Cost Savings, Market Performance, and Economic Benefits of the U.S. Acid Rain Program

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Abstract

This paper reports on four areas of research concerning Title IV of the 1990 Clean Air Act Amendments that regulates emissions of SO_2 from electricity generation. The first is the costs of the program over the long-run as estimated from the current perspective taking into account recent changes in fuel markets and technology. We compare projected costs with potential cost savings that can be attributable to formal trading of emission allowances. The second area is an evaluation of how well allowance trading has worked to date. The third area is the relationship between compliance costs and economic costs from a general equilibrium perspective. The fourth area is a comparison of benefits and costs for the program.

Key Words: acid rain, benefit-cost analysis, air pollution, permit trading, Clean Air Act

JEL Classification Numbers: H43, Q2, Q4

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COST SAVINGS, MARKET PERFORMANCE, AND ECONOMIC BENEFITS OF THE U.S. ACID RAIN PROGRAM

Dallas Burtraw*

INTRODUCTION

Title IV of the 1990 US Clean Air Act Amendments regulates emissions of SO_2 from electric utility facilities and instituted two important innovations in US environmental policy. The more widely acknowledged of these is the SO_2 emission trading program, which is designed to encourage the electricity industry to minimize the cost of reducing emissions. The industry is allocated a fixed number of total allowances and firms are required to hold one allowance for each ton of sulfur dioxide they emit.[1] Firms are allowed to transfer allowances among facilities or to other firms, or to bank them for use in future years. This approach enables firms operating at high marginal pollution abatement costs to purchase SO_2 emission allowances from firms operating at low marginal abatement costs, thereby lowering the cost of compliance.

The second and less widely acknowledged innovation is the annual cap on average aggregate emissions by electric utilities, set at about one-half of the amount emitted in 1980. The cap accommodates an allowance bank, so that in any one year aggregate industry emissions must be less than the number of allowances allocated for that year plus the surplus that has accrued from previous years. Unlike most previous regulations in the US, including technology standards or emission rate standards, the emissions cap represents a guarantee that emissions will not increase with economic growth.[2]

This paper begins with a summary of recent projections of the *long-run* costs of compliance when the program is fully implemented in the next decade, and estimates of *potential cost savings* stemming from the trading program in the long run. Second, I evaluate how well the allowance trading has worked to date, and what one can expect to happen in the future.

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[1] Allowances are allocated to individual facilities in proportion to fuel consumption multiplied by an emission factor during the 1985-1987 period. About 2.8 percent of the annual allowance allocations are withheld by the EPA and distributed to buyers through an annual auction run by the Chicago Board of Trade. The revenues are returned to the utilities that were the original owners of the allowances.

[2] Title IV also used a more traditional approach in setting NO_x emission rate limitations for coal-fired electric utility units, although this approach has been modified to allow emission rate averaging among commonly owned and operated facilities. Hence, there is no cap on NO_x emissions, but Title IV is expected to result in a 27 percent reduction from 1990 emissions for electric utilities.

Most attention has been focused on the reduction in "out-of-pocket" compliance costs that may result from allowance trading. However, compliance costs are not the same thing as economic costs. A third focus of this paper is to explain how hidden economic costs inflate the total cost of the program in an important way, and how recognition of these costs provides an important lesson for the design of future programs. Fourth, I return to the primary purpose of the program, which after all is to reduce acidification of the environment and associated effects on human well-being. An economic assessment of benefits, though extremely uncertain, indicates that benefits are an order of magnitude greater than costs under the program. An important component of this favorable assessment rests with the design of the tradable permit program which has helped to reduce costs substantially.

COSTS OF THE SO_2 PROGRAM AND COST SAVINGS FROM ALLOWANCE TRADING

To make sense of the wide variety of claims about the costs of the SO_2 program one has to put these claims in historic perspective. In the 1980s there were over seventy proposed pieces of legislation that suggested a variety of regulatory approaches aimed at the problem of acidification.

One prominent proposal was the Sikorski/Waxman bill in 1983 that sought to rollback emissions, by about the same amount as eventually required under Title IV, by requiring the installation of scrubbers (flue gas desulfurization equipment) at the fifty dirtiest plants.[3] The estimated levelized cost of this proposal ranged from about $7.9 billion per year according to government studies (OTA, 1983) to $11.5 billion per year according to an industry study (TBS, 1983; 1995 dollars).

Another bill (H.R. 4567) in 1986 was aimed at similar environmental gains but promoted cost reductions by applying a target average emission rate for each utility company. Taking account of changes in fuel and other input prices between 1983 and 1986, an industry study (TBS, 1986) found costs would be $7.5 billion per year compared with estimates of $3.5 to $6.2 billion by ICF in a study for the EPA, and $3.4 to $4.3 billion by the OTA (1995 dollars).[4] Though ultimate regulation did not involve either of these approaches the estimates provide an indication of what the program might have cost under alternative regulatory approaches, and have often been used as a basis for comparison.

