MEMORANDUM | 24 July 2006

TO Jim DeMocker, EPA OAR/OPAR

FROM Jim Neumann, IEc

SUBJECT Alternative Methodology for Estimating Emissions for the Year 2001 Without-CAAA Scenario for the Electric Generating Unit Sector

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INTRODUCTION The purpose of this memorandum is to provide a brief outline of an alternative method for generating an emissions inventory for one component of the Section 812 Second Prospective: the year 2001 without-CAAA scenario for the electric generating unit (EGU) sector. In reviewing the draft emissions projections for the EGU sector, questions were raised within the 812 Project Team regarding the validity and reliability of the year 2001 IPM validation run being proposed for adoption as the 812 study's target year 2000 results. The results of that run are provided in Chapter 3 of the document, *Emission Projections for the Clean Air Act Second Section 812 Prospective Analysis Draft Report*, June 21, 2006. Appendices B and C of that document provide further detail comparing the results of the with-CAAA scenario for the year 2001 with actual historical emissions rates, fuel prices, and allowance prices.[1] Differences between the spatial distribution of emissions as modeled by IPM compared to the actual spatial distribution from continuous emissions monitor (CEM) data, and differences in modeled versus actual fuel and allowance prices for the historical, with-CAAA case, have led us to consider the possibility of an alternative approach for modeling the effect of the CAAA on the EGU sector in the year 2000 or 2001.

One of the key questions in determining whether an alternative approach is feasible is whether we can construct a defensible counterfactual without-CAAA scenario for the historical year 2001, for comparison to the historical CEM data. This memo focuses on a method for developing an EGU sector sulfur oxide emissions counterfactual that closely follows an approach developed by Dr. A. Denny Ellerman. The method is described in some detail in a series of published papers and working papers.[2]

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[1] See, in particular, Exhibits B-1 through B-3 in Appendix B for emissions comparisons and Exhibit C-4 in Appendix C for fuel and allowance price comparisons.

[2] The working papers are: "The Sources of Emission Reductions: Evidence from U.S. SO2 Emissions from 1985 through 2002," (Ellerman and Dubroeucq, 2004), "Ex Post Evaluation of Tradable Permits: The U.S. Cap-and-Trade Program," (Ellerman, 2003a), and "Lessons from Phase II Compliance with the U.S. Acid Rain Program" (Ellerman, 2003b); all of which are available at http://web.mit.edu/ceepr/www/workingpapers.htm. The basic methodology for development of a counterfactual case, however, was first published in A. Denny Ellerman, Paul L. Joskow, Richard Schmalensee, Juan-Pablo Montero, and Elizabeth M. Bailey, Markets for Clean Air: The U.S. Acid Rain Program, Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology (Cambridge, MA: 2000).

The remainder of this memorandum consists of three sections. First, we provide some general background on the sulfur oxide provisions of Title IV of the Clean Air Act. Amendments Second, we describe the basic elements of constructing a counterfactual for sulfur oxide emissions as outlined in Ellerman et al. (2000) and Ellerman (2003a). Third, we provide a short summary of the steps that would be necessary to develop a unit-level counterfactual emissions inventory consistent with Ellerman's approach, for both sulfur oxide and nitrogen oxides.

SECTION 1 BACKGROUND ON SULFUR OXIDE COMPONENTS OF TITLE IV OF THE CAAA

Title IV of the CAAA imposed certain limitations on the overall amount of sulfur dioxide (SO_2) emissions from fossil fuel fired electric generating units. The restrictions were imposed in two phases. Phase I lasted from 1995 through 1999 and applied to generating units of capacity over 100 MWe and base period (an average of 1985 to 1987) emissions in excess of 2.5 pounds SO_2 per million BTU (#SO_2/mmbtu) of heat input. Phase I units were required to reduce emissions from approximately 10.0 million tons of SO_2 in the 1985 to 1987 period to approximately 6.9 million tons in 1999. This level is equivalent to 2.5 #SO_2/mmbtu of heat input for Phase I facilities.

Phase II began in 2000 and continues indefinitely. In Phase II, virtually all fossil fuel fired generating stations are included in the limits, which are set based on 1.2 # SO_2/mmbtu of heat input to all units in the base period. By 2010, electric generators must reduce SO2 emissions to 8.9 million tons per year, compared to 1985-1987 emissions of some 16 million tons.

To implement these restrictions, the U.S. EPA issues allowances to generating units to emit SO_2. Allowances are generally issued each year to those generating units that were in existence during the base period, in proportion to each unit’s baseline heat input. In addition, the EPA sells a certain number of allowances in a public auction on an annual basis. The allowances may be bought and sold between generating units (and other parties), and may be “banked” for future use.

SECTION 2 KEY ELEMENTS OF A COUNTERFACTUAL CASE

In the absence of Title IV, it is plausible to assume that SO_2 emissions rates would have been more like those seen just prior to adoption of the CAAA in 1990. This premise is the basis for the "simple counterfactual" scenario developed in Ellerman et al. (2000) (see Chapter 5, pages 110-113). The simple counterfactual relies on unit-level heat input data and unit level SO_2 emission rates from 1993; the counterfactual sulfur oxide emission estimates are the product, at each unit, of the heat input (in mmBTU) and the emissions rate at that unit in 1993 (in pounds SO_2/mmBTU).

Ellerman notes that three key assumptions are made in construction of this simple counterfactual. First, that none of the emissions reduction observed by 1993 was attributable to Title IV. Second, that unit emission rates would not have changed between 1993 and our target year in the absence of Title IV. Third, that heat input would not be influenced at the unit-level by Title IV.[3] Ellerman acknowledges the potential for error in

[3] Ellerman et al. (2000) describes a few obvious exceptions to this basic approach, including opt-in units and retirements, but concludes that the effect of the first can be modeled by the allocation of allowances to these units in the factual case, and the effect of the second is very small.

this estimate, and then develops a much more rigorous econometrically estimated counterfactual scenario to test the potential for error. In subsequent work, however, Ellerman concludes that the likely effect of Title IV on unit-level heat input is probably small, while acknowledging that the potential for errors in emissions rates may be significant.[4] We review each of these two important factors below.

ELECTRICITY DEMAND, PLANT DISPATCH, AND UNIT-LEVEL HEAT INPUT

Imposing limits on SO_2 emissions necessarily impacts the cost of generating electricity. For traditional rate-of-return regulated electric utility generating stations, that cost increase is generally passed on to ratepayers through regulated rates. For generating stations that are in competitive generation markets, however, the cost of the programs may be reflected in rates paid, leading to the potential for effects on electricity demand. Ellerman concludes that this effect is nonetheless likely to be small:

> "This counterfactual assumption has the effect of making the estimated emission reduction equal to the heat-input-weighted changes in observed emission rates at affected units and to assume that no emission reduction can be attributed to changes in demand, either at individual units or in the aggregate. Since the demand for electricity is price inelastic, the cost of SO_2 controls is relatively small on a kilowatt-hour basis, and the major element determining the dispatch, or utilization, of individual generating plants is the cost of fuel, the error arising from assuming no effect on demand is probably small. Nevertheless, to the extent that the added costs from the program reduce the demand for electricity or change the order of dispatch of generating units in meeting that demand, the effect of the program is under-estimated." (Ellerman 2003a, pg 6-7)

By way of background, overall U.S. electricity demand has continued to grow since the base period used for allocating allowances (1985 to 1987), although at a somewhat slower pace than the overall economy, indicating that the electricity intensity of the economy is declining modestly. From 1985 to 2004, domestic electricity consumption has increased by an average of 2.5 percent per year compared to GDP growth of 3.0 percent. Combined with the assumption of a constant emissions rate, then, an increasing trend in electricity demand yields a slightly upward sloping trajectory for aggregate counterfactual emissions.

SULFUR EMISSIONS RATE

Counterfactual sulfur emissions rate is determined by the sulfur content of the fuel used in the scenario and the emissions control technologies assumed (e.g, scrubbers). Fossil fuel-fired generating stations are affected by a variety of environmental restrictions that affect both of these parameters. For the purpose of developing the simple counterfactual, however, it appears reasonable to assume that the SO_2 emissions rate per unit of fossil fuel consumed would have remained constant from the base period levels in the counter-factual scenario. As noted above, the approach used by Dr. Ellerman was to adopt 1993 emissions rates; yet as Ellerman notes:

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[4] See "Ex Post Evaluation of Tradable Permits: The U.S. Cap-and-Trade Program," Working Paper, A Denny Ellerman, 2003a, provided as an attachment to this memo.

> "A more likely source of error arises from the assumption about the counterfactual emission rate. To the extent that other environmental regulations, or changes in relative fuel prices, cause the emission rate at affected units to fall during the period of evaluation, the effect of the SO_2 program is over-estimated. Increases in the true counterfactual emission rates would have the opposite effect, but the scope for these is limited since all units face emission rate limits under the pre-existing command and control regulation and those limits are rarely, if ever, increased." (Ellerman 2003a, pg 7)

As noted above, the assumption of a 1993 emissions rate as the baseline rate implies that none of the emissions reduction observed by 1993 was attributable to Title IV. Because Title IV was passed in 1990, and with the knowledge that many EGUs complied early with the requirements of Title IV, this may seem like a poorly justified assumption. One of the major events that is important to keep in mind, however, is the rapid change in coal economics during the 1990 to 1993 period owing to the ready availability, at low costs, of low-sulfer Powder River Basin (PRB) coal. This change, coupled with the deregulation of railroad transport that greatly reduced the transport cost of these coals, meant that many utilities were able to switch to these low sulfur coals at no cost or even at a savings relative to the costs they faced for higher sulfur coal prior to this period. Ellerman et al. (2000) conducts an econometric analysis to support this assumption and concludes that "the effect of changing coal economics is clearly more important in the aggregate than are factors related to early compliance with Title IV." (see especially pages 99 to 105 in Ellerman et al. 2000). Predicting EGU activity in the absence of Title IV is never conclusive, but it is not unreasonable to assume that much of the compliance activity that occurred prior to 1993, at least that involving fuel switching rather than scrubber installation, would have occurred regardless of Title IV.

SECTION 3 NEXT STEPS IN DEVELOPING A COUNTERFACTUAL WITHOUT-CAAA SCENARIO FOR EGUS FOR THE YEAR 2001

The preceding discussion suggests that Title IV may have had only a relatively small impact on the construction and operation of coal-fired power plants during the relevant period. Nevertheless, because electricity generation from coal has increased even with Title IV, it is reasonable to assume that SO_2 emissions would also have increased, but for the adoption of Title IV, associated with this increase in coal generation. We therefore propose to construct a counterfactual sulfur emissions scenario using a constant emissions rate assumption, reflecting an assumption that Title IV had relatively little effect on fuel choice but an important effect on emissions rates from existing units.

Consistent with the analysis prepared by Dr. Ellerman, if this alternative method for characterizing emissions in 2001 is chosen we will set the baseline emissions rate for Phase I units at the actual 1993 levels, and for Phase II units at the actual 1998 levels. We will also examine any significant changes in emissions rate prior to those dates, to evaluate whether any major change resulted from Title IV. As noted above, this scenario implies that, but for Title IV, overall SO_2 emissions would have grown modestly because overall heat input and electric output at existing coal-fired generating plants increased over this period. Developing the unit level counterfactual estimates will be relatively straightforward, as IEc has already developed a database of electric generating units that includes actual SO_2 emissions and fuel heat inputs from 1985 to the present to support the analyses summarized in Appendices B and C of the draft emissions report. This database also allows us to employ hybrid approaches, such as using 1993 emissions rates for all facilities except those Phase I facilities that installed scrubbers in the 1990 to 1993 period, or Phase II facilities that installed scrubbers between 1990 and 1998. Unlike the fuel switching decision, which is greatly affected by the availability of inexpensive low sulfur PRB coal, the decision to install a scrubber could reasonably be attributed to Title IV and therefore represents an exception to the broad use of 1993 or 1998 emissions rates; for those facilities, we propose to use the 1990 rates as the baseline emissions rate.

