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THE EFFECT OF THE TITLE IV ACID RAIN CONTROL PROVISIONS ON SO_2 COMPLIANCE COSTS

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ABSTRACT

Title IV of the 1990 Clean Air Act Amendments instituted a number of regulatory mechanisms designed to lower the cost of reducing emissions of acid rain-causing pollution from electric utility power plants. In this paper we estimate the cost-savings associated with three flexibility-enhancing provisions of Title IV: (1) intra-utility allowance trading, (2) allowance banking, and (3) inter-utility allowance trading. Utility compliance costs under each provision were estimated and compared with compliance costs under a less flexible command-and-control policy using the Utility SO_2 Compliance Planning Model (USCPM), a dynamic optimization model hat we have developed. The results of the analysis indicate that each of the flexibility enhancing provisions analyzed can contribute to significant overall cost-savings. Another important result is that substantial cost-savings are possible even in the absence of an active inter-utility allowance trading market.

INTRODUCTION

The Title IV (Acid Rain) Provisions of the 1990 Clean Air Act Amendments requires reductions in emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) from electric utility power plants. SO_2 and NO_x react in the atmosphere to form acidic species that contribute to "acid rain." Wet or dry deposition of these acidic species, can have adverse impacts on sensitive forests and aquatic ecosystems by changing the natural acidity of soils, lakes, and streams. Acid deposition can also damage buildings and monuments and corrode metallic structures such as bridges.

In 1985, approximately 70% of U.S. SO_2 and 30% of NO_x emissions came from coal-fired electric power plants (USEPA, 1992). The large majority of these sources were located in the Midwest and Northern Appalachian regions of the country where high-sulfur coal interests had effectively blocked previous attempts at passing acid rain control legislation.

A major concern of stakeholders in these regions was that acid rain legislation would reduce the demand for high-sulfur coal, thus adversely impacting local economies that relied on revenues from high-sulfur coal production. Additionally, since the costs of reducing SO_2 and NO_x would be borne largely by electric utilities and their customers in one region of the country, while the benefits would be likely realized elsewhere, equity issues were a major stumbling block to enacting legislation.

It became clear that flexible regulatory approaches were needed to reduce compliance costs, and thus make acid rain legislation more politically palatable. Title IV represented one such approach. Instead of using a traditional "command-and-control" regulatory framework that required pollution abatement on a source-by-source basis, Title IV instituted a number of provisions designed to increase utility compliance flexibility and thus lower compliance costs. Perhaps the best known of these provisions is the SO_2 emissions trading market, which was designed to provide financial incentives to utilities to reduce SO_2 in a cost-effective manner.

Because Title IV is the first large-scale implementation of a flexible incentive-based environmental regulatory framework, economists, regulators, environmental groups, and industry managers have taken a keen interest in assessing its success and merits compared to other forms of (less flexible) regulation. The legislation also has been viewed as a test case for evaluating the potential of flexible incentive-based methods for regulating other forms of industrial pollution. It is therefore important to evaluate the successes and failings of the legislation in order to improve upon it in future applications of incentive-based regulatory frameworks (Hahn and May, 1994).

From a purely economic point of view, there are two criteria that can be used to evaluate the success of market-based environmental regulations like Title IV (Burtraw, 1995). The first is the improvement in cost effectiveness of obtaining

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abatement goals relative to other, less flexible, environmental regulations. The second is allocative, or market efficiency, which measures the extent to which social opportunity costs are reflected in resource prices, and thus the economic decisions made by electric utilities and their customers.

In this paper, we concentrate on the cost-effectiveness measure. We evaluate the cost savings associated with three flexibility-enhancing provisions of Title IV: (1) intra-utility allowance trading or averaging, (2) allowance banking, and (3) inter-utility allowance trading. Cost savings are calculated relative to a command-and-control baseline.

Although other analyses (e.g., USGAO, 1994; USEPA, 1989) also have estimated the savings associated with intra- and inter-utility trading, this analysis is the first (insofar as we can infer from the literature) to isolate the cost-savings potential of emissions banking. Banking has proven to be an extensively utilized provision of Title IV to date and, according to our estimates, accounts for a significant fraction of the overall cost-savings associated with Title IV.