One of the earliest studies of the cost under an allowance trading system was Elman et al. (1990) who estimated the marginal cost of compliance and inferred this would be the

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[3] These plants represented 89 percent of the nation's pre-New Source Performance Standard coal-fired capacity. Fuel switching to low-sulfur fuel and other facility improvements would have been required at other facilities. Scrubbing would have been applied to about half of the affected capacity and accounted for 70 percent of the SO_2 reduction.

[4] It is noteworthy that an industry study (TBS, 1986) suggested the costs would be higher as a result because although "intra-firm trading" would reduce the need for scrubbing, it would increase reliance on low sulfur coals resulting in an increased premium on low sulfur coal that would raise costs for units already using low sulfur coal. This prediction is contradicted by the turn of events under Title IV, when the cost of lost sulfur coal fell with its expanded use.

value of emission allowances. Under a perfect trading market, this study predicted marginal costs (presumed to equal allowance prices under perfect trading) of $742-1032 (1995 dollars) and costs of $1935 for imperfect trading, ranging up to $2580 or $5160 at a number of utilities. However, for evaluation of the program compared to prior expectations, the most useful study is ICF (1990), which was done for the EPA and available prior to enactment of the legislation. This study captured more accurately the ultimate design of the regulation, and projected marginal costs of $579-760 (1995 dollars) for full compliance under the program. This and a number of other studies are summarized in Table 1.[5]

Table 1: Estimates of Long-run (2010) Annual and Marginal Cost

Study	**Annual cost** (billion 1995 dollars)	**Marginal cost per ton SO_2** (1995 dollars)	**Average cost per ton SO_2** (1995 dollars)
Carlson et al. (1998)	1.0	291	174
Burtraw et al. (1997)	0.9		239
White (1997) [EPRI]		436	
ICF (1995) [EPA]	2.3	532	252
White et al. (1995) [EPRI]	1.4-2.9	543	286-334
GAO (1994)	2.2-3.3		230-374
Van Horn Consulting et al. (1993) [EPRI]	2.4-3.3	520	314-405
ICF (1990) [EPA]	1.9-5.5	579-760	280-467

An important feature of the studies summarized in Table 1 is that, as a group, they have successively estimated a sequence of declining projections of annual and marginal costs of compliance. There are several contributing reasons for this. One is that the trading program ignited a search for ways to reduce emissions at less cost, as theory suggests is likely to occur with this type of regulation, and the fruitful results of this enterprise are measured by latter studies (Burtraw, 1996).

It is also the case that advantageous trends in fuel markets contributed to a decline in emission rates, making it easier for utilities to attain the goals of the program thereby reducing program costs (Ellerman and Montero, 1998; Burtraw, 1996). Indeed, the right-hand column in Table 1 reporting average cost per ton estimated by the various studies reflects this decline. The differences in average cost estimates are due to differences in annual cost reported in the

[5] These estimates describe long-run costs expected to obtain when the allowance bank, which is expected to build up to about 11 million tons by the end of Phase 1 (in the year 2000), is drawn down and net contributions to the bank are zero.

first column, but also they are due to differences in the estimate of tons reduced under the program compared to various specified baseline projections of emissions that would occur in the absence of the program. To the extent these emission reductions would have occurred even in the absence of the SO_2 program then the program should not be given credit; however, it appears the trading program encouraged utilities to capitalize on these advantageous trends while other regulatory approaches might not have.

A third reason for declining projections of cost is that the market structure for industries offering compliance services to utilities was dramatically changed under the trading program. What were previously independent factor markets supplying services to utilities (coal mining, rail transport, and scrubber manufacturing) were thrown into a competition with each other by the program's flexible implementation. This unleashed competitive pressure to find ways to reduce costs in all these markets.

All of the explanations listed appear to contribute to some degree to the decline in estimates of compliance costs. The Carlson et al. (1998) model can help to sort out these factors because it provides a framework in which we can vary factors one at a time and explore their significance. While most of the studies in Table 1 rely on engineering-based models of compliance options and their costs, Carlson et al. uses a simulation model based on marginal abatement cost functions derived from an econometrically estimated long-run total cost function for electricity generation for a sample of over 800 generating units over the period 1985-1994.[6] From an economist's perspective, this study is superior because it takes into account behavioral responses to changes in relative input prices. These behavioral responses generally take the form of substitution among inputs to reduce jointly the costs of generating electricity and of complying with emission reduction requirements. The econometric approach also affords a method for measuring the role of technological change in reducing the costs of SO_2 abatement over time, and to develop forecasts of future compliance costs and gains from trade that implicitly incorporate future behavioral changes including future responses to changes in technology.

Table 2 presents several estimates using this model, varying assumptions about fuel prices and technological change. The columns in the table represent the annual cost of a command and control approach (uniform emission rate standard), the annual cost of efficient trading, its associated marginal abatement cost and finally the estimated gains from trade that are available from efficient trading.