The unit-level results for the counterfactual scenario will then be compared to the unit-level CEM data; the latter would constitute the with-CAAA scenario. These unit-level data would then be used as the EGU emissions inputs for the subsequent air quality modeling step in the overall analysis.

We have identified one potentially important concern in applying the simple Ellerman approach. Most of Ellerman's work has focused on overall cost estimates for Title IV. As a result, emissions outcomes may have been of secondary importance. In the Second Prospective analysis, however, emissions outcomes are the basis not only for cost estimates, but also for benefits estimates. As a result, the spatial distribution of differences between the with-CAAA and without-CAAA results are more important than they might be for an analysis focused only on cost estimates. Some of Ellerman's work applying the simple counterfactual does, however, evaluate whether emissions trading outcomes were optimal - the trading analysis might demand unit-level resolution of emissions outcomes. We propose to discuss with Dr. Ellerman whether adoption of the simple counterfactual might present any known biases in the spatial distribution of emissions outcomes. In particular, we hope to discuss with Dr. Ellerman whether and how adjustments to the simple counterfactual results might be applied to incorporate some of the unit-level shifts in dispatch that he estimates in his econometrically estimated counterfactual.

Once the emissions results for sulfur oxides are complete, remaining work would include the following tasks:

1. *Development of cost estimates for the SO_2 reductions.* We believe this task could be relatively straightforward. Costs could be generated either directly from the published Ellerman estimates, perhaps through direct collaboration with Dr. Ellerman, or by an offline application of IPM cost functions.

2. *Development of counterfactual estimates for NO_x emissions from EGUs.* The Ellerman work does not address nitrogen oxide emissions. We have not yet had the opportunity to develop a detailed approach, but a screening level estimate might involve a direct analog of the simple counterfactual approach outlined above, using 1993 emissions rates and historical heat input data at the unit level.

3. *Development of cost estimates for NO_x reductions.* Cost estimates for nitrogen oxide reductions might be based on cost functions available in the AirControlNET database for EGU NO_x controls, or could developed by an offline application of IPM cost functions.

Ex Post Evaluation of Tradable Permits:

The U. S. SO_2 Cap-and-Trade Program[1]

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Introduction

A Brief Description of the Program

The U.S. SO_2 cap-and-trade program was established as a result of the enactment of the 1990 Clean Air Act Amendments (1990 CAAA) under the authority granted by Title IV, which included several measures to reduce precursor emissions of acid deposition.[2] The SO_2 component consisted of a two-phase, cap-and-trade program for reducing SO_2 emissions from fossil-fuel burning power plants located in the continental forty-eight states of the United States. During Phase I, lasting from 1995 through 1999, electric generating units larger than 100 MW^e in generating capacity with an annual average emission rate in 1985 greater than 2.5 pounds of SO_2 per million Btu of heat input in 1985 (hereafter, #SO_2/mmBtu) were required to reduce emissions to a level that would be, on average, no greater than 2.5 #SO_2/mmBtu. In Phase II, beginning in 2000 and continuing indefinitely, the program was expanded to include fossil-fuel electricity generating units greater than 25 MW^e, or virtually all fossil-fuel power plants in the United States. Emissions from these affected units are limited, after accounting for any allowances banked from Phase I, to an annual cap of 8.9 million tons, or about half of total electric utility SO_2 emissions in the early 1980s. The Phase II cap is equivalent to an

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[1] This paper was prepared as a case study report under the program for the "Ex Post Evaluation of Tradable Permits: Methodological and Policy Issues" being conducted by the National Policies Division of the Environmental Directorate of the OECD.

[2] The most important of the other measures reduced NO_x emissions by two million tons by imposing technology-based, maximum average annual NO_x emission rates on affected sources. In meeting these standards, utilities were allowed to average emission rates among the units they controlled, but not to trade NO_x emissions among utilities.

average emission rate of 1.2 #SO_2/mmBtu, when divided by the mid-1980s level of heat input at fossil-fuel burning power plants.

This cap on national SO_2 emissions was implemented by issuing tradable allowances—representing the right to emit one ton of SO_2 emissions—equal in total to annual allowed emissions from affected units in each year after 1995, and by requiring that the owners of these units surrender an allowance for every ton of SO_2 emitted. Allowances not used in the year for which they are allocated can be carried over or banked for future use by the original owner or by any party to whom the banked allowance is sold. Allowances are allocated to owners of affected units free of charge for the next thirty years, generally in proportion to each unit's average annual heat input during the three-year baseline period, 1985-87. A small percentage (2.8 percent) of the allowances allocated to affected units are withheld for sale through an annual auction conducted by the EPA to encourage trading and to ensure the availability of allowances for new generating units. The revenues from this auction are returned on a *pro rata* basis to the owners from whose allocations the allowances were withheld.

The SO_2 cap-and-trade program also contained several provisions that allowed generating units not subject to the cap until Phase II to opt-in to Phase I and to receive allowances for the year in which the unit participated. These units were then subject to the same compliance requirements as the 263 units that were mandated to be part of Phase I, namely, that they must surrender allowances equal to emissions in that year. Also, SO_2-emitting industrial sources not otherwise affected by Title IV could establish baselines and be allocated allowances and participate like any other unit in Phases I and II.

The Political and Regulatory Context of Title IV

Three features of the political and regulatory context are important in evaluating the SO_2 cap-and-trade program. The first is that the cap-and-trade system is not the only means, nor the first means, of controlling SO_2 emissions from electric utility power plants in the United States. The cap-and-trade system supplements an extensive set of command-and-control regulations that has been in effect since the early 1970s. These regulations take two principal forms according to whether power plants were in existence when the regulations implementing the 1970 Clean Air Act Amendments became effective. Plants already in existence or under construction in 1971 must meet emission rate limits imposed by State Implementation Plans (SIPs), which the individual states are required to develop in order to bring all areas of the country into compliance with National Ambient Air Quality Standards (NAAQS) for six "criteria" pollutants (including SO_2). New units constructed after the effective date of the 1970 Amendments are required to meet the New Source Performance Standard (NSPS), which is a technology-based, uniform national requirement that, in the case of SO_2, effectively requires new coal-fired generating plants to install flue gas desulfurization equipment (or a scrubber).[3] New sources have additional requirements if they are to be located in areas not in attainment with the NAAQS (non-attainment areas). Sources locating in areas that are in attainment may also face prevention of significant deterioration (PSD) requirements, which are intended to ensure that areas in attainment do not slip into non-attainment status. Finally, any source located near a national park or other pristine (Class I) area may be required to meet additional limits, such as those aimed at preserving visibility. Typically, all of these pre-existing regulatory requirements impose either emission rate limits or technology mandates on individual units. This complex and comprehensive, underlying command-and-control structure means that Title IV is not burdened with meeting all environmental objectives. Other regulatory mechanisms are available to ensure that adverse local health effects are avoided and that other environmental values, such as visibility, are preserved. Another consequence of this regulatory context is that the ability of individual power plants to participate in emissions trading can be, and often is, limited by these other requirements.

The second notable feature of the political and regulatory context is that the motives lying behind enactment of Title IV are mixed, as is the case for most legislation. The ostensible purpose and most commonly cited motive is to reduce the effects of acid deposition, a cumulative environmental problem, the effects of which are experienced

[3] The scrubber mandate for new units was added by the 1977 Amendments to the Clean Air Act. The original NSPS provisions of the 1970 Clean Air Act required only that emissions from new coal-fired power plants be limited to 1.2 #SO_2/mmBtu. This standard was achievable either by installing a scrubber or switching to a limited sub-set of coals (thereafter known as compliance coals) that emitted less than 1.2 #SO_2/mmBtu without scrubbing. Ackerman and Hassler (1981) provide the now classic account of the interest group politics and other considerations leading to the redefinition of the NSPS.

mainly in the Northeast in large part as a result of SO_2 emissions originating from the heavy concentration of coal-fired power plants in the Mid-West. Yet, SO_2 emissions from power plants located in other parts of the country, such as Florida, that have little effect on the Northeast or other areas suffering from acidic deposition are included in the Acid Rain Program; and emissions from these sources are considered, for the purposes of emissions trading, as completely equivalent to emissions from power plants located in areas that are far more likely, given the prevailing patterns of atmospheric transportation, to have an affect on sensitive receptor areas. Two other motives operated at the time of enactment. The first concerned fine particulates, which research on health effects was beginning to implicate as a threat to public health. Although considerable controversy surrounded the origin of fine particulates—and such questions would need to be resolved in order to revise the appropriate NAAQS—SO_2 emissions from coal-fired electric power plants were considered a likely contributor. A second, and probably more important, motive was a desire to narrow the disparity between the emission limits imposed on new sources by the NSPS and the limits imposed on existing sources by State Implementation Plans. If SO_2 emissions were to be reduced for any of these reasons, something more than the existing regulatory structure would be needed since nearly all areas of the United States were in compliance with the SO_2 NAAQS by the 1980s. Moreover, the use of tall stacks to loft SO_2 emissions high above ground to avoid violating the ambient standard exacerbated the acidic deposition in more distant down-wind regions. A fifty percent reduction in the aggregate level of SO_2 emissions came to be viewed as a measure that would at once significantly reduce the amount of SO_2-originated deposition in the Northeast, contribute to some reduction of fine particulates, and largely close the disparity between the emission requirements imposed on new and existing sources. It is telling with respect to this last motive that the emission rate standard used to decide the cap and to allocate allowances in Phase II is identical to the original New Source Performance Standard enacted in the 1970 Amendments to the Clean Air Act.

The third and final feature of the political and regulatory context surrounding enactment of the SO_2 cap-and-trade program is that it ended a decade of debate concerning additional controls on existing coal-fired power plants. Earlier proposals would have achieved a similar 50% reduction of total SO_2 emissions by mandating scrubbers on the largest power plants and mandating switching to lower sulfur coal with limited trading. These earlier proposals were viewed as very costly, they faced the adamant opposition of the Reagan Administration, and they failed to gain a legislative majority in several sessions of Congress. The willingness of the new Bush (père) Administration to back significant SO_2 emission reductions, so long as they were achieved by market-based mechanisms, and of some environmental lobbying groups, notably the Environmental Defense Fund, to experiment with new and potentially more effective means for achieving environmental goals broke the stalemate and allowed a legislative majority to coalesce around a proposal that would reduce aggregate SO_2 emissions significantly and achieve the disparate goals that motivated various actors in the political process.

Institutional Location and Methodology

Unless otherwise noted, this paper is based on the continuing ex post evaluation of the U.S. SO_2 cap-and-trade program that faculty and students associated with the Center for Energy and Environmental Policy Research (CEEPR) at the Massachusetts Institute of Technology (MIT) have conducted since 1995. This effort was initially funded by the National Acid Precipitation Assessment Program (NAPAP) to support the 1996 Quadrennial Report to the U.S. Congress and the research has received continued funding through grants from the U. S. Environmental Protection Agency and from the underlying financial support provided to CEEPR by a number of corporate sponsors. This evaluation has been a major focus of CEEPR's research program, which aims to inform the public policy process by providing the results of objective, theoretically sound, and empirically rigorous research through publications and less formal presentations to interested audiences.

The results of the first years of this research are presented comprehensively in *Markets for Clean Air: The U.S. Acid Rain Program* (Ellerman et al., 2000), which is cited by Smith (2001) as an example for conducting ex post evaluations. This paper updates *Markets for Clean Air*, and it incorporates more of the work of other researchers who have since published on various aspects of the program.

