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SO_2 Allowance Trading: How Experience and Expectations Measure Up

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Abstract

The SO2 trading program has achieved reductions in emissions ahead of schedule, with allowance prices below the marginal costs that were anticipated for the program. This paper explores the experience with the program and proposes a taxonomy of reasons why allowance prices are low. The overarching reason is that the most costly investments to accommodate full emission reductions have been successfully delayed. Application of a discount rate to these long run marginal costs yields an estimate of allowance price close to that observed today. Several factors have contributed to the delay in bearing these costs, and helped to reduce their magnitude. One group of factors stems from market fundamentals, especially the cost of rail transport of low sulfur coal. A second group includes the influences of state and federal regulators. A third group includes distinctions from the "imagined" program compared to that which was actually been enacted.

SO_2 Allowance Trading: How Experience and Expectations Measure Up

Douglas R. Bohi and Dallas Burtraw[1]

1. INTRODUCTION

The sulfur dioxide (SO2) emission allowance trading program enacted through Title IV of the 1990 Clean Air Act Amendments (CAAA) ushered in the first nationwide effort to use a market in tradable "emission allowances" as the way to encourage the electricity industry to minimize the cost of reducing emissions. The electricity 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. Firms may choose to buy allowances to meet their requirement rather than reduce emissions, or to sell excess allowances not required for compliance.

Since the first phase of the program began in January, 1995, the experience has been full of pleasant surprises. Firms are reducing emissions in excess of statutory requirements in Phase I and accumulating an unexpectedly large bank of allowances for use in the second phase of the program that begins in January 2000. Probably the most surprising development has been the decline in the price for allowances, compared with the expectations of many analysts at the inception of the program. Also the cost of emission reductions using low sulfur coal or flue gas scrubbing equipment has been lower than expected. At the same time, it appears that the volume of allowance trading to date, while substantial, has been less than analysts had first believed necessary to take full advantage of allowance trading. Hence, there is an apparent puzzle: greater than expected cost savings have been achieved under the allowance trading program with a lower than expected level of trading (Conrad and Kohn, 1996, offer another perspective on a similar question).

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An explanation for these observations is called for not only for evaluation of the current program, but also to arrive at lessons that might guide the use of tradable permit programs in other applications in the future. This is especially important with respect to the differences between expectations of allowance prices and their current value, because some analysts assert that engineers and economists so overstated the cost of meeting SO2 reductions that their cost projections for future environmental regulations such as carbon dioxide controls should be discounted significantly.

This paper will evaluate the experience with the emission trading program to date and explain why the surprises indicated above came to pass. We offer a taxonomy of reasons why allowance prices are below the expectations of some. The lesson is not so much that prior estimates were wrong (at least the more sophisticated and unbiased ones) but that they were static snapshots taken in a dynamic policy environment. We argue the program should be given credit for the attainment of cost savings in emissions reductions because it has provided incentives for firms to innovate and to exploit advantageous trends in fuel markets and in the industry. Nonetheless, there have been impediments to trading allowances and other idiosyncrasies in program design that have promoted uneconomic investments and prevented firms from realizing additional savings. The experience to date illustrates that the potential savings from incentive based environmental policies such as the allowance trading program are enormous. However, improvements in trading behavior will be increasingly important for the industry to capture these savings as it approaches the more stringent second phase of the program. Due to increasingly competitive pressures to reduce costs in electricity generation, we are optimistic that a boost in allowance trading will be realized, but this is far from certain.

2. AN EXPERIMENT IN REGULATORY REFORM

In contrast to traditional command and control environmental regulation, where firms typically adopt a common technology to reduce emissions by a specific amount, the emission trading program allows each firm to choose its own individual emission rate and the means to achieve that rate. This flexibility allows firms to identify the cheapest way to reduce its compliance costs. Allowance trading takes advantage of the fact that emission control costs vary across different generating plants, and encourages firms with the cheapest control costs to undertake the most emission reduction.

To work in this idealized way, however, each firm must have the incentive to minimize its costs. One should be careful in assuming that electric utilities will seek to, or even will be allowed to, minimize the cost of reducing emissions. The problem is that electric utilities are not allowed to maximize their profits. Instead, their prices and profits are regulated by the states in which they operate. The state regulators allow the firms to charge prices for electricity that will recover only those costs of production that are deemed to be prudently incurred.