[6] The cost function they estimate treats fuel type (high-sulfur and low-sulfur coal), labor and generating capital as fully variable inputs. The econometric model consists of the cost function plus two share equations that specify the share of total costs attributed to capital and labor, and an equation for the firm's mean annual emission rate. The study uses a translog form for the cost function, adding dummy variables for each plant in the database to measure fixed effects that vary among the plants. Costs for units with scrubbers are taken directly from reported data. The model does not investigate whether early commitments to build scrubbers was economical, but several studies have suggested that several of these investments were not.

Table 2: The Contribution of Price and Technological Change to Compliance Costs

Scenario	**Command and control** (million 1995 dollars)	**Efficient trading** (million 1995 dollars)	**MAC** (1995 dollars)	**Potential gains from trade** (million 1995 dollars)
Benchmark estimate: (1995 prices/ 1995 technology)	**2,230**	**1,510**	*436*	**720**
Benchmark with: 1989 prices/ 1989 technology	**2,670**	**1,900**	*560*	**770**
Preferred estimate	**1,820**	**1,040**	*291*	**780**

The first row in Table 2 reports numbers for a benchmark scenario that uses assumptions comparable to those in previous studies, including assumptions that relative fuel prices remain stable at 1995 levels, technology including the utilization rate of scrubbers is characterized at 1995 levels and the historic method for measuring emissions based on sampling of coals and engineering formulas remains in effect. The retirement rates for coal facilities, and replacement with scrubbed coal technology, is taken from projections by the Energy Information Administration (EIA, 1996). The estimates assume that no additional retrofit scrubbers are constructed after Phase I.

This benchmark predicts long-run marginal abatement costs will be $436 (1995 dollars). The second row presents an estimate under most benchmark assumptions but with prices held to their 1989 level (implying a higher price for low sulfur coal relative to high sulfur coal than obtained in 1995) and the time trend for technological change (factor productivity) also held at 1989 levels.[7] From this vantage point, marginal abatement costs rise to $560, or 28 percent greater. One should note that this is not far from that offered by ICF (1990) calculated with comparable information reported in Table 1.

The last row in Table 2 presents the Carlson et al. (1998) preferred estimate, reproduced for convenience from Table 1. Compared to the benchmark, this scenario adopts 1995 prices and 2010 technology. It assumes utilization rates and performance of in-place scrubbers continues to improve. It assumes a slower retirement rate of coal-fired facilities, and half of retired facilities are replaced by gas. Also it assumes that the use of continuous emission monitoring systems in place of the historic measure of emissions will raise emission

[7] Technological change here captures both exogenous efficiency improvements at the power plant and improvements induced by the program, but it does not capture improvements in scrubber technology and performance.

estimates and necessitate a greater level of control.[8] Explicitly missing from consideration in all of these studies is the influence of other potential regulatory actions, such as further control on particulates or NO_x emissions or actions to meet global warming goals.

Based on this information and model, the savings from allowance trading that are expected from an efficient allowance market are about $780 million annually, or about 42 percent of the costs under command and control. Previous studies (Van Horn Consulting et al., 1993; GAO, 1994) suggested an efficient allowance market would result in cost savings of about twice this much in percentage terms. In all these studies, the command and control approach that is modeled is "enlightened" in that it is a performance standard (emission rate or emission tonnage standard) applied to each facility, calibrated to achieve the same level of total emissions.[9] This approach already encompasses many of the beneficial incentives of the SO_2 trading program compared to a technology forcing approach by providing individual facilities with flexibility in achieving the standard. Other command and control approaches that were seriously considered in the US, such as forced scrubbing at larger facilities, could have cost substantially more. Forced scrubbing is also the approach embodied in the New Source Performance Standards for SO_2 from power plants.[10]

In summary, estimates of both a command and control approach and allowance trading have fallen over time due to a number of factors. Allowance trading is expected to result in cost savings relative to a command and control approach, but the absolute magnitude of these savings is expected to be somewhat less than previously envisioned due to changes in fuel markets. However, a more rigid approach that forced firms to adopt specified technologies would have precluded them from taking advantage of some of these trends in the industry. Compared to this, allowance trading could be argued to constitute a greater savings than we estimate.

Though they are substantial by any accounting, cost savings have been exaggerated in many accounts of the program. Advocates of ambitious climate change policies have suggested that SO_2 allowance prices are "so low" and that economists and engineers got it "so wrong" that policy makers should virtually ignore cost projections when developing new regulations such as a carbon permit trading program (or trading of nitrogen oxide (NO_x) permits). These exaggerated comparisons have often used inconsistent estimates of cost,

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[8] In 1995 the continuous emission monitors estimated seven percent higher emissions than did the historic approach on average, although there was considerable variability among facilities.

[9] In their command and control scenario, Carlson et al. (1998) apply a uniform emission rate standard to all facilities. GAO (1994) and Van Horn Consulting et al. (1993) allow intra-utility trading, but no trading between utilities. GAO (1994) also models a scenario that requires each facility to achieve its SO_2 allowance allocation without trading, and finds cost savings more than double that in the case in which internal-trading is allowed in the command and control baseline.