In specifying the requirements of an ex post evaluation, Smith (2001) seconded the reinforced the admonition of Frondel and Schmidt (2001) that "the essential task of any evaluation analysis is the construction of a credible counterfactual situation—a precise statement of what economic agents would have done in the absence of the policy intervention." With this in mind, the rest of this section describes the counterfactuals used in evaluating the SO_2 emissions trading program.

Two counterfactuals are involved in assessing any emissions trading program: one to assess the amount and cost of the emission reduction and the other to assess the cost savings and other effects of trading. The counterfactual for assessing the emission reduction requires assumptions about basic economic drivers, such as the demand for electricity and the relative price of fuels, and about other environmental regulations that may limit emissions. These factors can be observed and used in formulating this first counterfactual. In the case of the SO_2 program, the observed utilization of individual units provides a reasonably close estimate of the effect of the basic economic drivers in any given year. The effect of the pre-existing regulatory regime can be captured in the emission rate observed shortly before the start of the cap-and-trade program. Accordingly, the counterfactual used in this paper, as in previous work by the author and colleagues, is based on the heat input observed at affected units in each year and an unchanging pre-Title IV emission rate at those units.

This counterfactual assumption has the effect of making the estimated emission reduction equal to the heat-input-weighted changes in observed emission rates at affected units and to assume that no emission reduction can be attributed to changes in demand, either at individual units or in the aggregate. Since the demand for electricity is price inelastic, the cost of SO_2 controls is relatively small on a kilowatt-hour basis, and the major element determining the dispatch, or utilization, of individual generating plants is the cost of fuel, the error arising from assuming no effect on demand is probably small. Nevertheless, to the extent that the added costs from the program reduce the demand for electricity or change the order of dispatch of generating units in meeting that demand, the effect of the program is under-estimated.[4] A more likely source of error arises from the assumption about the counterfactual emission rate. To the extent that other environmental regulations, or changes in relative fuel prices, cause the emission rate at affected units to fall during the period of evaluation, the effect of the SO_2 program is over-estimated. Increases in the true counterfactual emission rates would have the opposite effect, but the scope for these is limited since all units face emission rate limits under the pre-existing command and control regulation and those limits are rarely, if ever, increased.

The other counterfactual, that used to assess trading, is much harder to specify. This other counterfactual requires a hypothetical, equally effective, alternative program without emissions trading. Estimates of cost savings are necessarily more subjective since they depend directly on the degree of inefficiency assumed in the imagined alternative regime. In this paper, a source-specific, quantity limit equal to the allowance allocation to specific units is used. This assumption conforms with the well-established propensity to source-specific limits (although rarely on total emissions from an individual plant), but it is relatively benign in not having a technology mandate similar to that characterizing much of the existing regulatory structure and to that contained in earlier, failed legislative proposals.

Economic efficiency

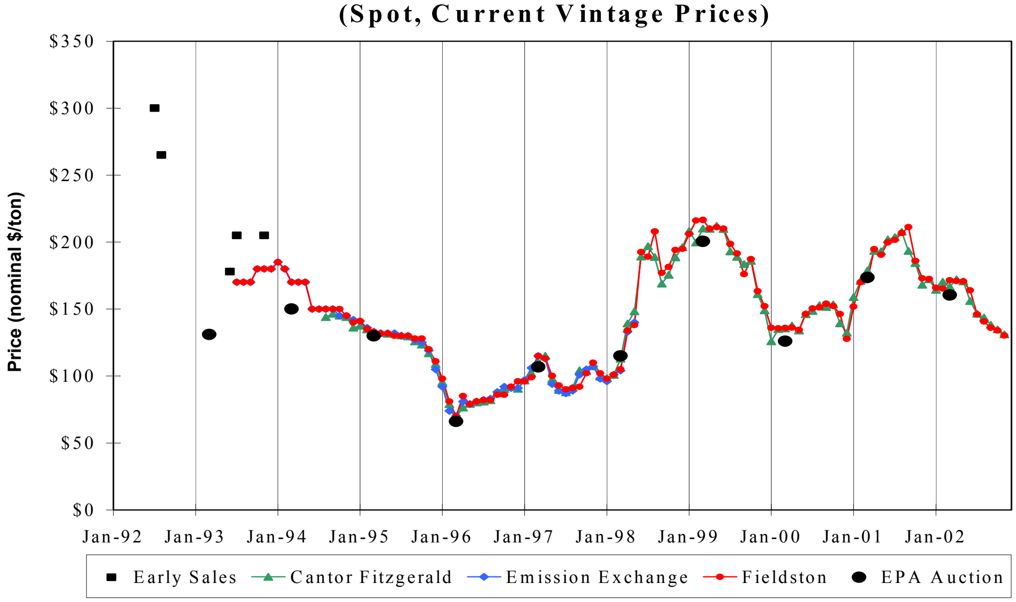
Two aspects of economic efficiency need to be distinguished in evaluating cap-and-trade programs. The first concerns trading among firms subject to the cap and the extent to which they realize the full cost savings attainable through emissions trading. The second aspect of economic efficiency concerns the broader welfare effects from the tax and regulatory interactions resulting from the treatment of abatement costs and the scarcity rents generated by the environmental constraint. From the standpoint of this second aspect, it has been argued that Title IV did not achieve full economic efficiency because first, allowances were not auctioned and the proceeds used to reduce

[4] The appendix to *Markets for Clean Air* contains an econometric estimation of the extent to which Title IV requirements changed the dispatch of generating units during Phase I. In brief, the demand placed on unscrubbed units subject to Title IV was shifted to affected, scrubbed units and to non-affected, Phase II units. Both effects are relatively small and the latter did not increase emissions perceptibly since the emission rates for unscrubbed units under the cap in Phase I were generally higher than the emissions rates for non-affected units, all of which were exempt from Phase I because of a lower emission rate.

distortionary taxes on labor and capital, and second, the average cost rules applying to units remaining under public utility cost-of-service regulation prevent the full marginal cost of abatement from being passed on to customers in the price of electricity (Goulder *et al*., 1997). A full discussion of this aspect of the economic efficiency of Title IV would involve consideration of the practical likelihood of economically efficient recycling, of equitable concerns, and how public utility regulation is applied in practice: all topics that are beyond the scope of this paper. Henceforth, all references to economic efficiency in this paper refer to the conventional use in emissions trading, that is, to the cost savings resulting from the flexibility provided by emissions trading without regard to the larger welfare issues reflecting allocative inefficiencies that may result from the existing regulatory and tax system.

The primary evidence for the economic efficiency of the SO_2 cap-and-trade system lies in the early emergence of an allowance market and the significant amount of trading that has occurred since before the program started. Figure One depicts the movement of allowance prices from the earliest observations through late 2002 as reported monthly by various brokers and in the annual EPA auction.

Figure 1: SO_2 Allowance Prices, 1992-2002
(Spot, Current Vintage Prices)

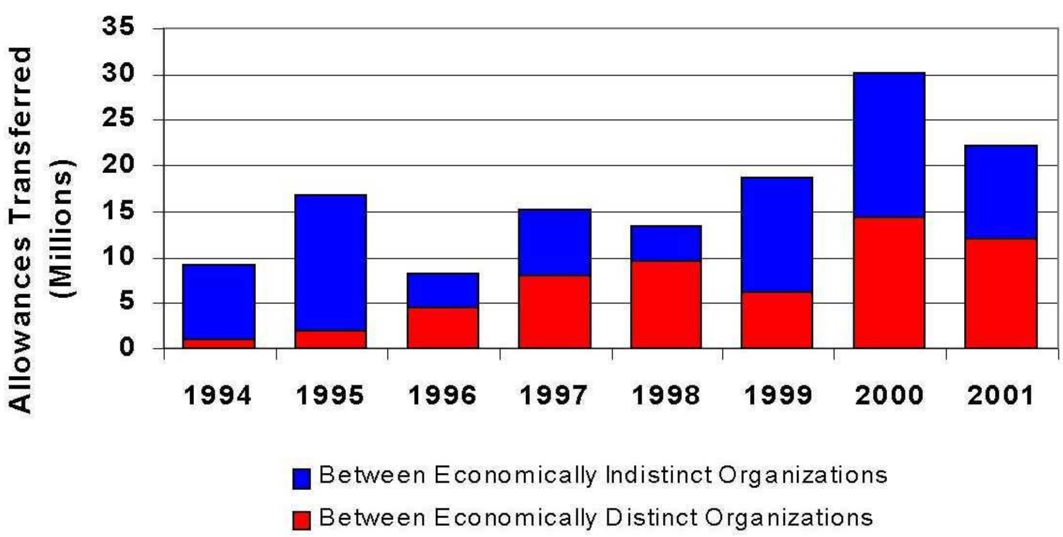


Source: Compiled by the author from monthly broker reports and the annual EPA auction reports

Prices have varied substantially over time—from an all-time low of $65 in early 1996 to highs slightly above $200 in 1999 and again in 2001—but at any one moment in time a single price prevails. The earliest reported trades took place at widely disparate prices, which were higher than the clearing price in the first EPA auction, held in March 1993. At this time, it would be hard to say that a market existed; however, by mid-1994, approximately six months before Phase I entered into effect, a market seems to have formed and the law of one price has prevailed since then.

Since allowances are readily substitutable for abatement, this single price provides a common point of reference and a coordinating mechanism for all owners of affected sources in deciding whether to abate more or less at any one time and thereby to equalize the marginal cost of abatement. Moreover, the significant and increasing volume of trading between economically distinct organizations, as illustrated in Figure Two, suggests that utilities are taking advantage of the cost-saving opportunities provided by emissions trading.