In fact, many state public utility regulators have imposed cost recovery rules that distort the firms' incentive to minimize costs (see Rose, 1997; Bohi, 1994; Rose, 1992; and Bohi and Burtraw, 1992). For example, regulators typically allow more favorable cost recovery on scrubbing and fuel switching than on allowance purchases. Several states have granted preapproval for the recovery of scrubber costs. Investments in capital costs such as scrubbers or fuel handling equipment in the case of fuel switching can be depreciated or expensed beginning as soon as facilities are in operation, and in some states scrubber costs can be recovered even before the units are in operation. Fuel cost increases are typically passed through to customers in the year the expense is incurred. In contrast, though allowance acquisitions may be necessary for investment and planning purposes years in advance of their use, their cost cannot be recovered until after the allowances are used for compliance. If the price of an allowance falls over the period of time between acquisition and use the state regulator may deny full recovery of cost on the grounds that a particular transaction was imprudent. If the price rises and the utility decides to sell the allowances and adopt a different compliance strategy, the utility is unlikely to be able to capture the capital gains. Hence, the utility faces a downside risk for which there is no upside compensation.

In summary, the potential savings from allowance trading are tremendous but for a variety of reasons firms may have an incentive to pursue abatement options over allowances transactions even when they appear to be more expensive. Several studies have estimated a high cost associated with impediments to trading (Fullerton *et al.*, 1996; Winnebrake *et al.*, 1995; USGAO, 1994). For a dissenting view on whether state regulators have impeded trading, see Bailey (1996).

In the last year, apparently despite these impediments, there has been a tremendous boost in allowance trading (Dean and Kruger, 1997). One reason may be that regulators have corrected the early signals given to utilities, but evidence of this is lacking. It is more likely the case that the potentially achievable cost savings from trading overwhelm the restrictive signals issued by some regulators, especially as utilities come to recognize the oncoming pressures of competition set in motion by the 1992 Energy Policy Act. While many have complained that regulators stopped paying attention to emission trading in 1992 (Rose, 1997), it may turn out to be a good thing.[2]

3. OBSERVATIONS OF THE EARLY PERFORMANCE

Four interrelated aspects of the experience with the emission trading program deserve to be highlighted and they are listed in Table 1. First, the volume of sulfur dioxide actually emitted since the law was passed in 1990, and before it took effect in 1995, is significantly lower than expected.[3] Utilities have been aggressive in taking advantage of the opportunity to

[2] One utility employee told us that the utility had stopped filing the burdensome paperwork that the public utility commission required to be filed for every allowance transaction. So far, he reported, the regulators did not notice or care.

[3] Projections by both ICF (1989), p. 24, and Molburg et al. (1991) Table 5.1, p. 47, showed emissions rising steadily from 1985 to 1995 when the new Clean Air Act requirements went into effect. Instead, emissions rose only to 1990, the year the Clean Air Act was enacted, and dropped steadily thereafter. For a comparison of these studies see Reid, Bohi and Burtraw (1994).

save allowances earned through emission reduction actions, and the volume of "banked" allowances that will be available for use in Phase II of the program is larger than expected. The bank represents a "win-win" outcome for the environment and for industry. The early reductions provide an opportunity for environmental recovery and improved public health at an earlier point in time than would occur otherwise, while the bank provides an opportunity for industry to lower its overall costs of compliance and the ability to ease into the more stringent Phase II. Estimates of the volume of banked allowances expected to accumulate during Phase I range between 7 and 15 million. White *et al.* (1995) estimate the allowance bank will reach 9.4 million tons in the year 2000. RDI (1995) estimates the bank will reach 12-15 million. In 1991 the estimate of total Phase I banked allowances made for the Department of Energy (DOE) was only 4.35 million (Molburg et al., 1991, Table 4.10, p. 44). The more recent estimates of the Phase I bank are equivalent to 25% to 50% of the allocation of allowances during the first five-year phase of the program.

Table 1: Four observations of SO2 allowance trading to date.

1. Over-compliance in Phase I will lead to a substantial bank for Phase II.
2. The volume of allowance trading has been less than anticipated.
3. The price of allowances is low.
4. The cost of emission reductions is low.