[10] 1978 Clean Air Act regulation of sulfur emissions from newly constructed fossil fuel-fired electricity generating facilities imposes a rate-based standard that requires a 90 percent reduction in a smokestack's SO_2 emissions, or 70 percent if the facility used low-sulfur coal. Although nominally a performance standard, it effectively dictates technological choices and precludes compliance through the use of process changes or demand reduction. The only available technology to achieve such reductions is scrubbing, and the use of low-sulfur coal is not a permissible way to avoid the threshold for the strict standard.

leading to erroneous conclusions (Bohi and Burtraw, 1997). The most obvious of these errors is to compare allowance prices today directly with long-run marginal cost estimates. This is erroneous because long-run marginal cost estimates describe costs that will not be incurred until late in the next decade, when the allowance bank is drawn down and net contributions to the bank are zero. Allowance prices today should be proximate to short-run marginal cost and these are related to long-run marginal costs by the rate of interest. Discounting long-run marginal costs for the year 2010 to the present reduces them by about two-thirds!

A proper comparison of program costs indicates they are expected to be less by almost one-half that indicated in information available to legislators in 1990. Further, program costs are perhaps half again the cost of an inflexible technology standard. However, they are not reduced by fifteen fold, as some have claimed.[11] Furthermore, as described previously, a significant portion of the actual decline is due to factors exogenous to the program. Nonetheless, after accounting for these factors the remaining decline in costs is impressive, and in general it points toward success for the program.

PERFORMANCE OF THE PROGRAM TO DATE

The previous section reported on estimates of the cost of compliance when the program is fully implemented. The second phase of the program begins in the year 2000, when an expanded set of facilities will be brought into the program and the average emission rate for all facilities will reduce to about 1.2 lb. per million Btu. In the first phase of the program, which began in 1995, firms have been over-complying in order to save allowances in the bank and to ease the transition into Phase II. In the second phase, utilities will begin to draw down their allowance banks until net contributions to the bank are zero and annual emissions equal annual allocations for an average year. This is projected to occur by the year 2010.

A specific economic relationship is expected to govern use of banked allowances, and the magnitude of the marginal costs in a given year. As previously mentioned, allowance prices in a given year should reflect marginal abatement costs in that year. To appreciate why this is so, imagine instead that allowance prices were less than a firm's marginal costs. Then the firm could decrease its compliance activities and purchase allowances in the market as an alternative means of compliance, earning positive net revenues.

A similar reasoning governs the relationship between marginal costs at different points in time. Marginal costs in any given year should equal the present discounted value of marginal abatement costs in the future. Imagine instead that allowance prices were less than the present discounted value of marginal costs in the future. Then again the firm could purchase allowances in the current year and "bank them" for use in place of compliance

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[11] For instance, March 10, 1997 EPA Administrator Carol Browner argued: ". . . During the 1990 debate on the acid rain program, industry initially projected the cost of an emission allowance to be $1500 per ton of sulfur dioxide. . . . Today, those allowances are selling for less than $100." ("New Initiatives in Environmental Protection," *The Commonwealth* (newsletter), March 31, 1997, Commonwealth Club of California. See also "Economists' Cold Forecast; Assumptions: Expect their dire predictions about the impact of the global warming treaty on the United States. Ignore all of them," by Elaine Karmarck, *Baltimore Sun*, December 28, 1997.

activities in the future, generating net revenues. Of course, the converse would hold as well, if allowance prices were greater than these respective measures of marginal costs. Hence, the banking provision in the allowance market serves an intertemporal arbitrage function that allows firms to identify the least cost means of compliance over time just as allowance trading allows firms to identify the least cost means of compliance over geography.

Using this relationship from economic theory provides one way to check on the performance of the market and the likely accuracy of estimated costs. If cost estimates for the long-run are correct, and using a discount rate of 8 percent reflecting the opportunity cost of capital for firms in the industry, current allowance prices should be about one-third of projected long-run costs. The present discounted value of long-run marginal costs of $291 in 2010 should be about $95 in 1997. Allowance prices hovered between $100 and $110 for most of 1997, suggesting that the model is roughly consistent with current activities, and that intertemporal arbitrage is working to an important degree. The explicit omission of other potential regulatory actions (NO_x, CO_2) in the models may explain much of the remaining difference.

Another way to measure the performance of the market to date is to look at the allocation of compliance activities among firms in the current period. Economic theory suggests that the marginal cost of compliance activities should be the same at all facilities (except as may be constrained by local ambient air quality restrictions).

To investigate this Carlson et al. (1998) evaluated their estimated marginal abatement cost functions at the level of emissions in the industry in 1995. These results are reported in Table 3. The cost of efficient trading is projected to be $552 million, with a marginal cost for fuel switching activities of $101. This compares with a cost under a command and control emission rate standard of $802 million, representing a savings of 30 percent.[12] Further, the projected marginal cost of $101 is remarkably close to allowance prices in this period (around $90 in 1995), reinforcing the notion that intertemporal arbitrage is working as it should.