Figure 2: Annual Allowance Trading Activity



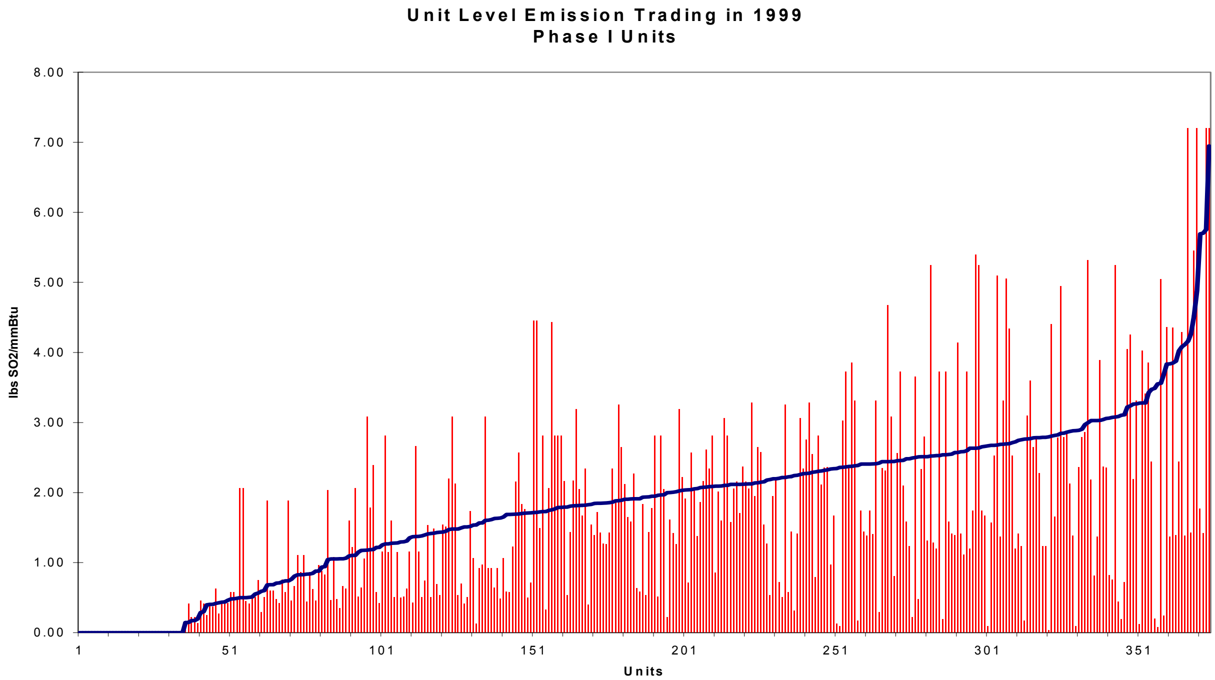
Source: US EPA

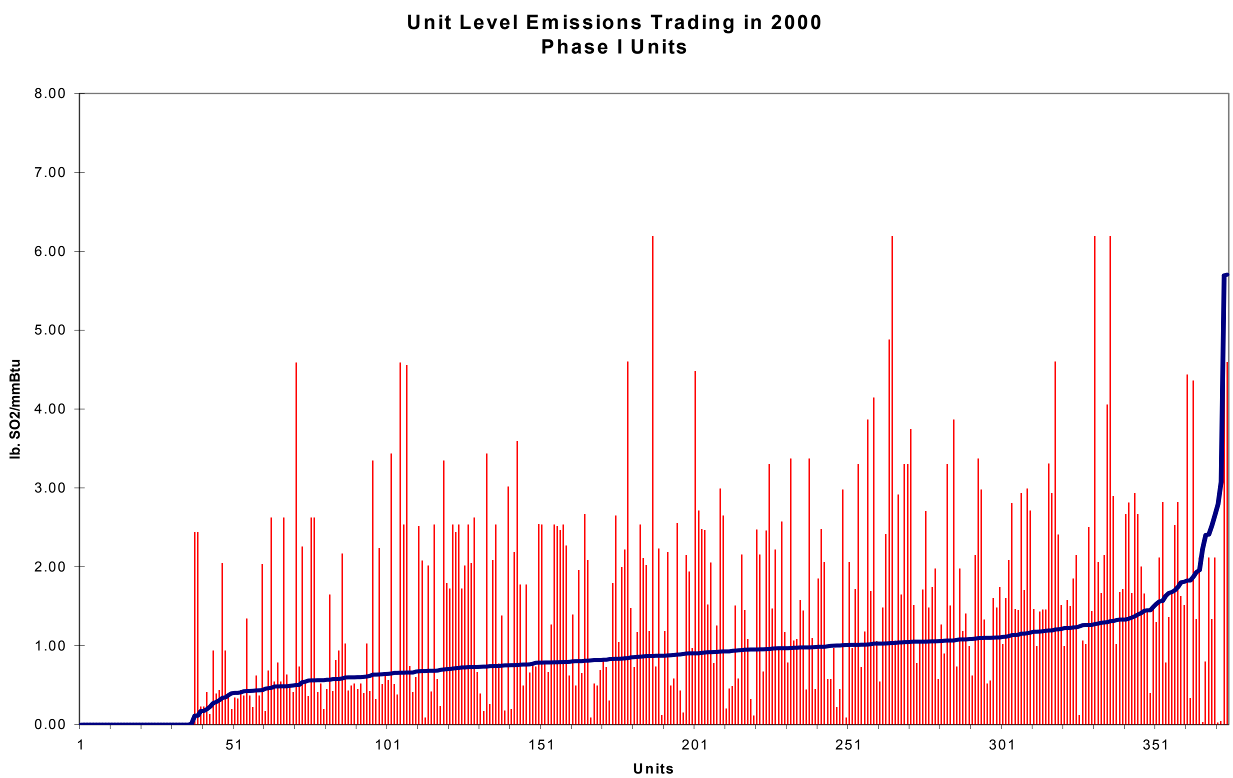
Since the equalization of marginal costs presumes a common price and trading among sources facing different costs, the preconditions for cost-effective abatement are being observed. An argument that the efficiency goals of the program are not being achieved would require an alternative hypothesis to explain the existence of a market and the observed volume of trade. In fact, no observer argues that observed trades are motivated by other than expected cost savings. As will be discussed later in this paper, the only disagreement among analysts concerning the economic efficiency of the SO_2 cap-and-trade program concerns the extent to which the full potential cost savings have been achieved.

Further evidence to support the argument for economic efficiency can be observed in the unit-level differences between allowances and emissions. The two panels of Figure Three show for Phase I affected units in 1999 and 2000 the emission rate that would be observed with no trading (the solid line) and the actual rate (the columns), given the heat input at each unit in these years. Few units are along the solid line, where they would have to be in the absence of trading, either when the allowance allocation is relative generous in 1999 or when the significantly reduced Phase II allocation went into effect. The average difference between observed emission rates and the no-trading rate is about 50% of the mean emission rate: 0.81 #SO_2/mmBtu over 1.64 #SO_2/mmBtu in 1999 and 0.86 #SO_2/mmBtu over1.48 #SO_2/mmBtu in 2000.

A further indication of economic efficiency is given by the relatively small change in average emission rates (-10%) when the allowed emission rate declined by 53%, from 1.85 #SO_2/mmBtu in 1999 to 0.87 #SO_2/mmBtu in 2000, when Phase II began. This smaller change in emission rates could occur only with banking; and in fact these 375 units went from banking 1.8 million allowances in 1999 to drawing the accumulated bank down by 1.5 million tons in 2000. This pattern of aggregate abatement over time is characteristic of an optimal banking program with certainty, in which firms take future required abatement and prices into account in formulating current abatement plans. In turn, this behavior implies that allowance prices rise at the interest rate and abatement increases gradually over the entire banking period. Such a pattern is observed in the transition from Phase I to Phase II among the units affected in both years. Moreover, despite all the stochastic variation in allowance prices since early 1994, as shown in Figure One, a definite upward trend can be observed.

Figure 3


Unit Level Emission Trading in 1999
Phase I Units
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
lbs SO2/mmBtu
1
51
101
151
201
251
301
351
Units


Unit Level Emissions Trading in 2000
Phase I Units
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
lb. SO2/mmBtu
1
51
101
151
201
251
301
351
Units

Recent research by Ellerman and Montero (2002) confirms that in the aggregate banking has been surprisingly optimal. The surprise resides in the general consensus, voiced in *Markets for Clean Air* as well as elsewhere, that too much banking had occurred in Phase I. The explanation of the surprise lies in the discount rate applicable to SO_2 allowances. The prices shown on Figure One allow a discount rate to be derived for SO_2 allowances by application of the capital asset pricing model to determine the amount of *undiversifiable* risk associated with holding SO_2 allowances. This risk is expressed by the correlation of returns from holding allowances (i.e., the monthly change in allowance prices) with returns from a well-diversified portfolio of equities over the same period of time. This correlation is zero, which makes SO_2 allowances zero-beta assets that should be discounted at the risk-free rate for comparable holding periods.

Compliance Costs and Savings from Emissions Trading

While the emergence of an SO_2 allowance market and the concomitant growth in the volume of SO_2 allowance trading suggests strongly that cost savings are being realized, these data alone provide no estimates of the magnitude of the cost savings, nor of the relation of these savings to actual or avoided, command-and-control compliance costs. In the case of the Acid Rain Program, many assertions have been made about the cost savings, but only two rigorous ex-post evaluations of compliance cost have been made [Carlson et al., 2000; Ellerman et al, 2000; hereafter, CBCP (for the initials of the authors) and MCA (for *Markets for Clean Air*)]. These two studies agree in finding the more extreme claims of cost savings unfounded, and their estimates of actual compliance costs are approximately the same, but they differ concerning the extent of the cost savings in the early years, as well as in methodology.

Ex Post Estimates of Compliance Cost

In reviewing the debates about the cost savings from Title IV, two distinctly different definitions must be kept in mind: one, loosely defined but more repeated; the other, more rigorous but less frequently cited. The former defines the cost savings as the difference of actual observed costs from predicted costs. The difference is loosely attributed to emissions trading even though other factors can and did intervene to cause actual costs to be lower. The second definition, used by the two studies cited above, relies upon a more rigorously defined no-trading alternative that incorporates identifiable cost-reducing exogenous factors. Accordingly, the following discussion will discuss first the findings of the two studies on actual compliance cost, then compare them with earlier estimates, and finally address the differences between the two studies concerning the magnitude of the cost savings.

CBCP and MCA agree roughly on the cost of compliance in the early years of the Acid Rain Program. The latter estimates the cost of compliance at $726 million in 1995 and about $750 million in 1996, while the former places the cost at $832 million in 1995 and $910 million in 1996, all stated in 1995 dollars. These estimates are not as far apart as they would seem. Complete comparability is not possible because of differences in methodology; however, both treat scrubber expense in the same manner.[5] Although they largely agree on the fixed cost of scrubbers ($375 million in MCA and $382 million in CBCP), they differ significantly on the variable costs associated with scrubbers ($89 million and $274 million, respectively).[6] CBCP uses scrubber data that reflect pre-1995 estimates of the variable cost of scrubbing, but the actual performance of the Phase I scrubbers has been much better than predicted, as will be discussed more fully in the section of this paper concerning dynamic aspects. Correction of this item alone largely removes the disparity in cost estimates between these two ex post evaluations. As an approximate figure, $750 million is probably a good estimate of the annual cost of abatement in the first years of Phase I.

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[5] MCA provides a bottom-up, plant-by-plant analysis based on reported capital costs and observed sulfur premia. CBCP conducts an econometric estimation of a translog cost function and share equations of unit-level data for 734 *non-scrubbed* units over the 1985-94 period and then takes the resulting parameter values to form marginal abatement cost functions for individual units, which are then used to estimate actual costs based on observed 1995-96 emission levels. Scrubbed units are handled separately on a cost accounting basis using identical cost of capital and depreciation assumptions as in Ellerman *et al.* (2000). It should be noted that the estimation of 1995-96 cost in CBCP is almost an aside to the main purpose of the article which is to explain the reduction in abatement cost from pre-1995 estimates and to provide updated estimates of the cost of compliance in 2010.

[6] The numbers cited from CBCP are from their break-out of the costs of 2010 compliance. This estimate will be approximately the same as the scrubber costs in 1995-96 since the fixed costs are annualized over 20 years, fuel costs are assumed not to change after 1995, the number of scrubbers remains unchanged, and costs are stated in 1995 dollars.

Comparison with Ex Ante Estimates of Cost

The important difference, however, is not the minor one between CBCP and MCA concerning actual costs in 1995-96, but the larger one between these two careful ex post estimates and ex ante estimates of the same Phase I cost, as well as of predicted costs in Phase II. Most of the disparity between ex ante and ex post estimates reflects very different assumptions about the nature of proposed acid rain controls, the demand for electricity, and the relative availability and cost of low sulfur coal. For instance, the total annual costs associated with some of the early proposals to control acid rain precursor emissions were estimated at amounts ranging from \$3.5 to \$7.5 billion. Although the details of these earlier proposals varied, they generally mandated scrubbers at a significant number of units and allowed very limited emissions trading. Once the proposal that ultimately became Title IV was proposed (in 1989) and enacted (in 1990), the ex ante cost estimates for the fully phased-in program with trading fell to a range from \$2.3 billion to \$6.0 billion, with most of this variation reflecting varying assumptions about the extent to which emissions trading would be used.[7] The now current estimates for compliance costs in 2010, as provided by CBCP and MCA, are significantly lower still, \$1.0 billion and \$1.4 billion, respectively, for what is the same program but updated to reflect more current market conditions.