A second observation is that the volume of allowance trading has been less than many anticipated. The overwhelming portion of the approximately 53 million private allowances transferred in 3,300 transactions that have been recorded through the EPA's Allowance Tracking System were accounting transfers within firms. A relatively small percentage, roughly about six to ten percent, were economic transfers between independent parties. The actual number of economic transfers is not easily deciphered from the allowance data. Three efforts to identify economic transfers that reach somewhat different conclusions are reported in

Table 1. As of the middle of 1995, White *et al.* (1995) find less than 1.6 million allowances have been traded among utilities. Joskow *et al.* (1996) find that as of the first quarter of 1996 about 6.5 million allowances have been traded among utilities, between utilities and third parties and between non-utility parties. In addition, 775,000 allowances have been purchased at EPA auctions (excluding allowances offered for sale by private parties through the auction). Dean and Kruger (1997) report that economically meaningful transactions (defined as allowances acquisitions by utilities) involving 4.8 million allowances had occurred as of the end of 1996. Lile et al. (1996) review the issues involved in these assessments and promote the perspective developed in Dean and Kruger. Montero, Ellerman and Schmalensee (1996) find that for compliance in 1995, "spatial" trading (as opposed to "inter-temporal" trading, or banking) account for about 500,000 out of 5.3 million tons from facilities covered by the program in Phase I. About two-thirds of this trading was intra-utility, and only one-third (involving primarily six utilities) was inter-utility, representing about 3% of allowances used for compliance.

The data suggest that a good number of utilities have failed to take advantage of the allowance market to reduce their costs of compliance, though most have taken advantage of the flexibility in the allowance trading program to bank allowances for Phase II, and to pursue fuel switching.

Eighty-five percent of the base allowances issued in the first phase (excluding facilities in the Substitution and Compensation Program) go to utilities located in only eleven states (see columns 1 and 2 of Table 2). All of the states may be said to actively reduce the incentive to trade. For example, all of the states proscribe that the benefits that may result from allowance trading will be passed on to customers. The State of Connecticut provides the one exception to this rule, wherein it allowed a utility to retain 15% of the revenue from the sale of allowances (Rose, 1997). In addition, six states provide a regulatory bias in favor of scrubbers as a compliance option (column 3). All six states have significant indigenous coal industries and have acted to protect their markets against encroachment from lower sulfur coal. Out of 110 affected generation facilities, 26 generating units at 14 facilities opted for scrubbing and all of these units are located in states with a regulatory bias in favor of scrubbing.

Table 2: Allowance trading and compliance plans by state.

(1) State	(2) % of Phase I Allowances	(3) Regulatory Bias For "Other" Compliance Options	(4) Plans to Trade Allowances	(5) Expected Status Toward Allowances	(6) Phase I Compliance Plans
Ohio	16.9	Yes	Intrafirm	Buy	Mainly Switching; Scrub Gavin
Indiana	12.6	Yes	Sell	Buy	Mainly Switching; Scrub 7 Units
Georgia	10.2	No	Bank or Intrafirm	Sell	Switching Only
Penns	9.4	Yes	Buy	Sell	Scrub 5 Units; Switching
West Va	8.7	Yes	Intrastate	Sell	Scrub 4 units; Switching
Illinois	6.9	Yes	Intrastate and Buy	Sell	Switching and Buying Allowances
Missouri	6.2	No	No	Sell	Switching Only
Kentucky	4.9	Yes	Intrastate and Sell	Buy	Mainly Switching; Scrub 6 Units
Alabama	4.1	No	Intrafirm	Sell	Switching Only
New York	2.7	No	No	Sell	Switching; Scrub 2 units
Florida	2.4	No	No	Buy	Switching Only
TOTAL	85.0				