Table 3: Cost Estimates for Compliance in 1995

Study	**Annual cost** (million 1995 dollars)	**Marginal cost per ton SO_2 (fuel switching)** (1995 dollars)	**Average cost per ton SO_2*** (1995 dollars)
Carlson et al. (1998) ***Efficient Trading***	552	101	194
Carlson et al. (1998) ***Actual emissions***	832	180 *(weighted marginal cost)*	291
Ellerman et al. (1997)	726	153 *(average cost)*	210

* Includes scrubbing costs

[12] As noted previously, in their command and control scenario, Carlson et al. (1998) apply a uniform emission rate standard to all facilities.

However, the second row of the table reports the estimated actual cost of compliance when the estimated abatement cost functions are evaluated using observed emissions at individual facilities. The *actual* cost to the industry in 1995 is estimated to be $832 million, or 50 percent more expensive than a least cost solution (reported in row 1) according to the model. The only other estimate for 1995 that we are aware of is Ellerman et al. (1997) who found costs in 1995 to be $726 million.

The notion of an industry marginal cost does not apply in this context, since costs presumably differed among firms. However, Carlson et al. calculate the marginal cost at each facility weighted by that facilities portion of total generation and summed for the industry results in an estimate of $180. Ellerman et al. do not report marginal cost but they find an average cost from fuel switching activities of $153. Both of these figures compare poorly with observed allowance prices in 1995. We consider the proximity of the Carlson et al. econometric estimates to the Ellerman et al. survey estimates of actual costs, and the distinction between these estimates and the estimated cost of efficient compliance as evidence that in the first year of the program there were unrealized potential gains from trade suggesting that important imperfections characterized the allowance market in the first year of the program. Moreover, the difference between the observed price of allowances (approximately $90 in 1995) and both Ellerman et al. and Carlson et al. estimates of actual compliance cost provides further evidence that the new program of allowance trading was not yet a mature institution in 1995.

What appears to have occurred in 1995 is that different patterns of compliance behavior co-existed in the industry. Many utilities appear to have taken advantage of the flexibility afforded by the allowance program to find ways to reduce costs of compliance, including taking advantage of allowance trading per se. However, many other utilities appear to have pursued a solitary strategy, rationalizing to some degree the cost of emission reductions within the firm, but not taking advantage of the allowance market to rationalize costs with other firms in the industry (Bohi and Burtraw, 1997).

This glance at the first year of performance in the market is disconcerting, but it may be a poor indicator of the rich long-run prospects for the program. One should expect that an industry that has heretofore been subject to cost recovery rules in a regulated setting would take some time in adjusting to a new incentive-based approach to environmental regulation. In fact, one can be relatively confident that the future holds better things in store for the program. One reason is that trading activity is increasing. Trades can be recorded with the EPA at any time prior to the use of an allowance for compliance, and recorded trades are monitored in the EPA's electronic, on-line Allowance Tracking System (ATS). The EPA has developed an algorithm for classifying trades as "economically significant" if they are transfers between independent firms, and the majority of trades that are recorded have been transfers for accounting convenience or other reasons within firms. However, the number of economically significant trades has virtually doubled each year through 1997.

A second reason for optimism about the efficiency of the market is that the industry-wide level of emissions increased slightly in 1996. An adjustment was necessary because the weighted average costs in 1995 were greater than the present discounted value of marginal costs in the future and greater than allowance prices that reflect the latter measure. Behavior at the outset of the program appears to have been risk averse, with firms making sure they could achieve compliance through a "go-it-alone" strategy. Subsequently, there appears to be a growing level of comfort with the use of the market as a way to ensure compliance.

A third reason for optimism has to do with over-arching trends in the electric utility industry in the US. The industry is in a fundamental period of realignment as competition at the wholesale level, and perhaps ultimately at the retail level, is beginning to emerge. This type of competition is placing pressure on the industry to find ways to reduce costs in all segments of its business. One should not expect the industry to absorb $300 million in unnecessary costs in the future when allowance trading provides a fairly simple means of reducing those costs.

COMPLIANCE COSTS VERSUS ECONOMIC COSTS

Though widely known, it is not often acknowledged that compliance costs and economic costs are not the same thing. Compliance costs describe the out-of-pocket expenses by a firm or industry to comply with regulations. Economic costs describe the value of goods and services that were lost to the economy due to the regulation. This can include so-called hidden costs or benefits, such as costs incurred but not reported as compliance costs or indirect productivity changes that result from environmental compliance.

One type of important hidden cost stems from the interaction of the program with the pre-existing tax system. Important distortions away from economic efficiency stem from pre-existing taxes. Labor income taxes are particularly important because of their magnitude in the economy. Labor taxes impose a difference between the before-tax wage (or the value of the marginal product of labor to firms) and the after-tax wage (or the opportunity cost of labor from the worker's perspective). This difference causes workers to substitute away from labor to leisure compared to an efficient outcome were these two measures equal.