CBCP provides a very helpful quantification of the causes of the change between the early estimates of Title IV and the current estimates. In examining the changes over the period of their panel regression, 1985-94, they find that the marginal cost of abatement for a representative unit reduction has been approximately halved and that 80% of the reduction in cost is attributable to falling price of low-sulfur coal relative to the price of high sulfur coal and that the remaining 20% is attributable to technological change. The change in the relative price of low sulfur coal is discussed in more detail in Ellerman and Montero (1998), who attribute the change to reduced rail rates, made

[7] MCA includes (pp. 231-235) a discussion of the few ex ante estimates of Phase I costs and compares them with the MCA estimate of actual cost. Most of the variation in these estimates, made only a few years before Phase I began, reflects differing assumptions about the extent to which utilities made full use of the flexibility afforded by emissions trading. When compared on an average cost basis to account for differences in assumptions about the quantity of abatement, the MCA estimate of actual cost in 1995 was slightly above (3-15%) ex ante estimates assuming full use of emissions trading and 20-35% below estimates that assumed relatively little use of emissions trading.

possible by rail deregulation, for transporting distant, but cheap western coal to mid-western markets where local, high-sulfur coal had predominated. They estimate that the switching of mid-western high sulfur coal units, most of whom were mandated to be subject to Title IV in Phase I, to lower sulfur western coal because the latter had become cheaper reduced the amount of abatement required to meet the Phase I cap by about 1.7 million tons, or by about half of that predicted by early estimates of required abatement.

Table 1 provides CBCP's quantification of the effects of these exogenous changes on estimates of compliance costs for a fully phased-in Title IV program.

Table 1: Total Cost of Compliance with Title IV in 2010
(billion 1995 dollars)

Cost Assumptions	Command-and-Control	Efficient Trading
1989 Prices and Technology	\$2.67	\$1.90
1995 Prices and Technology	\$2.23	\$1.51
1995 Prices and 2010 Technology	\$1.82	\$1.04

Source: Carlson et al. (2000), Table 2, p. 1313

The changes in relative fuel prices and technology between 1989 and 1995 lowered costs by about 20% and CBCP's preferred estimate for 2010, which maintains 1995 relative fuel prices but extrapolates the 1985-94 rate of technological progress to 2010, reduces predicted costs by another third. The assumption of continued technological change also explains the difference between the CBCP and MCA estimates of Phase II annual cost, since the latter does not make any allowance for this factor.

To summarize, most of the explanation for the lower than expected cost of Title IV is attributable to changes in the nature of the proposed controls, from prescribing technology to the flexibility of a cap-and-trade system, and to changes in related sectors of the economy that were reducing SO_2 emissions anyway. As can be seen by comparing cells in Table 1, the difference in total cost between a relatively benign command-and-control alternative and fully efficient trading accounts for a relatively small part of the difference from the earliest cost estimates, which remained for better or worse stuck in many observers' mind. Moreover, the impression of dramatically lower costs was reinforced by the price of SO_2 allowances, which has been the most visible manifestation of cost to most observers. No one predicted the allowance prices of $100 and even less that occurred in late 1995 and for most of 1996. Most predictions of early Phase I allowance prices ranged between $250 and $400, prices that have yet to be realized. Furthermore, many casual observers remembered only the predictions of Phase II prices, usually after the bank had been drawn down, which ranged from $500 to as much as $1000. The very low, early 1996 allowance prices may have reflected an over-reaction to the correction in early expectations of market conditions; but, with eight years of experience with SO_2 allowance trading, there seems little doubt now that changes in technology and the availability of low sulfur coal fundamentally changed the quantity and cost of abatement that would be required to comply with Title IV and shifted allowance prices commensurately lower.

The Extent of Cost Savings from Trading

The principal area of disagreement among analysts about the economic efficiency of the program concerns whether the full cost savings potential of emissions trading is being achieved. The point in dispute concerns the effect of cost-of-service regulation on the incentives of electric utilities to engage in trading with each other. The argument takes two forms: first, that conventional cost-of-service regulation provides no incentives to trade in the external market, since the gains would be passed on to rate-payers and losses might not be recoverable; and second, that public utility commissions have adopted policies that encourage sub-optimal choices by individual utilities, such as to scrub local high-sulfur coal in order to protect in-state jobs (Bohi and Burtraw, 1997; Rose, 1995; Rose, 2000). Research that simulates the effect of several of these disincentives suggests that compliance costs might be as much as doubled (Fullerton *et al*., 1997; Winebrake *et al*., 1995).

Empirical research tending to confirm this effect has been published. The most striking result was that in CBCP which found that the actual cost of compliance with Title IV in 1995 and 1996 was slightly higher than the cost of compliance under a benign command-and-control alternative (quantity caps equal to allowances at each affected unit). Moreover, their estimate of total cost with fully efficient trading was some $200-

$250 million lower. This finding indicated that the unrealized cost savings were substantial and implied that emissions trading had not resulted in any cost savings in the first two years of the program. The authors were quick to note that the volume of emissions trading was increasing and to state that they did not expect the apparent forsaking of the gains from emissions trading to last. More recently, Arimura (2002) has published research supporting the view that public utility commission regulation influenced abatement choices and contributed to low allowance prices.

The contrasting point of view is associated with researchers at MIT and is stated most completely in MCA, although also published in earlier articles and working papers (Joskow *et al*.,1998; Schmalensee *et al*.,1998; Ellerman and Montero, 1998; and Bailey, 1996). Here, the findings are that a reasonably efficient allowance market emerged as early as mid-1994; trading volumes have increased significantly, even in the early years; the effect of state PUC rulings on trading activity is insignificant; and that cost savings have been realized.

Much of the contrast between these two interpretations is a matter of tone, although substantive differences exist concerning the effect of PUC regulation on emissions trading. It is beyond the scope of this paper to explore these differences in any detail, but a reader not already familiar with this debate should keep several points in mind.

First, the argument on cost savings is as much one of whether the glass is half full or half empty. The MIT group makes no estimate of what the full cost savings might be and allows that some cost savings are undoubtedly unrealized, but they emphasize that cost savings have been realized and that no market is perfect. The MCA estimate of the cost savings in the early years of Phase I ($350 million, about half the observed cost of compliance) is derived from observed data assuming that the data reflect nearly efficient choices by abaters. In other words, this particular estimate assumes away the problem insisted on by the other school. This particular estimate was developed to discourage the then current views that the cost savings from emissions trading under Title IV were much greater. With the exception of the CBCP finding, the other camp does not dispute the existence of cost savings from Title IV. For instance, Bohi and Burtraw (1997) refer to the “puzzle” of cost savings with limited trading and Rose (2000) concludes that Title IV shows that “trading mechanisms appear to be robust enough to allow substantial savings…to occur even when faced with less than ideal conditions.” The problem with the accuracy of the scrubber costs in the CBCP finding has already been mentioned, but even setting this aside, the focus in CBCP is more on quantifying the extent of unrealized cost savings as it is insisting that their less costly CAC alternative is realistic.[8] Thus, one camp tends to emphasize the short-fall, while the other stresses the achievement. Still, a difference remains concerning magnitude. The difference is perhaps more aptly whether the glass is nearly full or only half full.

A second point to be kept in mind is that the debate about regulatory influence is at bottom one about how public utility regulation works in practice. Although not so far publicly stated, the MIT group would not dispute the theoretical effect of the alleged influences; their contention would be that the theory of regulation applied is over-simplified and not representative of the performance-based, rate-making as practiced in the 1990s. The only direct empirical test of the hypothesis of significant regulatory influence on emissions trading is Arimura (2002), which is unsatisfactory in attributing a difference found between the abatement decisions at Phase I units owned by the Tennessee Valley Authority, a publicly owned utility, and those owned by PUC-regulated utilities to test a hypothesis concerning differences between profit-maximizing firms and regulated electric utilities.

Environmental effectiveness

The arguments in favor of emissions trading programs always assume that trading will not jeopardize environmental effectiveness, and this is invariably the main concern of environmental groups and those who tend to be skeptical of emissions trading. The experience with Title IV has provided no grounds for concern about environmental effectiveness; in fact, the experience suggests that environmental performance may be better than that experienced with command-and-control analogues. This section of the

[8] Still, their CAC counterfactual is identical to the one assumed in MCA, which is found to cost about 50% more than the observed cost of compliance. Also, the methodology adopted by CBCP would attribute the same change in scrubber cost to the CAC alternative so that the finding of no cost savings would still hold.

paper addresses this point, adduces the evidence indicating greater environmental effectiveness, and provides some tentative explanations for this result.

An important first issue in evaluating environmental effectiveness is identifying the appropriate metric. The acid rain motivation of this program would suggest that an appropriate one would be the amount of wet deposition, or even the acidity of lakes and forests in sensitive regions; however, the most obvious and easily measured metric, total emissions, is the one typically used.

No doubt surrounds the issue of whether SO_2 emissions have been reduced.[9] The two panels of Figure Four show actual emissions, the caps, and an estimate of counterfactual emissions for the 375 units first subject to Title IV in 1995 and for the much larger cohort of units that have been subject to Title IV since 2000. For both the Phase I and Phase II cohorts of units, the largest annual emission reduction is made in the first year, when the affected units first incur a cost for every ton of emissions. Given the phased-in nature of the requirement facing the Phase I units and the ability to bank, the annual reduction by these units was much greater than required. The annual reduction of emissions in 1995 was 3.9 million tons and that quantity of abatement has increased steadily and now stands at 6.3 million tons in 2001. Banking implies that emissions in the first years of Phase II will be greater than the allowances issued for these years, but the appropriate metric is the cumulative reduction since 1995, which has been 33.7 million tons, about 29% more than the 26.1 million tons that would have been required as of 2001 without banking. By the end of Phase I, the actual cumulative reduction was twice what was required, and that ratio will now decline steadily to 1.0 when the accumulated Phase I bank will be exhausted, probably in the second half of this decade.

[9] Suggestions to the contrary, such as those contained in *Darkening Skies*, a publication of the New York Public Interest Research Group, are misleading in citing specific plants and comparing 1999 emissions with 1995 emissions.