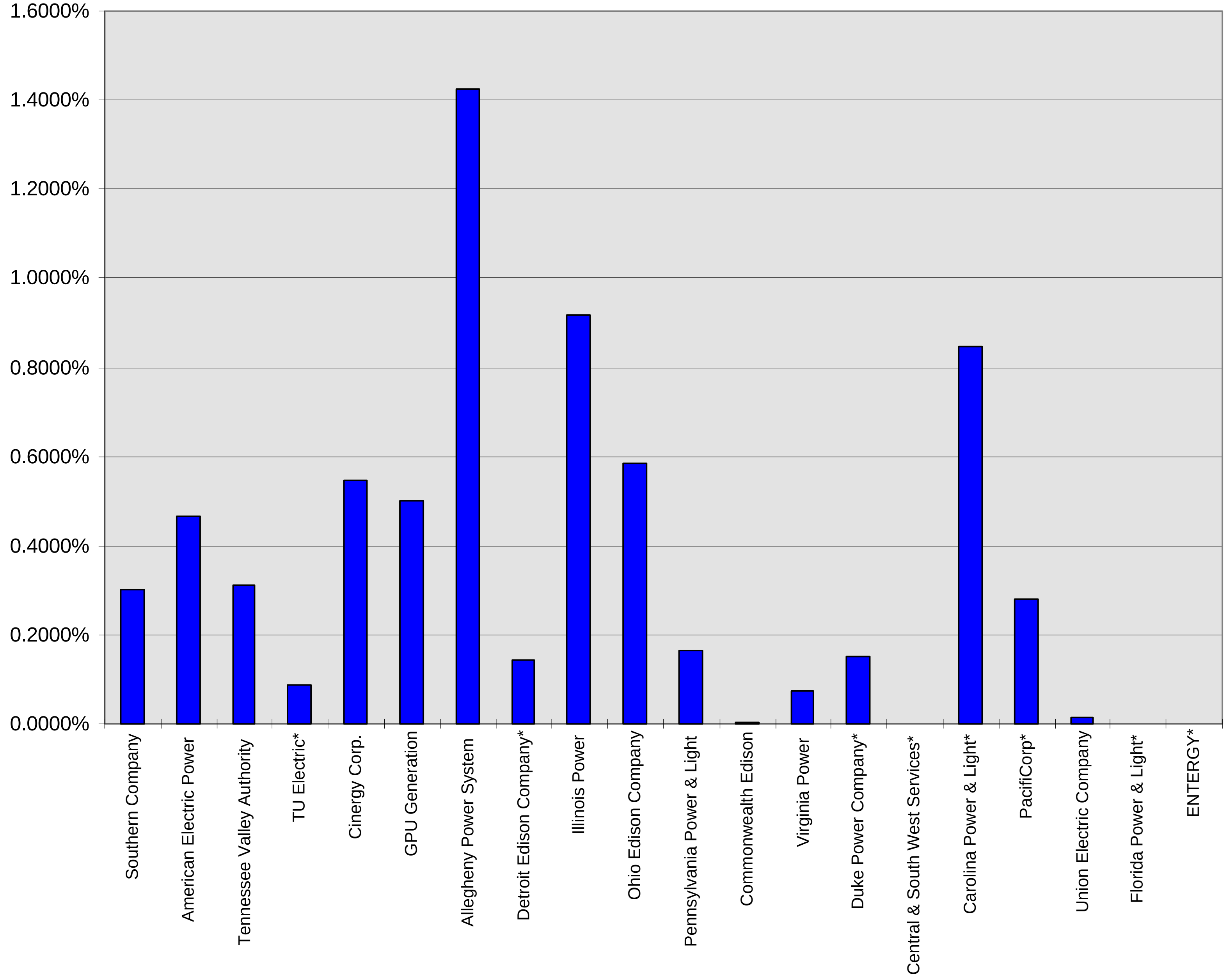
SOURCES: Column (3) and (4) from interviews with public utility commission staff; Column (5) from ICF model with "Low-Flexible" assumptions, reported in National Acid Precipitation Assessment Program, *1990 Integrated Assessment Report*, p. 425; and Column (6) from U.S. Environmental Protection Agency, "SO_2 Phase I and II Boiler Compliance Methods," Office of Air and Radiation, June 14, 1993.

One indication of the unexpected nature of the amount of allowance trading so far is reflected in the discrepancies between the expected status of the utilities in each state as a buyer or seller of allowances (column 5) and the actual compliance plans (column 4). The lack of correspondence between plans and estimates is of interest because the ICF optimization model was the primary source of estimates of the efficiency gains from a system of allowance trading that was used in the political debate over the acid rain provisions in the CAAA. Though the costs of the program have been low, experience so far suggests that the promised benefits of allowance trading are not being realized in the way they were initially expected.