Any regulation that raises product prices potentially imposes a hidden cost on the economy by lowering the real wage of workers. This can be viewed as a "virtual tax" magnifying the significance of previous taxes, with losses in productivity as a consequence. If there were no pre-existing distortions in the economy, the impact of regulatory costs would be of little concern. However, the cost of distortions associated with taxes grow more than proportionally with the size of the tax, and hence the hidden cost of regulation can be of great importance when pre-existing taxes are taken into account.

This hidden cost has been termed the tax-interaction effect (Parry, 1995) and it tends to erode the usual efficiency benefits identified with setting prices to include external costs. The tax interaction effect is particularly important in the allowance trading system, relative to a command and control approach, because the price of the final product in a competitive market should reflect not only compliance cost for emission reductions but also the opportunity cost (or price) of allowances used for compliance. As the electric utility industry in the US moves toward competition, this effect of allowances on electricity prices is expected to emerge. The trading program is expected to result in significant savings in compliance costs, but commensurately it internalizes additional costs in the way of allowance prices into electricity prices.[13]

Goulder et al. (1997) have investigated the magnitude of the tax-interaction effect in the context of the SO_2 program using both analytical and numerical general equilibrium models. They find that this effect will cost the economy about $1.06 billion per year (1995 dollars) in Phase II of the program, adding an additional 70 percent to their estimated compliance costs for the program.

There are important lessons here for the design of other environmental programs that may refer to the SO_2 program as a model. First Goulder et al. (1997) find that the tax interaction effect is more significant, relative to the magnitude of compliance costs, for programs that are aimed at small emission reductions such as may describe possible policies for CO_2 reductions.[14] Further, since the tax-interaction effect is positive even for a small emission reduction, then it is possible for the economic costs of regulation to be greater than the benefits even when compliance costs start at zero.

Second, the cost of the tax-interaction effect can be largely (but not entirely) offset by policies that raise revenues for the government, because these revenues can (in principle) be used to offset preexisting taxes and correct distortions in the labor market resulting from these taxes. The authors find that over half of the economic cost of the tax interaction effect, or $622 million, could be avoided if emission allowances were auctioned rather than grandfathered and the revenue was used to reduce the marginal tax rate on labor income. Unfortunately, the SO_2 program does not raise revenues since allowances are distributed for zero cost. Consequently, the current program design imposes a hidden cost on the economy that could be avoided if allowances were auctioned instead of allocated without charge.

The recommendation that allowances be auctioned comes with significant political liability. The endowment of allowances without charge, so-called "grandfathering" of allowances, is an important form of compensation to the electric utility industry. The industry's attitude toward the SO_2 program would have been considerably more negative had this compensation not existed. Hence policy makers face a trade-off between efficiency and compensation in the design of the program.

There is an equity aspect to this issue that counter-balances the concerns of industry as well. At the time legislators adopted the SO_2 program in 1990, state public utility commissions were in the business of regulating the industry and setting electricity prices, and they were the safeguard to ensure utilities could not charge customers for something the utilities received for free. Hence, endowing allowances at zero cost was not controversial to

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[13] The effect on product prices should occur without regard to how the firm acquired allowances originally, if prices reflect marginal costs and allowances are valued at their opportunity cost.

[14] Small emission reductions require small compliance expenditures, leaving a larger quantity of emissions to be included in a permit trading scheme. Allowance prices would be low, relative to a case with greater emission reductions, but they apply to a larger quantity of emissions. Hence, the portion of costs associated with permit use relative to the portion of costs associated with compliance cost is greater.

the design of the SO_2 program. However, in the near future we expect regulators to exit the business of setting prices, at least with respect to electricity generation, and electricity prices will be set in a competitive market.[15] In the textbook and presumably in the market, SO_2 allowances take on the value of their opportunity cost, and this will be passed on through marginal cost pricing in a competitive electricity market, regardless of how the utility acquired the allowances originally. The value of this endowment, coming out of the hides of electricity consumers and accruing to the industry, is potentially very large.

A potentially important qualification concerns whether coal-fired electric generating facilities which are the source of SO_2 emissions are likely to be the marginal unit that is the highest cost unit that is operated to meet electricity demand and hence will be determining electricity price. For example, at times when a gas-fired unit is the marginal unit, the price of electricity should reflect the marginal costs of that unit and will not reflect allowance costs for coal-fired generation that may be running at costs below the margin. On the other hand, when coal-fired units are the marginal unit then all infra-marginal technologies that operate at less cost than the marginal unit will receive the same price of electricity, which reflects the costs of allowances.

To investigate this issue, we exercised an electricity dispatch model aggregated by season, time block and region, that is maintained at Resources for the Future. The model is intended to characterize the industry under competitive conditions expected to prevail after deregulation. We find that coal-fired facilities can be expected to generate about one-half of all electricity generated in the US, just as they do under current regulatory practice. Further, we find that about one-half of all electricity would be generated when a coal facility is the marginal unit. Hence, on a per kilowatt-hour basis, the effect on electricity prices from emission allowances appears to be about the same as it would be if we were to assume generation from coal-fired units always occurred when these were the only units operating and their marginal costs were to determine electricity prices when they were in operation.