Figure 4a. Phase I Unit Emissions, Caps, and Counterfactuals

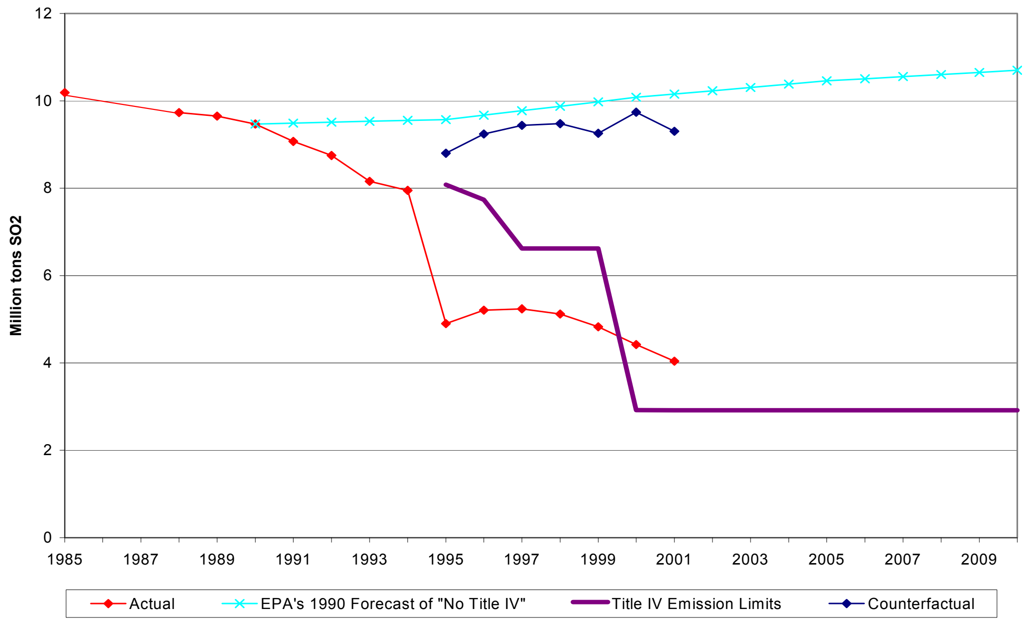
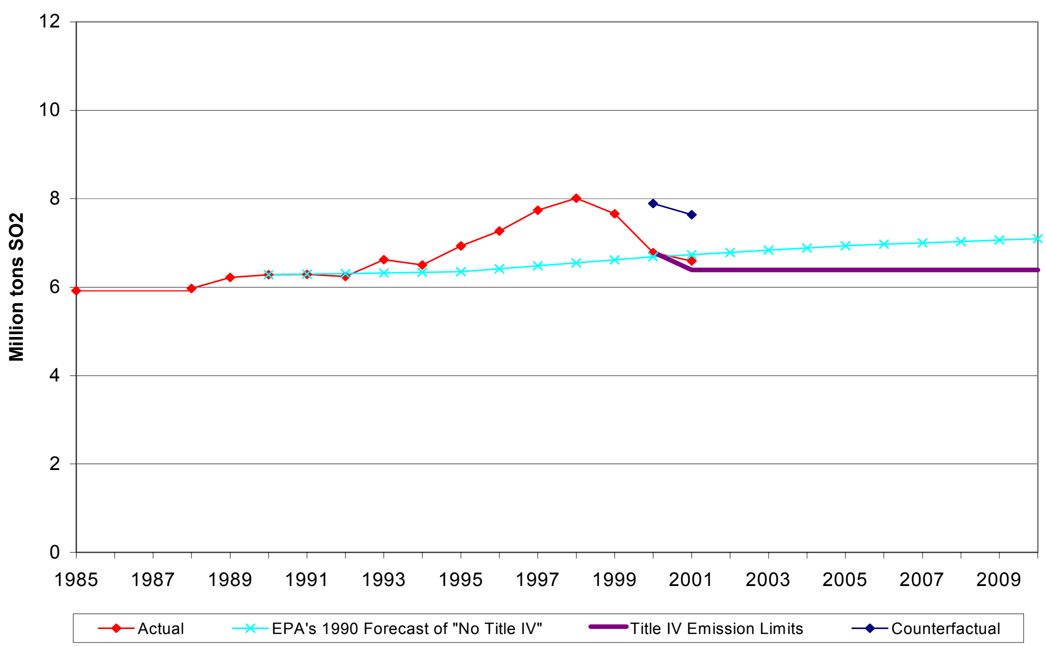
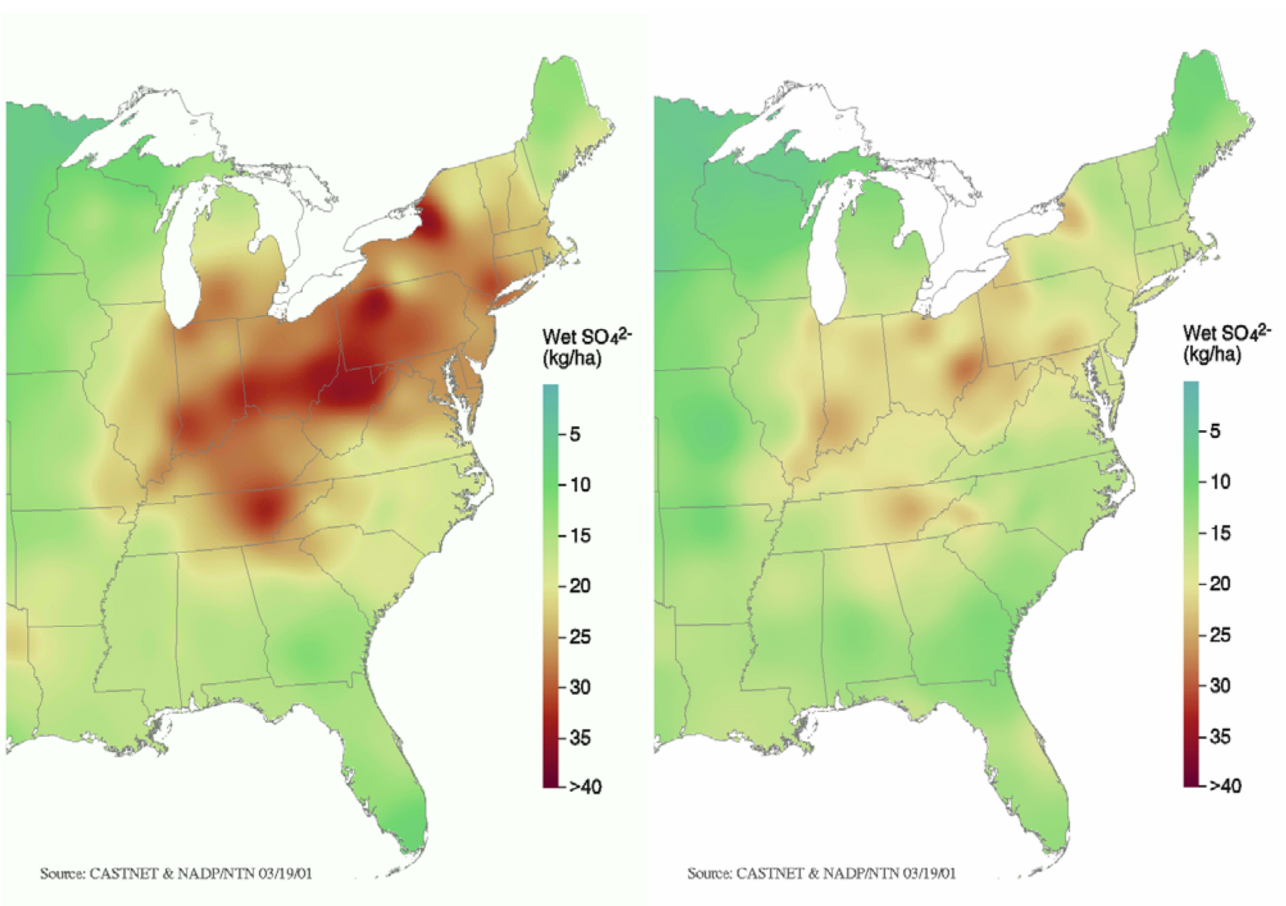


Figure 4b. Phase 2 Unit Emissions, Caps, and Counterfactuals



The significant and accelerated reduction of emissions implies that the deposition of acidic particles has also fallen. The latest progress report from the U.S. Environmental Protection Agency (USEPA, 2002) reports that all of the conventional indicators relative to SO_2 have declined markedly because of the Acid Rain Program. Figure 5 provides a graphic illustration of the change in wet sulfate deposition in the eastern U.S. between the late 1980s and the late 1990s.

Figure 5: Monitored Reduction in Wet Sulfate Deposition



Similar diagrams could be shown for ambient concentrations of SO_2 and sulfate concentrations in the atmosphere, both of which have fallen generally across the Northeast and mid-Atlantic regions and in some places by as much as 50%. Sulfate concentrations in lakes and streams have declined significantly in all monitored regions of the Eastern United States, except Virginia, and in some areas, notably Pennsylvania and the Adirondacks, the acid neutralizing capacity of the soil has begun to increase, which is an indication of the beginning of recovery in ecosystems suffering from acidification.

Another aspect of the environmental effectiveness of the Acid Rain Program is the extent of compliance. With the exception of a few very small, new gas units in 2000, all generating units have been in compliance with Title IV requirements in all years. This record of virtually 100% compliance is not encountered with command-and-control regulation under which sources not infrequently receive various forms of dispensation that have the effect of delaying and sometimes permanently relaxing the applicability of the standard. The reason is that a single standard imposes greater costs of some than on others because of differing site-specific considerations and these firms pleading unique hardship petition for administration relief that is often granted. Although such relief is may be justified in the interest of equity, compensating tighter standards are not imposed on firms facing relatively less onerous costs and these latter never step forward to assume a greater cost burden in the interest of equity, nor are regulators able to identify who they are and thus to impose compensating, more stringent standards on them. The information asymmetries between regulator and regulated in CAC systems effectively lead to a form of adverse selection that makes the standard less effective than it otherwise would be.

This problem is avoided in a cap-and-trade system for two reasons. First, the market removes the rationale of unique hardship since the greatest burden borne by any is the price of an allowance; and, in a market with many buyers, no single one can claim to be uniquely disadvantaged. Second, the market provides at once a cheaper means of relief and the offset that preserves environmental integrity. Nothing prevents a firm from petitioning for relief from the requirement to surrender allowances, even if the grounds for doing so are weak; however, doing so can be costly and a market makes it cheaper simply to pay another to make the compensating reduction. In a sense, the ability to trade, and the market that it implies, renders special pleading uneconomic.

A frequently voiced worry about the environmental effectiveness of emissions trading programs concerns "hot spots." This phrase refers to the potential in a trading system for emission reductions to be transferred away from areas where emissions cause greater damage to those where the emissions cause less damage. Well-designed programs would not have this problem since emissions would not be traded unless they had equal environmental effect; however, real programs contain unavoidable compromises and the SO_2 program is no exception. The enabling myth of the acid rain program is that location does not count, when in fact from the standpoint of acid rain effects, location obviously does. The fear in the acid rain program is that emissions in the Midwest would not be reduced if utilities in this region could pay others located in parts of the country with little impact on the Northeast to reduce on their behalf.

This fear has proved to be unfounded (Swift, 2000). Sources in the Midwest have provided about 80% of the emissions reduction achieved in Title IV while accounting for about 55% of emissions in 2000. It may be argued that emissions from the Midwest are still too high, but it can hardly be argued that emissions trading has allowed sources in the Midwest to avoid abating. A tendency to autarkic compliance in initial planning and a program incentive to scrub early also encouraged reductions in this region, but the more important reason appears to be that the cheapest abatement is to be found where the largest sources are located.

This happy result is not accidental. Most deep abatement technology, like scrubbing, is capital intensive and the per-ton cost depends how many tons are removed per MW^e of capacity. Higher utilization and higher sulfur content of the coal being burned means more tons of abatement over which the fixed capital cost can be spread and lower total cost per ton. Thus, where capital-intensive, deep-abatement technology is an option, market systems will direct abatement to relatively larger and more heavily utilized sources with relatively high sulfur coal. And, if these sources are the most damaging from an environmental standpoint, the experience with Title IV suggests they will be cleaned up first and that hot spots will not appear.

Voluntary Aspects of Title IV[10]

Title IV had several provisions that allowed sources of SO_2 emissions outside of the cap to opt-in to the program. Such features are attractive as a further means of

[10] The discussion of this section is based largely on the work of Juan-Pablo Montero (Montero, 1999, and Montero, 2000), which is summarized in chapter seven of *Markets for Clean Air*.

lowering program costs if sources that are excluded from the cap are able to provide cheaper abatement. In the case of Title IV, certain utility sources that were not required to be under the cap until Phase II could opt-in to Phase I, and non-utility sources that were otherwise not a part of the program could do so in either phase.[11] The response of these two groups was very different: many eligible utility sources opted-in, while few industrial sources did so. The response of the utility sources also revealed an unavoidable trade-off between the economic and environmental objectives of the basic program.

The theory underlying voluntary features is obvious enough: if the aggregate cap is set optimally and non-capped sources can reduce emissions at lower marginal cost than the price of allowances traded among capped sources, then costs are reduced without harm to the environmental objective by allowing non-capped sources with lower marginal costs to opt-in. In Title IV, sources opting-in received allowances equal, in theory, to what emissions would have been without participation and were then held to the same compliance requirements as capped sources.[12] The manner of opting-in implied both that emissions were monitored and that the opt-in unit's counterfactual emissions would be accurately determined. This meant that continuous emissions monitoring systems, or an equivalent system, would have to be in place and that counterfactual baselines would have to be established. The differing responses and the revealed trade-off can be traced back to these two problems of implementation.