In order to make these estimates, we have developed a dynamic optimization model of electric utility SO_2 compliance. The Utility SO_2 Compliance Planning Model (USCPM) predicts utility SO_2 compliance strategies over time subject to demand and emission constraints. The model utilizes publicly available data sources on generating-unit characteristics such as capacity and heat rate, the price and availability of various coals, existing environmental control devices, as well as other factors influencing the cost of compliance alternatives.

The next section of this paper briefly reviews the Title IV SO_2 and NO_x provisions. We then analyze utility compliance behavior to date, and explore the extent to which the various flexibility-enhancing provisions of Title IV have been employed. This discussion motivates our analysis of the cost-savings potential of the three flexibility-enhancing provisions of Title IV mentioned earlier.

TITLE IV ACID RAIN PROVISIONS

The primary goal of Title IV is to achieve environmental and public health benefits through reductions in emissions of SO_2 and NO_x, the primary causes of acid deposition (USEPA, 1992a). To achieve this goal in a cost-effective manner, the program makes use of innovative, market-based approaches for controlling air pollution. These approaches are most closely tied to SO_2 control but some of their provisions apply to NO_x reductions as well. In the following two sections, the SO_2 and NO_x emission reduction programs are briefly reviewed.

The SO_2 Reduction Program

Title IV of the Clean Air Act Amendments mandates a reduction of annual SO_2 emissions by 10 million tons below 1980 levels. To achieve this goal, the law requires a two-phase reduction of emissions from fossil fuel-fired electric power plants. Phase I began in 1995 and affects 263 units at 110 of the highest emitting (mostly coal-burning) power plants. A unit is subjected to Phase I requirements if it emitted SO_2 at a rate of 2.5 pounds per million Btu (lb/MBtu) or more in 1985 and has a generator capacity of 100 MW or more. Utilities may voluntarily bring other units into the pool of Phase I affected units via the "substitution" provision of Title IV and have done so with approximately 175 additional units (see Montero (1997) for details). Phase I affected units are allocated tradable allowances based on their average annual heat input (MBtu) over the 1985 to 1987 time period. The average annual heat input is multiplied by 2.5 lb/MBtu and then divided by 2000 to yield a total number of SO_2 allowances that the unit is allocated in each year of the Phase I (1995-1999) period. There are a few exceptions to this basic rule, the most notably being the 3.5 million "Phase I extension" allowances given to certain utilities that installed scrubbers in Phase I. Each allowance entitles a unit to emit one ton of SO_2 during or after the year it was issued. Each year, the total number of allowances a utility holds must equal or exceed the sum of emissions from all affected units that were issued allowances.

Phase II, which begins in the year 2000, tightens the annual emissions limits imposed on Phase I units and also sets restrictions on smaller, cleaner plants fired by coal, oil, and gas. The program affects existing utility units with a generator capacity of 25 megawatts or more. In most cases, allowances are allocated to these units in a similar fashion as they are Phase I, except the base SO_2 emission rate is 1.2 instead of 2.5 lbs-SO_2/MBtu. The number of allowances allocated is independent of future electricity demand growth. This was done to ensure a known and stable cap on emissions.

The transfer of allowances from one generating unit within a utility system to another within the same system (termed "intra-utility trading") is permitted. Title IV also established a market for the sale and purchase of SO_2 allowances between utility companies (termed "inter-utility trading.") In theory, a tradable market system will minimize the cost of achieving the national cap on SO_2 emissions by allowing utilities with low marginal costs of control to absorb some, or possibly all, of the abatement responsibilities of utilities that have high marginal abatement costs. Allowance transactions among utilities are allowed as long as the purchaser of allowances does not end up emitting SO_2 at a level that would violate federal or state air quality limits set under Title I of the Clean Air Act to protect public health.