Under the assumption that the program works efficiently and firms value SO_2 allowances at their opportunity cost (the price of an allowance, equal to the marginal abatement cost) then the magnitude of the compensation under the program (the grandfathering of allowances valued at their opportunity cost) far outweighs the compliance cost incurred by firms. I estimate that the present discounted value of this difference is between $10 and $20 billion (1995 dollars). This represents a tremendous transfer of wealth from electric utility customers to the industry, and this transfer should be of interest in the design of other programs.

In particular, the design of a CO_2 permit program would involve smaller emission reductions in percentage terms and therefore a much greater transfer of wealth relative to the cost of compliance and also in absolute terms. Both the equity and the efficiency aspects of

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[15] This will occur if state or federal policy-makers move to retail competition. At the time of this writing, fifteen states have committed to retail competition to be implemented at some future date, and virtually all states are actively considering doing so (Ando and Palmer, 1998). Even if retail competition is slow to develop, wholesale competition is likely to emerge in the near future.

the tax-interaction effect can be largely remedied by a carbon tax or auctioned carbon permits. Recognizing that there may political obstacles to a revenue-raising carbon policy, a hybrid system involving an auction of some portion of the permits and grandfathering the remaining may be a useful compromise.

COMPARING BENEFITS AND COSTS

The primary measure of success of the SO_2 program, from the perspective of economics, is the comparison of benefits and costs. Burtraw et al. (1997) describe an integrated assessment of the of benefits and costs through the year 2030, with benefits quantified for health, visibility and aquatics.[16] The accounting of benefits is incomplete because several environmental pathways could not be modeled completely. The cost estimate and estimate of health benefits are calculated for the entire nation, but visibility and aquatic benefits are calculated only *per affected capita* to illustrate the potential relative magnitude of these benefits; and, the estimates do not necessarily apply to the entire nation. Midpoint estimates of the benefits and costs per affected capita for the year 2010 are summarized in Table 4.

Table 4: Benefits and Costs Expressed as *per affected capita* in 2010

Effect	**Benefits per affected capita** (1995 dollars)
Morbidity	4.09
Mortality	69.25
Aquatic	0.72
Recreational Visibility	3.90
Residential Visibility	6.79
Costs	6.19

Source: Burtraw et al. (1997)

The study finds that benefits of the SO_2 program are an order of magnitude greater than costs, a result that contrasts sharply with estimates in 1990 that pegged benefits about equal to costs (Portney, 1990). What explains the difference between the earlier and recent estimates?

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[16] The integrated assessment involved nearly thirty researchers at a dozen institutions The assessment is based on reduced-form models that were calibrated to several larger models of utility emissions and costs, atmospheric transport of pollution, visibility impairment, effects on aquatic systems and human health, and valuation of effects. Economic assessment of costs are calculated with an engineering model constructed for the assessment. Economic valuation of damage to aquatic systems relied on random utility models of recreational use. Health mortality valuation relied on compensating wage and contingent valuation studies and morbidity valuation relied on a number of studies and methods. Valuation of visibility effects at national parks used contingent valuation methods, and valuation of visibility in residential areas used a combination of contingent valuation combined with hedonic property value studies.

The lion's share of benefits result from reduced risk of premature mortality, especially through reduced exposure to sulfates, and these expected benefits measure several times the expected costs of the program. Significant benefits are also estimated for improvements in health morbidity, recreational visibility and residential visibility, each of which measures approximately equal to costs. These areas, namely human health and visibility, were not the focus of acid rain research in the 1980s, and new information suggests these benefits are greater than were previously anticipated.

In contrast, areas that were the focus of attention in the 1980s including effects to soils, forests and aquatic systems still have not been modeled comprehensively, but evidence suggests benefits in these areas to be relatively small, at least with respect to "use values" for the environmental assets that are affected.