Over 200 electric utility units opted-in for one or more years of Phase I, and 110 of them participated in all five years. In contrast, only a few industrial sources chose to opt-in to the program. The different response is largely explained by the differences in transaction costs for each category of participant (Atkeson, 1997). Industrial sources that considered participation but decided not to do so cited the costs of monitoring as the largest consideration. Moreover, the few that did participate already had monitoring

[11] The legislative and regulatory provisions for industrial units are known as the Industrial Opt-in Program and utility units fell under the substitution or compensation provisions; however, all are referred to here as voluntary or opt-in participants. Electric utility units eligible for opting-in to Phase I were those owned by utilities with other units mandated to be part of Phase I. Provisions were included for opting-in units owned by a utility without Phase I units through contract with a utility having Phase I units, but these contract provisions were little utilized.

[12] Note that this mode of voluntary participation is different from many instances in which tradable credits are issued only for the emissions avoided. Thus, most of the allowances issued to opt-in units were needed to cover emissions from these units.

equipment in place as a result of other environmental requirements or otherwise did not need to install monitors.[13] This obstacle was not faced by eligible electric utility units because all sources subject to the Acid Rain Program were required to install a continuous emission monitoring system by 1995 regardless of whether the unit was required to participate in Phase I beginning in 1995 or in Phase II beginning in 2000. Also, the utilities owning the units eligible for becoming substitution and compensation units in Phase I were already incurring the overhead costs of managing emissions and accounting for allowances. Finally, electric utility units did not need to establish a baseline. The number of allowances that would be granted to eligible electric utility units was pre-determined by a set of mathematical formulae that were similar to those used for units required to participate in Phase I. As a result of all these factors, the additional costs of participation were very low for eligible electric utility units and a significant number of them volunteered.[14] In contrast, industrial sources would have had to incur the costs of monitoring emissions in addition to those of establishing a baseline and keeping track of allowances and emissions. These transaction costs were greater than the potential gains from trading that would have been possible through voluntary participation.

While the voluntary participation in the Acid Rain Program was heartening, an analysis of which eligible units opted in and which did not reveal a strong element of adverse selection, which resulted from the impossibility of specifying a true contemporaneous baseline (Montero, 1999). The pre-specified baseline, which greatly reduced transaction costs, relied mostly on 1989-90 data; however, changes in coal markets and in the utilization of electric generating units in the intervening years caused the true counterfactual emissions for eligible units in 1995-99 to be different. Thus, units that had already switched to lower sulfur coal for purely economic reasons because of changes in coal markets tended to opt-in and to receive some allowances in excess of

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[13] For instance, in one case, an electric utility subject to the program undertook to provide steam and power to an industrial facility thereby allowing that facility to shut down the boilers it had previously used to generate electricity and steam. Allowances equal to what the closed down facilities would have produced in supplying the ongoing needs of the industrial facility were then awarded to the electric utility providing the facility's power and steam needs.

[14] A further consideration was motivating electric utility participation was the NO_x grandfathering provision. Units with certain types of boilers could be grandfathered from Title IV's Phase II NO_x emission limits if they participated in the SO_2 program in 1995. While many did, these units generally did not receive excess allowances and were not part of the adverse selection problem that characterized most electric utility opt-in units.

what might be considered the true baseline. And those who might have had low cost abatement to offer but whose emissions had risen above the pre-specified baseline tended not to opt-in since they would incur the costs of reducing emissions to the baseline before they would receive any benefits from emissions trading. The end result was that the units opting in were not so much low cost abaters, although some may have been, as they were units that were abating anyway.

This problem of adverse selection was exacerbated by allowing the owners of eligible units to wait until November 30 of each year to decide whether to opt-in for that year and to take the unit out of the program in the following year if opting-in would be disadvantageous. While many eligible units remained in the program for the entire five years of Phase I, a number of units can be observed opting in and out according to whether emissions were higher or lower than the allowances they would receive by opting in.

While the evidence of this selection bias is very strong, the environmental effects from the loosening of the Title IV cap must be kept in perspective. The number of allowances that could be considered excess amounted to only 3% of the total issued during 1995-99 and the inflation of the cap during Phase II, when these allowances will be used is only about 2%. These magnitudes are not great and they cannot be said to have threatened the overall integrity of the SO_2 cap. In addition, many of the units opting in also abated emissions in response to allowance prices and thereby contributed some cost savings to the program. Whether these cost savings were greater than the reduced environmental benefit depends greatly on the assumption about the true but unobservable baseline. In summary, it is hard to avoid the conclusion that the environmental damage was not great, but neither was the economic benefit, and that on balance, the voluntary features of Title IV were not worth the extra administrative effort.[15]

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[15] See Ellerman *et al*. (forthcoming) for an argument that this conclusion, which results from a balancing of costs and benefits, ought not to be carried over to potential applications of emissions trading for the control of greenhouse gases.

Dynamic effects

Theoretical work has long predicted that market-based instruments, such as a cap-and-trade program, would provide greater impetus to innovation than command-and-control regulation, and thus add another cost-reducing attribute to these instruments (Magat, 1978; Milliman and Prince, 1989). Title IV has provided the occasion for testing this theoretical prediction and there is plenty of anecdotal evidence of what could be interpreted as innovation. Nevertheless, there is only one study that has attempted to address this issue rigorously and its results provide some confirmation, but not much (Popp, 2001). It may be still too early to be able to test the hypothesis confidently; and, under the best of circumstances, the difficulty of disentangling the effects of the regulatory instrument from exogenous technological change is great. Accordingly, in ths section, the term, dynamic effects, is interpreted broadly to encompass factors other than the direct trading of emission rights that contribute to lower compliance cost.

In considering dynamic effects, it is natural to focus of flue gas desulfurization, or scrubbers, since they are capable of removing 95% or more of SO_2 emissions from the stack, they are commercially available and widely used, and they are costly. Moreover, the total costs of scrubbing for the Title IV scrubbers installed at the beginning of Phase I has been less than predicted and a second cohort of Title IV scrubbers that have come on line at the start of Phase II have shown even lower cost. The key components of this change in cost are given in Table 2.

Table 2: Evolution of Scrubber Costs

	Ex Ante Phase I	Ex Post Phase I	Phase II
Initial Capital Cost ($/KW^e)	$240	$249	$150
Tons SO_2 Removed per MW^e	99	137	137
Per ton Fixed Cost ($/ton)	$273	$206	$124
Fixed O & M Cost ($/ton)	$75	$15	$15
Variable O & M Cost ($/ton)	$116	$65	$65
Total Cost per ton ($/ton)	$464	$286	$204

Source: MCA, Table 9.3 at p. 236 and discussion on p. 240.

The costs of scrubbing can be broken down into three components: 1) the initial capital cost, conventionally expressed as dollars per kilowatt of capacity, 2) the tons of SO_2 removed per unit of capacity over some period, which depends on the sulfur content of the coal and the utilization of the scrubber, and 3) the O&M costs, which are often expressed as cents per kilowatt-hour but are more properly stated as dollars per ton removed. Ex ante estimates for the cost of scrubbing a retrofitted Phase I unit typically fell between \$400/ton and \$500/ton, but ex post average cost has been below \$300 a ton, well above allowance prices, but not as uneconomic as often assumed. And this average masks huge variation, from a few units with apparent costs higher than \$500/ton to several with costs around \$200/ton. As shown in Table 2, the calculated 33% reduction in average cost was due not to lower initial capital costs, which were as expected, but to 25% higher utilization of the retrofitted units and a halving of operating and maintenance costs from what had been predicted. Operating costs were lower mostly because of improved instrumentation and control, which reduced the parasitic loss of power and manpower requirements, and it is probable that this improvement was a reflection of broader changes in information technology that were occurring throughout the economy.

The more interesting change from the standpoint of the effects of Title IV was the increase in utilization from 65% of total hours to 85%. This shift in dispatch reflected the effects of the sulfur premium that appeared in coal markets across the entire sulfur gradient and which tended to be equal (when appropriately converted) to the price of allowances. Whereas the only coal receiving a sulfur premium prior to Title IV was "compliance" coal, that required in generating units meeting the pre-1978 NSPS by burning coal with less than 1.2 #SO_2/mmBtu, a sulfur premium now extended across the entire range of sulfur content. This differentiation in the prices of coals having more than 1.2#SO_2/mmBtu had other consequences that will be discussed below, but it had two effects that influenced the utilization of units with retrofitted scrubbers. Since the sulfur premium and allowance prices tend to equality and allowance prices were higher than the variable cost of scrubbing, a scrubbed unit would have lower marginal cost for generating electricity than an unscrubbed unit, if all else were equal. The second effect, and undoubtedly the more important one, reflected the change in fuel cost, the major component in the variable cost of generating electricity, due to the new sulfur premium.

Unscrubbed units, typically burning mid- to low-sulfur coals, found themselves facing not only higher marginal abatement costs, but also higher fuel costs relative to scrubbed units, which would typically burn the higher sulfur coals that were now cheaper relative to coals with lower sulfur content.[16] Thus, the lower cost of scrubbing observed in Phase I is not the result of new technology but of the new requirement that the cost of emitting sulfur dioxide to be incorporated into operating costs in a systematic way.[17]

After the first cohort of Phase I scrubbers, vendors touted a reduction in capital cost for follow-on scrubbers, and these claims became real in 1998 when allowance prices rose to $200 and scrubber retrofits were announced for eight additional units, which are now online. Many of these units came in with initial capital costs around $100/KW[e] (which implied total costs below $200/ton), but these units were able to achieve cost savings because of previously installed scrubbers at other units at the same generating plant. The total cost indicated for Phase II scrubbers provides a good estimate of the long-run marginal cost of SO_2 removal by scrubbing, but that cost will rise as the scrubbers are retrofitted to units that are less utilized and burning lower sulfur fuels (Ellerman and Joskow, forthcoming). Nevertheless, it is clear that there has been a large reduction in the cost of scrubbing, and the question is whether this can be attributed to Title IV.

The only research so far to address this question explicitly is Popp (2001) who compared patents relating to scrubbers from the early 1970s through 1997 with scrubber performance as reported in annual submissions to the Energy Information Administration. He finds that the passage of the 1990 Clean Air Act Amendments did not increase the level of innovative activity, and that in fact it fell somewhat, but that the nature of innovation did change in a more environmentally beneficial way. Throughout the period, the continuing level of innovative activity led to lower operating cost, but the patents granted after 1990 are associated with an improvement in removal efficiency that had remained constant previously. Popp's finding conflicts in part with those of two other

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[16] This effect applies only to scrubbed units. Unscrubbed units burning higher sulfur coals would pay less for fuel but require more allowances and on balance enjoy no advantage over unscrubbed units burning lower sulfur coals.

[17] As exemplified by the compliance coal phenomenon, the costs of complying with environmental regulations often entered into marginal cost decisions, but it was not systematic as it became after the introduction of SO_2 allowances.

studies of changes in scrubber technology (Bellas, 1998; and Taylor *et al*., 2001). Bellas examined the same cost data as Popp but only through 1992 and found "no significant progress…in abatement technology," which he associated with "the small incentives for innovation [associated with] the form of regulation typically used in the U.S." Taylor *et al*. (2001) examine a slightly different question in seeking to determine the relative efficacy of R&D spending and regulatory constraint in inducing innovative activity related to scrubbers, and in doing so they find the same decline in patent activity as Popp but a continual increase in removal efficiency as well as a steady decline in capital cost, both of which are attributed to "learning by doing."[18] These interesting but conflicting results concerning the trend in scrubber costs do not provide very solid ground for attributing dynamic effects, as usually defined, to Title IV.