Another indication of the amount of trading is illustrated in Figure 1. Arrayed along the horizontal axis of this figure are utilities (at the holding company level) according to the number of total allowances allocations they are to receive between 1995 and 2026. The vertical axis is a ratio of the amount of "economically distinct" transactions each utility has been involved in to their total allowance allocation. We include intra-utility trades, which could be more important for the larger firms and holding companies. The ratio captures our intuition that utilities with more allowances should be more involved in trading, so one might expect the ratios across firms to be approximately equal if all firms attempted to take equal advantage of the market. The variation in these ratios suggests that utilities vary greatly in the amount of activity in the market, even when we control for their size and allowance allocations.

A third and particularly important observation is that the price of allowances has been lower than expected. Table 3 reports expected and actual allowance prices and the volume of inter-utility trades. Prior to the enactment of the Clean Air Act Amendments in 1990, the estimated price of allowances ran as high as $1500, a number that was enshrined in the Act as the fixed price of direct sales by EPA. During 1990, the EPA cited a price estimate of $750 as the best guess of what allowances (and emission reductions at the margin) would cost.

Total Number of Economically Distinct Allowances Bought/Sold as % of Initial Allowances



Instead, actual prices for inter-utility trades have been considerably lower, starting out in the range of $250-300 in 1992, they fell steadily to $110-140 in 1995, and to around $70 in 1996 before rebounding to the low $90s at the time of this writing.

Table 3: Allowance prices and volumes.

	Allowance Price	**EPA Auction Clearing Price** (Spot)	**Quantity of Inter-Utility Trades (thousands)** White *et al.*[*]	Joskow *et al.*[**]	Dean & Kruger
Expected					
1989	$1500				
1990	$750				
Actual					
1992	$250-$300		70	130	
1993	$130-$300	$157	639	226	
1994	$130-$140	$159	562	1,467	
1995	$110-$140	$132	320[***]	4,918	
1996	$90	$66			4,800[****]

Notes: The expected price in 1989 is from ICF (1989), and in 1990 it is from White *et al.* (1995). Actual prices and trading volumes are from White *et al.* (1995), Joskow *et al.* (1996) and the industry press. [*]White *et al.* (1995) report inter-utlity trades. [**]Joskow *et al.* (1996) report trades between April and March of the subsequent year, and include inter-utility trades, trades between utilities and third parties, and trades between two non-utility parties. [***]Data for 1995 is for first half of year only. [****]Dean and Kruger (1997) report all allowance acquisitions by utilities through the end of 1996.

Table 4: Projected annual costs under alternative implementations for Phase II.

billion dollars	Command and control baseline	Constrainted trading (internal transfers)	Flexible interutility trading
ICF (1989)		3.3 - 4.7	2.7 - 4.0
Van Horn Consulting *et al.* (1993)	5.1	3.4	2.2
GAO (1994)	4.3	2.5	1.4
Burtraw, *et al.* (1997)	2.5		1.0

A fourth observation, also related to the price of allowances, is that the cost of emission reductions has been dramatically less than industry projections before adoption of the program. Table 4 presents four sets of estimates compiled at various times of the relative annual costs in Phase II for three implementation scenarios: command and control, constrained trading (only among facilities within a firm), and interutility trading.

The estimates pertain to annual cost when the net contributions to the allowance bank are zero sometime in Phase II. The estimates illustrate an evolution as utility compliance plans have become known and set into motion, and new information has surfaced about compliance options and their costs. According to estimates made by ICF (1989) for the U.S. Environmental Protection Agency (EPA) before the CAAA was enacted, the levelized annual cost of the program was expected to be $2.7 - 4.0 billion. These costs reflect a cost savings of 40% over a command and control approach. The GAO study in 1994 also estimated that compliance costs in the year 2001 would be almost 40 percent less than they would have been under a command and control approach of emission rate limits applied to specific facilities, but costs in both cases were less than forecast in 1989. Specific technology requirements, which were also considered in various proposals in the 1980s, would have been even more expensive. The Burtraw *et al.* (1997) study differs from the others, which were primarily engineering based studies, by employing an econometric analysis. They find that permit trading would reduce the costs of the program by 60% compared with a command and control approach.