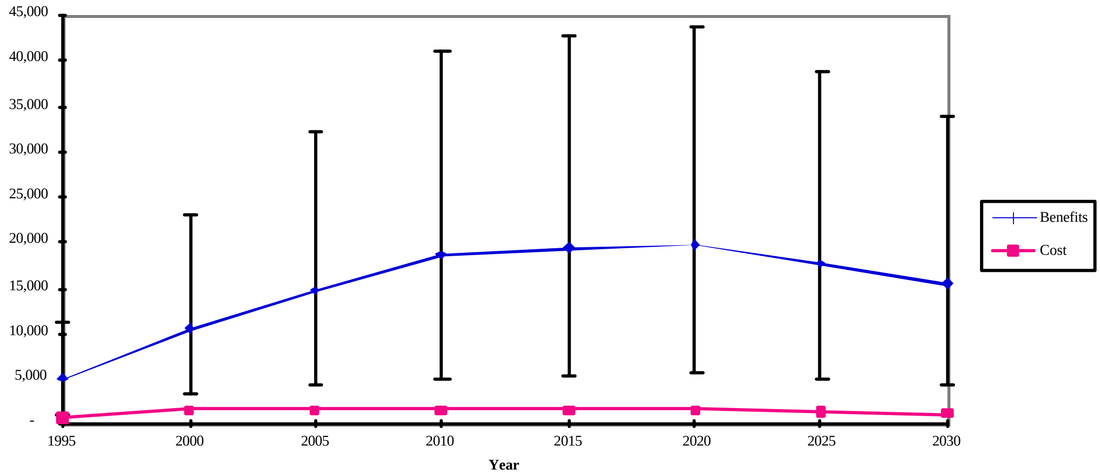
In the 1980s public attention to air pollution from SO_2 and NO_x emissions largely centered on the problem of acidification ("acid rain"), with particular concern for its affect on water and soil chemistry and ultimately ecological systems. It is surprising to many that relatively low benefits are estimated by economists for effects on aquatics (in Burtraw et al., 1997) or are expected to result from effects on forests and agriculture. One reason is that willingness to pay for environmental improvement depends on the availability of substitute assets. Economists would not expect changes in quality at one site to elicit large benefits if there are many sites available for comparable recreational opportunities. In contrast, individuals do not have the same kind of substitution possibilities with respect to health and visibility, which may help explain the relatively larger benefit estimates for these endpoints. Furthermore, one should note that the low values for aquatics stem from an assessment of *use* values, or *commodity* values in the case of agriculture. Environmental changes may also yield *nonuse* values, and estimates for nonuse values are not available. Nonetheless, the evidence, based on a small number of relatively narrow studies, suggests these values may be significant.

On the cost side, compliance has cost one-half or less what it was anticipated to cost in 1990. Trends in both directions, that is, increased appreciation of benefits and decreased estimate of costs have qualified the program as a tremendous success from an economic perspective.

There are huge uncertainties, especially on the benefits side of the ledger, especially in valuation of mortality. Recent economic critiques have argued that the use of the value of a statistical life as the basis for valuing health risks from air pollution, instead of a more appropriate measure of quality adjusted life years lost, could grossly overestimate mortality benefits. In addition, economists have questioned the appropriateness of using labor studies of prime age men to value changes in life expectancy that occur among an older population. On the other hand, we note that because environmental exposures are involuntary, compared with studies of labor market behavior, the latter may underestimate willingness to pay to avoid environmental exposures. Burtraw et al. (1997) used Monte Carlo analysis and a parametric one-sided sensitivity analysis to investigate some of these sources of uncertainties. Their analysis finds that there is no year in which health benefits alone at the 5 percent confidence interval are less than the levelized expected costs. These results are illustrated in

Figure 1, with millions of (1990) dollars on the vertical axis and years of the program on the horizontal axis. As noted, significant benefits are also estimated for improvements in health morbidity, recreational visibility and residential visibility, each of which measures approximately equal to costs. Despite tremendous uncertainties about benefits and costs, the main conclusion that benefits soundly outweigh costs appears to be robust.

Figure 1: Annual 90 percent confidence intervals for total health benefits compared with expected annualized costs



Source: Burtraw et al. (1997)

CONCLUSION

Although tremendous attention has been addressed to the innovative design of the SO_2 emission allowance trading program, an economic approach to policy analysis should perhaps focus first on the comparison of benefits and costs of the program. Evidence to date suggests that benefits are expected to greatly outweigh the costs of the program. Surprises on the benefits side that contribute to this favorable assessment are in benefit categories of human health and visibility that were not the primary focus of research on acid rain in the 1980s.

Favorable events on the cost side have to do with the expected successful implementation of the allowance trading program, and with advantageous trends in markets that supply the electric utility sector. Developments in these input markets, which include scrubber manufacturing, coal mining and rail transport of coal, are at least partially related to the SO_2 program. Due to advantageous trends in the industry leading to increased use of low sulfur coal, the quantity of emissions that had to be reduced is less than anticipated. This led to lower costs than many envisioned, and commensurately SO_2 trading could provide a smaller measure of cost savings. However, the SO_2 program deserves considerable credit for providing firms with the flexibility to capitalize on these advantageous trends as they strategize their compliance activities.

There is some reason for concern about the ability of the SO_2 market to function efficiently and for firms to capture possible cost savings based on evidence for 1995, the first year in which the program was binding. However, there are several reasons one can expect the market to become more efficient over time and the long-run prospects for the program are bright.

As scholars and policy analysts attempt to draw lessons from the SO_2 program, one area that should receive significant attention is the manner in which emission allowances are allocated to the industry. Evidence suggests that grandfathering of allowances can impose significant efficiency costs. Furthermore, this approach represents a tremendous transfer of wealth that raises equity issues as well. Rarely in economics do efficiency and equity issues point in the same direction, but in this case they do. The recommendation that follows is that emission allowances should be auctioned or allocated in some means that raises revenue for government that can be used to reduce other distortionary taxes. If the allocation of allowances is to serve as compensation for industry, this function should be weighed carefully against the benefits of raising revenue. A hybrid program, in which some portion of allowances are grandfathered and the rest auctioned by the government could offer a compromise that would improve programs of this type in future applications.

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