A final and very important characteristic of allowances is that they may banked. That is, they may be used to cover SO_2 emissions in the year issued or in any subsequent year. Once used for this purpose, an allowance is permanently retired from circulation. Since Phase I has been in effect, many utilities have accumulated a substantial bank of allowances to facilitate compliance with the more stringent Phase II SO_2 limits.

THE NO_x Reduction Program

The goal of the Title IV NO_x program is to reduce annual NO_x emissions by 2 million tons per year (Mton/yr) below 1980 levels by the year 2000. Reductions are achieved using a two-phase strategy with compliance deadlines similar to those for the SO_2 program. Phase I began in 1996 and extends through 1999. The annual reduction target in Phase I is approximately 400,000 tons of NO_x per year and covers all dry-bottom wall- and tangentially-fired coal units that are Phase I affected under the SO_2 provisions. All dry-bottom, wall-fired and tangentially-fired boilers, whether Phase I affected or not, are termed "Group 1" boilers under the legislation. Phase II, beginning in the year 2000, places stricter emission limits on Group 1 boilers not covered under Phase I and extends the purview of emission limits to Group 2 boilers, defined as wet bottom wall-fired, cyclone, cell burners, and all other firing types.

Title IV NO_x regulations are a mix of more traditional command-and-control-based policies and more flexible forms of regulation. On the one hand, emission rates are set to reflect EPA's determination of Reasonably Available Control Technology (RACT), a technology-based standard reminiscent of command-and-control regulatory mandates. However, EPA also affords utilities some measure of compliance flexibility. Utilities may meet the RACT emission limits by averaging the emissions of two or more boilers having the same owner or operator. This approach allows utilities to over-control at units where it is technically easier or less expensive to control emissions, thereby achieving emission reductions in a more cost-effective manner. Unlike the SO_2 program, however, national NO_x emissions are not capped at a fixed level.

The EPA has provided guidance to states wishing to establish NO_x trading programs. However, these guidelines, and the trading programs they are designed to foster, focus on reducing the cost of attainment with ambient air quality standards for ground-level ozone (set under Title I of the Clean Air Act) rather than the Title IV acid rain provisions.

THE PHASE I COMPLIANCE LANDSCAPE

Of the various provisions embodied within Title IV, the tradable SO_2 allowance market has been the most widely publicized. Given this widespread publicity, it is no small irony that the most notable feature of the early allowance market was the conspicuous absence of all but a handful of utility participants.

In 1995, only eight of 71 Phase I affected utilities emitted SO_2 in excess of their 1995 allowance allocation. Those eight utilities thus purchased allowances for the purpose of Phase I compliance (Siegel, 1997). Interestingly, 79% (111,000) of these allowances were purchased by *a single* utility (Illinois Power Co.). Additionally, only 61% (5.3 million) of the 8.7 million total allowances issued in 1995 were used to cover 1995 SO_2 emissions (Ellerman et al., 1997). The remaining allowances were held (banked) for future use in Phase II. Although there has been a recent rise in allowance trading volume, the emission data suggest that these transactions are intended for Phase II compliance, and/or are of a speculative nature.

Various explanations for this behavior have been offered in the literature. They include financial disincentives to trading introduced by state Public Utility Commissions (Kerr, 1995; Stavins 1995); biased cost-recovery rules favoring scrubbing (Bohi and Burtraw, 1992; Coggins and Smith, 1993); market developments which have made non-trading-based compliance strategies economical (Burtraw, 1995, Ellerman and Montero, 1996); and disincentives to trading embodied within Title IV itself (Burtraw, 1995; Siegel, 1997).

Some early observers such as Zorpette (1994) and Wald (1995) pointed to the inactive allowance market as a basis for questioning the overall success of Title IV. Others (Burtraw, 1995; Bailey 1996) have noted that although the level of utility participation in the allowance market has fallen short of the expectations of its early proponents, this benchmark alone is insufficient for evaluating the success of Title IV. Title IV instituted several innovative regulatory mechanisms designed to reduce the cost of meeting emission reduction goals. Utilities may reallocate allowances internally (i.e., intra-utility trading or averaging), use low sulfur coal, shift generation away from dirtier units towards cleaner ones, retire units, install flue gas desulfurization (FGD) systems, perform early abatement in anticipation of higher compliance costs in the future (i.e., bank allowances), etc. Cost savings do not, therefore, depend solely on inter-utility allowance transfers.