4. WHY ARE ALLOWANCE PRICES SO LOW?

In this section we reconcile the most widely discussed of the discrepancies between experience and expectations: Why allowance prices are so low? The answer, in this case at least, is not that the experts are wrong. In fact, the explanations for the divergence between expectations and observed allowance prices are several, and can be organized into three groups, as listed in Table 5. First are market fundamentals, which is analogous to the term used in financial economics that describe changes that have driven down marginal costs of compliance. Second are regulatory influences that also work to reduce observed allowance prices to date. Third are the distinctions between the imagined program that was the subject of many analyses, and the actual program as set forth in the Clean Air Act.

Table 5: Nine reasons why allowance prices are so low.

Market Fundamentals:
1. Discounting of future costs.
2. Widespread availability of low sulfur coal.
3. Competition and innovation.
4. General equilibrium effects.

Regulatory Influences:
5. Sunk “uneconomic” investments in scrubbers.
6. Annual auction invites strategic under-bidding.

The Imagined versus Real Program:
7. Bonus allowances subsidies for scrubbing delay future costs.
8. Two phases of program segregate sellers and buyers.
9. Substitution and Compensation units delay future costs.

Market Fundamentals

1. Marginal cost estimates that will be incurred in the future should be discounted to the present to be relevant for current allowance prices.

The single most important factor in comparing the marginal costs of the program with observed allowance prices to date is the role of discounting. An investment of *$126* that is to be made in the year 2000 for the purpose of compliance has a present value of $(1\text{-}d)^3\ 128$ in 1997, where d represents a discount rate. For instance if $d{=}.08$, then the investment in the year 2000 has a present value in 1997 of $100. Furthermore, anything that happens to delay this investment beyond the year 2000 serves to lower its present value.

Most analyses of long run marginal costs which were used for allowance price projections were built on models that accommodated full implementation of Phase II of Title IV, which will be felt when the bank from Phase I is drawn down and net contributions to the bank are zero. The bank is expected to be exhausted toward the end of the next decade. Table 6 reports several estimates along with the net present value (NPV) of the long run marginal costs obtained by discounting these estimates at a rate of 8% per year (real), assuming these marginal costs were incurred in the year 2010. White *et al.* (1995) suggest an 8% real discount rate as a benchmark, above the after-tax weighted average cost of capital (5% real), to account for increased risk as the industry enters a more competitive era, and uncertainty around the allowance market. White *et al.* (1995) and ICF (1995) are engineering studies of marginal costs. The RDI (1995) estimates are projections of allowance prices, rather than marginal costs *per se,* so the comparison with the engineering estimates is somewhat misleading. Several of the complementary explanations we discuss below have helped to delay the time at which these investments would be needed, thereby lowering the price of allowances in the present.

Table 6. Estimates of the long run marginal cost of emission reductions, and the role of discounting future costs for present allowance transactions.

	Long Run Marginal Cost Estimates	Net Present Value
White *et al.* (1995)	$528	$179
	($335-$614)	($114-$209)
ICF (1995)	$516	$175
RDI (1995)*	$220	$75
	($100-$360)	($34-$122)
Burtraw *et al.* (1997)	$284	$97

Notes: * RDI (1995) estimates are for allowance prices rather than marginal costs.

2. Low price and widespread availability of low sulfur coal.

Low sulfur fuel appears to account for about half of the emission reductions in Phase I, but more importantly it accounts for emission reductions at the margin, serving to set marginal costs and allowance prices. The most important aspect in the trend toward lower compliance costs is that, while the demand for low sulfur coal has gone up, the price has gone down due to dynamic changes in coal markets. Also, there is roughly equal access to low-priced coal to all utilities affected by Phase I regardless of their location.

The relevant factor for determining the marginal cost of fuel switching or blending as a compliance option is the difference between low and high sulfur fuel, termed the "sulfur premium." This premium widened in 1990, but then stabilized and narrowed in most states since then. Surprisingly, the shift in demand toward low sulfur coal did not cause the price of low sulfur coal or the sulfur premium to rise. Thus, switching to low sulfur coal did not entail a major economic burden, as some analysts for electricity industry had predicted it would in the 1980s.[4]

After Phase II requirements are in place in 2000, the range of sulfur content in coal that achieves compliance is cut to about half that in Phase I. Focusing demand on this narrower range of coals will test the capability of the supply system to deliver low sulfur coal at stable prices. Two questions are central to the determination of future compliance costs. Is it possible to further increase the infrastructure and efficiency in transporting coal from Wyoming to the east? Is the low sulfur coal resource base east of the Mississippi large enough to continue to be an important source of supply to eastern utilities?

