behavior and performance of allowance markets, and of the costs incurred by emission sources to comply with the program's requirements. Chapter 4 examines the historical patterns of SO_2 emissions before Title IV took effect in 1995. This is important because SO_2 emissions were declining even before Title IV became effective, due to changes in coal and transportation markets, as well as earlier emission-control regulations aimed at other adverse environmental effects of SO_2 emissions. Chapter 5 presents "counterfactual" estimates of what SO_2 emissions would have been, had there been no Title IV restrictions on them. The level of "counterfactual" emissions then becomes a baseline from which the reduction in emissions attributable to Title IV in the years 1995–97 can be determined. This chapter also discusses abatement techniques used to accomplish that reduction and the way the emission reduction was distributed geographically and among units. In particular, we provide an analysis of why "hot spots" have not appeared. In Chapter 6, we present an analysis of the extent to which operators of Phase I units have made use of the flexibility provided by Title IV to reassign and trade emission rights among units and over time.

Chapter 7 turns to a detailed analysis and evaluation of the development and performance of markets for SO_2 allowances. This analysis examines both the annual EPA auctions as well as the much larger

and more complex private markets for allowances and allowance derivatives that have developed in the last few years and the influence of state regulatory commissions. Chapter 8 analyzes why the voluntary compliance program was so heavily utilized and contributed so little to the overall reduction of emissions. In particular, we elucidate an important potential "adverse selection" problem that must be considered in the design of voluntary features of any future emissions-trading program. This problem may be especially important in the design of international CO_2 emissions-trading programs, since in the absence of a world government, all participation is necessarily voluntary. In Chapter 9, we develop estimates of the costs incurred by utilities to comply with Phase I of the program. Some have argued that the low allowance prices observed early in Phase I indicate that the allowance-trading system made large SO_2 emission reductions possible at a small fraction of the anticipated cost. Our estimate of the actual costs of complying with Phase I of Title IV is developed and compared to earlier predictions of the cost to comply with Title IV.

This book concludes with three chapters that identify and discuss a number of questions raised by the experience with the SO_2 trading program. As just noted, Chapter 9 provides an estimate of the cost of complying with Phase I. Of equal interest is the question of how this estimated compliance cost compares with the costs that would have been incurred if a reasonable "command-and-control" system had been employed instead of a cap-and-trade system. That is, how much was saved by turning to a cap-and-trade system instead of an alternative command-and-control system? Chapter 10 provides an estimate of the cost savings achieved by Title IV's emissions-trading provisions when compared to a plausible *alternative* form of SO_2 emission regulation that would achieve the same aggregate reduction in emissions but would not allow for trading of emission rights. Having focused on the benefits resulting from the flexible trading features of Title IV, we turn in Chapter 11 to a discussion of imperfections in certain aspects of emissions trading. We also address the inevitable "errors" (i.e., decisions that 20/20 hindsight reveals to have been suboptimal) made in a world of uncertainty. This discussion necessarily involves an interpretation of the behavior of allowance prices, which have been anything but smoothly rising, as textbook

presentations (which generally assume away uncertainty) would suggest. Chapter 12 offers concluding observations and presents some thoughts on the implications of the experience with the SO_2 trading program for the application of similar market-based emission-control approaches to other pollutants, such as air emissions that are thought to contribute to global warming.