In fact, the data show that utility SO_2 compliance costs to date *have* been low compared to early (pre-1990) predictions. This is because the cost of other compliance alternatives, such as switching to low-sulfur coal and installing FGD equipment, has dropped precipitously since Title IV was first drafted. The data also reveal smaller differentials in the cost of low-sulfur coal delivered to historically high-emitting eastern power plants (Siegel, 1997). This diminishes the economic incentive to engage in inter-utility trading since cost-savings hinge upon disparities in utility marginal control costs.

A question that arises in light of these market developments is the extent to which Title IV has influenced observed developments in the coal and FGD markets. In this paper, we assume that Title IV has not had an appreciable impact on such developments. That is, even if Title IV had afforded less compliance flexibility, we assume that technological improvements (e.g., more reliable scrubbers) and regulatory reforms (e.g., deregulation of the railroad industry) leading to reduced SO_2 compliance costs would have occurred anyway. A recent analysis by Burtraw (1997) lends support to this hypothesis. To the extent that the flexibility embodied within Title IV might have accelerated declines in low-sulfur coal and scrubber prices, our estimates for the cost-savings of Title IV may be understated.

THE ANALYSIS FRAMEWORK

We predict utility compliance behavior in Phase I (1995-1999) and early Phase II (2000-2005) under four forms of acid rain legislation. The first is a command-and-control (hereafter "C&C") framework that mandates emission caps on a unit-by-unit basis and allows neither averaging of SO_2 emissions between units nor inter-temporal banking. The emission caps are based on the allowances allocated to each unit under Title IV. The second and third forms of acid rain legislation are "variants" of Title IV. One allows more flexibility than C&C via intra-utility allowance trading or averaging (hereafter "intra-trading"). The third measure extends the level of flexibility by allowing allowance banking in addition to averaging (hereafter "intra-trading and banking"). Finally, the fourth measure represents the "full" Title IV provisions. As such, it grants the greatest degree of compliance flexibility by allowing inter-utility allowance trading in addition to intra-trading and banking. Hereafter this is referred to as "Title IV." Under this framework, we assume that a perfectly functioning allowance market allocates abatement responsibilities among utilities such that the total cost of meeting a national SO_2 emissions cap is minimized.

Table 1 lists the principal characteristics of the four regulatory policies considered. All policies rely on the same two-phase reduction schedule adopted for Title IV (1995-1999, 2000 and beyond.) The policies differ only with regard to the flexibility they afford in meeting the SO_2 reduction target.

Utility compliance behavior to date most closely follows what would be expected under intra-trading and banking. An analysis of the 1995 and 1996 emission data show that utilities have indeed made use of the intra-utility trading provision. Many units have emitted SO_2 at a rate in excess of 2.5 lb/MBtu while others have emitted well below this rate. Furthermore, allowance banking has been a readily visible characteristic of utility compliance strategies. By the end of Phase I, EPRI (1995) estimates that the cumulative reserve of banked SO_2 allowances will be between 7 and 15 million tons (Mtons).

The USCPM operates at the single utility level. Utilities are modeled as collections of generating units meeting a projected annual energy demand subject to SO_2 emission limits over a planning horizon. The model user can specify any of the policy options listed in Table 1 in addition to a "pre Title IV" case where units are constrained only by the State Implementation Plan (SIP) emission limits in place before passage of the 1990 Clean Air Act Amendments. We use the latter case as the baseline for calculating the compliance cost of the four regulatory policies discussed earlier.