Scrubbers may be more important for meeting compliance requirements in the future. For example, plants that were able to meet Phase I requirements by blending low and high sulfur coals are likely to be faced with a choice between a switch to low sulfur coal or the installation of a scrubber. The capital costs associated with switching from high to low sulfur coal is about 35% of the capital costs of a scrubber per kW of capacity. In addition, if the answer to either of the two questions raised above about the supply of low sulfur coal turns out negative, and low sulfur coal is not as competitive in Phase II, scrubbers may be the cheapest option for meeting the emissions cap.

[4] In fact, one industry study suggested the costs of sulfur abatement would be higher if fuel switching played an important role, because although "intra-firm trading" would reduce expensive scrubbing it would increase reliance on low sulfur coals resulting in an increased sulfur premium that would raise costs for units already using low sulfur coal. (TBS, 1986).

3. Competition and innovation.

The minemouth price of low sulfur coal located in the Powder River Basin has always been cheaper than eastern alternatives, but the geographic extent of the market has been limited by transportation costs. As noted by Ellerman and Montero (1996), Fieldston Company (1996) and Burtraw (1996), the cost of rail transportation from the Powder River Basin to delivery points east has fallen recently. Because of competition created by the Staggers Rail Act of 1980, the cost of transportation from the Powder River Basin has declined from a rate of over two mills per ton-mile in the early to mid 1980s to less than one mill per ton-mile today (Ellerman and Montero, 1996), p 5). Railroad competition has also reduced rail rates for central Appalachian and midwestern coals, but by less than the reduction in Powder River Basin rates for delivery to the midwest. As reported by Burtraw (1996, p. 13), transportation rates dropped from 20-26 mills per ton mile to 10-14 mills over the same period.

Another area of innovation has been coal-blending at the power plant. The blending of fuels with different sulfur contents was thought difficult before 1990. Since that time engineers have learned they can blend up to 40% low sulfur subbituminous coals with higher sulfur bituminous coal, without incurring major capital expense or a decline in performance.

Yet another leading compliance option is scrubbing. The cost of installing and operating scrubbers has fallen in recent years, no doubt in response to competition from lower sulfur coal while removal efficiencies have improved. In addition, the fact that "a ton of emissions saved is an allowance earned" gives an incentive for utilities and scrubber suppliers to find ways to improve the efficiency of existing scrubbers.

4. General equilibrium effects

One source of systematic bias in engineering models and many economic models is the failure to take into account all the opportunities that individuals in the economy have to alter the investment and consumption behavior in response to changes in prices. For instance, since electricity prices are affected by the SO2 program, consumers may decide to switch to other sources of energy services at less cost. Goulder *et al.* (1996) embed a ballpark estimate of marginal technological abatement cost within a computable general equilibrium model. This model allows producers and consumers to substitute among alternatives as the price of electricity changes reflecting expenditures on technological abatement. These substitutions tend to amplify emission reductions in their model; consequently, the environmental goal of a 10 million ton reduction is achieved with less investment in technological abatement than would be anticipated without such opportunities to substitute, and at a lower cost. They find the general equilibrium context to lower the private marginal abatement costs by 5 to 15 percent.

Regulatory Influences

5. Regulatory incentives promoted "uneconomic" scrubber investments that, once in place, have low marginal cost.

Scrubbing accounts for about 50 percent of the emissions reductions in Phase I. This compliance option has been heavily promoted in some states by the legislatures and state public utility commissions. Scrubbing involves large up-front capital costs, an anathema in an industry already burdened by excess generating capacity and facing the prospect that a significant part of their capital costs cannot be fully recovered in a more competitive market.[5] Although scrubbers have been installed on 14 plants (26 generating units) to meet Phase I compliance requirements, their choice may not reflect an underlying economic advantage as much as favorable regulatory treatment, as described previously. In addition, 19 units qualified for a significant bonus of emission allowances (3.5 million tons, or over 10 percent of the allocation in the five years of Phase I) awarded by the CAAA to utilities that add scrubbers in Phase I. Even with these bonuses, these investments appear uneconomic *ex post.* Although from the current perspective capital cost of investments in retrofit scrubbers appear