While scrubbing can be considered the backstop technology for SO_2 abatement, it is not the only way, and it accounts for relatively less (40%) of the total reduction in SO_2 emissions in Title IV than switching to lower sulfur coal. Cost reductions in switching are not as easy to document, since switching does not attract the same attention as installing a scrubber, but cost-reducing changes can be inferred, most of all in the ability of boilers built to fire bituminous Mid-western coals to accommodate lower sulfur, sub-bituminous coal from the West. It was always recognized that these units could be converted to the use of sub-bituminous coals, but the higher water and ash content of the latter would lead to a significant derating, or reduction, in the generating capacity of the unit. As a result, it was expected that the predominantly high-sulfur burning units in the Midwest would either install scrubbers or switch to low-sulfur bituminous coal produced in the Appalachian region. As the effects of rail deregulation increasingly reduced the significant transportation component in the cost of *western* low sulfur, sub-bituminous coals delivered to the Midwest, power plant engineers began to experiment with blending these coals with locally produced high-sulfur bituminous coals. While a 100% conversion to a sub-bituminous would result in a derating, it was equally evident that a 1% blend would have little effect and the operational question became at what mixture did the unit start to experience a reduction in operating efficiency. In what must be seen as a triumph

[18] Popp (2002) and Taylor *et al*. (2001) use the patent data in different ways. Popp constructs a "stock of knowledge" using various diffusion and decay assumptions as the independent variable while Taylor *et al*. rely on the annual count of patent grants.

of continuous thinking, the answer emerged that, depending on the unit and the coals being blended, mixtures of up to 60% of low-sulfur, sub-bituminous coal (and sometimes higher) could be used without significant derating in the generating capacity of the unit.

This re-engineering of existing bituminous coal-burning units to accommodate significant blends of low-sulfur, sub-bituminous coal could be considered an innovation. It was not observed before and not expected, but it can be seen also as diffusion of already known techniques for which there was previously no incentive to apply. It is clear that the previous regulatory instruments, which either mandated scrubbers or low sulfur coal, removed any incentive for experimenting with these blends which resulted in a coal of lower sulfur content (without being low sulfur coal) at much less cost than scrubbing or switching to a low-sulfur bituminous coal from Appalachia. The net effect was a lower sulfur premium for Appalachian low sulfur coal, consequent lower costs for switching in regions to the east beyond the economic frontier for western low-sulfur coals, and a lower allowance price.

Other cost-reducing changes that might be termed innovations can be observed upstream of the power plant in response to the sulfur premium. Mid-sulfur coal mines were developed in the Midwest where none existed before. These could supply a local coal at a price competitive with western blends, but when the only sulfur premium paid was for coal less than 1.2#SO_2/mmBtu, these mines could not compete with the lower cost but higher sulfur mines in the Midwest and were therefore not developed before. A similar shifting downward of the average sulfur content of coal being supplied was observed in Northern Appalachia, the other high-sulfur coal-producing region. These changes in coal supply to somewhat lower sulfur coals, which would still be considered mid- or high-sulfur coals, account for about 36% of the total reduction attributable to switching, or somewhat more than one fifth of the total. The causes were new mines now made economic in local markets, changes in mining practices that reduced the sulfur content of coal being already mined, and increased sulfur removal in coal preparation plants. The incentive for all of these changes was that premium now paid for lower sulfur content across the entire sulfur gradient. Whether these opportunities were known before to geologists, mining engineers, and prep plant operators and only needed the incentive to bring them forth awaits further research, but the answer will determine whether these innovative changes can be considered a change in the menu of technological options induced by Title IV or simply the diffusion of known techniques once the incentive was in place.

One further contribution of Title IV to lower cost that does not involve innovation is noted in Burtraw (1996) and labeled cost savings without emissions trading. Burtraw noted that giving plants the ability to choose between scrubbing, switching, and purchasing allowances created a competition among suppliers of abatement that was not present before. The threat to purchase allowances implies some trading to be credible, but it would not require a fully developed market and even without this threat, the ability to choose between switching and scrubbing increased competition and contributed to lower costs.

What emerges from the experience with Title IV is that costs are lower for reasons beyond the ability to trade emission reductions among sources. Improvements in productivity were occurring throughout the American economy during this period and Carlson et al. (2000) find that unspecified, exogenous productivity improvement applied to SO_2 abatement as well and accounted for as much as 20% of the reduction in the cost between 1985 and 1994. Quite aside from this background trend, a variety of industry sources indicate that the ability to trade emissions, and actual trading, have had effects in upstream markets and on the choice of technique that can be directly attributable to the flexibility that is inherent in market-based approaches to air emission regulation. Whether these changes, which often look like innovation, are true changes of the technical choices facing firms or simply the diffusion of known technology in response to the right incentive awaits further research. It is clear that costs are lower than expected for reasons beyond the extent of actual trading and that these changes were not expected.

Other Costs and Effects

All air emission control programs involve costs and effects beyond the directly observable abatement costs and the concomitant reduction in emissions. In the Acid Rain Program, administrative costs for both the regulator and the regulated are believed to have been less than in conventional regulatory programs, but no comprehensive study has been conducted on this subject. The more important aspect of the program's administration concerns the revolutionary change in the nature of the tasks that are now required of the regulator and the regulated (Kruger, McLean, and Chen, 2000).

The shift of regulatory instrument from site-specific mandates to cap-and-trade has been accompanied by a corresponding shift in enforcement from relatively labor-intensive but intermittent inspection to data-intensive but continuous measurement and accounting. When what each source is doing to abate matters to the regulator, a corps of inspectors is needed to check periodically on the performance of the regulated. In a cap-and-trade system, the requirement that allowances be surrendered for all emissions permits the regulator to be indifferent about each source's abatement, and therefore to do without the corps of inspectors (except for the monitors); however, the *quid pro quo* is continuous measurement and reporting of emissions. In turn, this requires the handling of more data and a greater focus on accounting than was true of more conventional regulation.

The hallmark of the new system of regulation is continuous emissions monitoring and these monitors impose a non-negligible cost on operators that is estimated at 7% of direct compliance cost (MCA, pp. 248-50). As shown by Atkeson (1997) in her study of Title IV opt-in candidates, this cost can be a significant deterrent to voluntary participation. In the case of electric utility units subject to Title IV, continuous emissions monitoring and reporting was mandated for SO_2, NO_x and CO_2. To the extent that the information from these systems is used for the implementation of other air emission control programs, such as the Title IV NO_x averaging program or the Northeastern NO_x Budget Program, or that the data provide benefits aside from compliance uses, this cost should be shared with those other uses. Nevertheless, the experience with Title IV makes clear that the cost of this prerequisite for emissions trading is not negligible.

The administrative costs incurred by EPA are recognized as being less although of a different nature. Kruger, McLean and Chen (2000) describe the significant data handling requirements that are now faced and they suggest that this would not have been much more costly before recent advances in computing and data management. Despite this change of the nature of regulatory activity, the number of people involved in administering the program is a third [get McLean quote] of what would be required for a more conventional air emission control program.

Although no researcher has attempted to address the issue, the administrative costs of the cap-and-trade program for the regulated are not as clearly less than with conventional regulatory means. The cost of continuous emissions monitoring is the main item in this accounting. As is the case for the regulator, corporate administrative resources are shifted to emissions reporting and allowance management, but a good comparison of how these costs compare with what is required for dealing with inspectors and reporting under conventional command-and-control systems has not been made. It may not be any greater, but it is not clearly less. Whatever the case, regulated firms seem to be unanimous in expressing their preference for this type of regulation, presumably because the gains in reduced, direct compliance costs more than offset whatever additional costs are involved in monitoring and allowance management.

Another notable achievement in the realm of other costs is the notable reduction in the transaction costs involved in trading. The creation of a standard unit of account in allowances and the lack of any review requirement for trading has avoided the very large transactions costs that limited EPA's earlier experiments with emissions trading (Ellerman *et al*., forthcoming; Kruger, McLean, and Chen, 2000). The right to emit has been made into a readily tradable commodity and broker commissions are correspondingly low. This feature has, of course, greatly facilitated the development of a market and the concomitant cost savings.

Two effects of the Acid Rain Program that are not related to ancillary costs are also important. The first has been the creation of institutions with a continuing interest in emissions trading. The emergence of intermediaries, such as brokers, banks, and others who can offer trading and risk-management services, has already been mentioned. And, as is perhaps inevitable for any economic activity of note, an association has been formed, the Emissions Marketing Association, to promote emissions trading through a variety of educational, lobbying, informational, and other out-reach programs. Finally, there seems to be no end to the conferences, meetings, and workshops that bring participants from the private and public sectors and academia together to discuss one aspect or another of emissions trading.

While this institutionalization of emissions trading has occurred, somewhat of a backlash has also emerged recently as represented by Clear the Air (2002) and Moore (2002). The latter succinctly states the position of these groups: "trading ought to be rejected when proposed and repealed where it now exists" (p. 2). Both of these purported studies are lobbying documents occasioned by the Bush Administration's Clear Skies Proposal, which in addition to lowering the SO_2 cap by two-thirds and instituting national NO_x and mercury caps would effectively exempt units subject to these proposed caps from the best available control technology requirements of the existing Clean Air Act. Based on the experience with Title IV, one might conclude that this is a good trade-off, as advanced by some academics (Ellerman and Joskow, 2000) and as suggested by the publications of some environmental organizations (Goffman and Dudek, 1995; Environmental Defense, 2000) and researchers at some environmentally oriented research organizations (Swift, 2000; Swift, 2001), but this is far from a universally shared view among the environmental community. The reasons for rejecting emissions trading are beyond the scope of this paper but disdain for pollutant trading as morally reprehensible and concern for the loss of administrative discretion (and its many uses for non-environmental purposes) are always present. Although these attitudes may be viewed as a rear-guard reaction to an increasingly dominant consensus, they do find an echo on the editorial page of the New York Times and they have been translated into a law in New York that would restrict emissions trading. In what is perhaps an example of the new institutions, this state law has been struck down in the federal court as a violation of the interstate commerce clause of the U.S. Constitution in a motion for summary judgment brought by members of the Emissions Trading Association. [Get references on above]

Conclusions and Implications

The experience with Title IV and, to a lesser extent, other cap-and-trade programs marks a turning point in the regulation of air emissions in the U.S. This experience has shown that market-based incentive systems can reduce emissions as effectively, and even more so, and at considerably less cost than through conventional command-and-control mandates. As it result, it has become virtually obligatory that any legislative proposal to limit air emissions in the U.S. include emissions trading. While the agreement of left and right in the political spectrum is not as complete as it may appear on the surface, there seems little doubt that emissions trading will play an increasing role in the regulation of air emissions in the U.S. and probably elsewhere.

The conventional wisdom is that emissions trading will be necessary for new emission control initiatives and that the existing structure of command-and-control regulation is sacrosanct. Hence, all legislative proposals granting new authority to regulate air emissions include emissions trading; yet, their passage has been no faster for this reason. The same issues of cost and benefit and the same imperatives of building a viable political consensus remain. While legislative proposals that include emissions trading do not appear to be going anywhere fast, a less noticed and potentially more important change is occurring. Cap-and-trade systems are being adopted as a preferred means for achieving environmental goals for which ample legislative and regulatory authority already exists. The RECLAIM and Northeastern NO_x Budget Programs, as well as the NO_x SIO call, are instances of cap-and-trade programs being implemented within existing regulatory authority. This trend is in keeping with the reliance on market forces that has become manifest in one regulatory domain after another and it indicates that the increased use of cap-and-trade programs may occur as much through such incremental changes in the existing command-and-control structure than through bold new advances in the legislative domain.

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