[5] Chao and Wilson (1993) estimate that the option value provided by holding allowances rather than scrubbing is worth $85 per ton, although their calculations assume that the price of allowances is $400 per ton and the elasticity of low sulfur coal is very low.

uneconomic, once in place their operating costs are low, perhaps $60-$90 per ton removed, so they will be run to full capacity. The operating costs of scrubbing do not determine the marginal abatement cost, since they are fully utilized. However, they reduce the need and lower the marginal cost for other compliance options, thereby affecting allowance prices.

6. The annual auction provides incentives for buyers and sellers to understate their opportunity costs, which may have an influence on allowance prices.

The auction design set forth in the statute is a discriminating price, sealed bid auction that provides strategic incentives for bidders and sellers to understate their reservation prices (Cason, 1993, 1995). Whether this incentive has led to average auction prices that are biased relative to opportunity costs is an open question. Joskow, Schmalensee and Bailey (1996) argue that the auction has been unimportant with regard to the performance of the allowance trading program generally. Furthermore, some utilities have argued that they could do better if they were allowed to retain ownership of allowances that are allocated through the auction. Ellerman and Montero (1996) suggest, however, that the auction played a useful role in the early stages of the program in signaling the relatively low compliance costs that faced many utilities. Further, some brokers and utilities report that future allowance transactions are hinged to the auction price, so that any change in the auction would disrupt the evolution of the market. Whether or not the auction design is amended in the future, evidence is consistent with the notion that the annual auction is poorly designed and provides a price signal below true opportunity costs. Whether the influence of the auction is or is not important has not been determined convincingly

The Imagined versus Real Program

7. Bonus allowances add to the surplus of allowances in the early stage of the program, with downward pressure on price.

One aspect of Title IV that was not included in many early models of the program is the role of bonus allowances for utilities that chose to meet emission reductions through scrubbing. These allowances expand the amount of Phase I allowances available by 3.5 million, over 10 percent of allocations in Phase I. This increase in supply in the near term places downward pressure on costs and on allowance prices by delaying the necessity of abatement expenditures.

8. The two phases of the program segregate most potential allowance sellers into Phase I and buyers into Phase II, resulting in a near term downward trend in the price of allowances.

Burtraw *et al.* (1997) estimate the mean marginal abatement cost weighted by emissions at various facilities in 1994. They find the cost for Phase I facilities in 1994 to be $60, and for Phase II facilities to be $384. This difference suggests that a substantial bank would accumulate to delay the relatively more expensive abatement efforts that otherwise would be required from Phase II facilities after 2000. If the allowance market performed perfectly, the accumulation of an allowance bank would not necessarily have an impact on the relationship between observable allowance prices and marginal costs. However, to the extent there are market imperfections, less than perfectly rational planning, or regulatory intervention, the asymmetry between Phase I and Phase II may exacerbate trends in the allowance market that are unrelated to technological costs pushing down current allowance prices.

9. The opportunity to rely on Substitution and Compensation units further reduces the costs of complying with Phase I emission reductions.

Substitution and Compensation units voluntarily brought into Phase I typically have the lowest marginal costs of units affected in Phase II. By opting into Phase I, managers at these units can begin emission reductions at these units and delay reductions at other units by building up their allowance bank. Hence, to the extent that the surplus of allowances in Phase I leads allowance prices to diverge from naive estimates of marginal abatement cost, this trend would be exacerbated by the opportunity to use Substitution and Compensation units in Phase I.

5. CONCLUSION

The puzzle that has emerged from the early experience with the SO2 allowance trading program is: Why are allowance prices so low, especially when trading volume appears to be lower than expected? This paper offers several answers to this question. The conclusion that emerges is that the institution of allowance trading and the flexibility it gives to firms has enabled electric utilities to achieve environmental goal at dramatic reductions in costs, compared to previous regulatory experience. However, one must also consider the particular aspects of this program that delay significantly the time at which future investments will be incurred. This often overlooked factor also contributes significantly to the low allowance prices that have been observed in the first years of the program.

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