Table 1. Characteristics of Regulatory Policies Considered

	Least Flexible	Regulatory Policy →		Most Flexible
Characteristics	**C&C**	**Intra-trading**	**Intra-trading and Banking**	**Inter-trading and Banking (Title IV)**
Nature of SO_2 emissions limit	Tonnage cap at each generating unit	Utility tonnage cap	Utility tonnage cap	Utility Tonnage Cap
Intra-utility trading of allowances (averaging)	no	Yes	yes	yes
Emission Allowance Banking	no	No	yes	yes
Inter-utility trading of allowances (national market)	no	No	no	yes

The choice of a compliance strategy for meeting the SO_2 emission limits is formulated as a multi-period optimization problem. SO_2 compliance planning decisions are made with respect to a set of decision variables that define the SO_2 control configuration for all units within a given utility. SO_2 control configurations are defined on the basis of fuel type, emission control equipment, generating unit commitment, and the time period in which these options are implemented.

Each utility is assumed to minimize the net present value (NPV) of generation costs while complying with energy demand and SO_2 emission constraints over a planning horizon. Emission abatement requirements constrain utility actions to those that meet the mandates of the particular type of legislation being studied. Utilities may comply with emission constraints by employing one or a combination of the following strategies at each unit:

1. fuel switching or blending to low-sulfur coal;
2. retrofitting a flue gas desulfurization (FGD) device;
3. reordering the dispatch of units to utilize cleaner capacity more intensively.

Allowance purchases are considered after the least-cost of abatement curve is generated for each utility. For a given utility-wide reduction level, this curve shows the least-cost means of compliance through the optimal use of each of the three compliance strategies listed above. The efficient abatement supply (marginal cost) curve can then be estimated for each utility. The behavior (i.e., whether it's a net buyer or seller of allowances) of a utility in the allowance market is determined by its abatement supply curve.

The model maintains data on all Title IV affected generating units. We have relied exclusively upon publicly available data such NADB (1994), USEIA767 (1980-1993), and FERC423 (1980-1995). A more detailed description of the USCPM (including economic parameter assumptions and technology cost and performance sub-modules) can be found in Siegel (1997). In order to minimize data handling and computational requirements, the analysis was limited to a set of 387 generating units that collectively bear approximately 93% of the SO_2 abatement required under of Phase II. We call this set, which contains only large and historically high-emitting coal-fired units, the 387 "big and dirty" or B&D units.

An essential component in any model that predicts SO_2 compliance cost is the method employed to estimate the delivered price of coal at different generating facilities. Site-specific characteristics such as access to various transportation modes can strongly affect the delivered price of coal at a given plant. The coal model in the USCPM divides the utility sector into 33 demand regions based on the geographic clustering of U.S. coal-burning plants. There are 11 coal-supply regions based on the locations of the principal coal-producing mines in the contiguous U.S. Delivered prices are estimated based on historical costs reported for each supply/demand pair, combined with assumptions for the future trajectories of coal prices. Because of the large number of geographical regions modeled, the coal-price estimation procedure implicitly accounts for at least some of the transportation-related coal price differences between plants.

MODELING RESULTS

The USCPM was run over a range of different input parameter assumptions affecting coal prices, FGD retrofit costs, electricity demand levels, and utility planning horizons. Model predictions for utility compliance costs and technology choice were most sensitive to the sulfur premium assumed for low- and mid-sulfur coals (i.e., the delivered price above high-sulfur coal). Five sulfur premium assumptions were modeled based on estimates given elsewhere (Torrens et al., 1992; EPRI, 1995). The assumptions for each scenario are given in Table 2. These values represent average sulfur premiums. Since the USCPM coal model incorporates a measure of site specificity, the sulfur premium realized at any given plant may be above or below the quantity listed in Table 2. The "Moderate" sulfur premium scenario yielded the best agreement with actual 1995 data on utility coal choice (Fig. 1), FGD retrofit capacity, and SO_2 emission levels. This scenario was used for all subsequent analyses for which we present results.

Cost-Savings of Title IV

Figure 2 shows the predicted SO_2 compliance costs for the 387 "big and dirty" generating units under the four regulatory policies discussed earlier. The estimates include only the fixed and variable costs associated with SO_2 reduction equipment, low-sulfur coal purchases, and the reordering of unit commitment schedules. All estimates are given in constant 1995 dollars. The costs of continuous emission monitors (CEMS) are not included in the estimates.

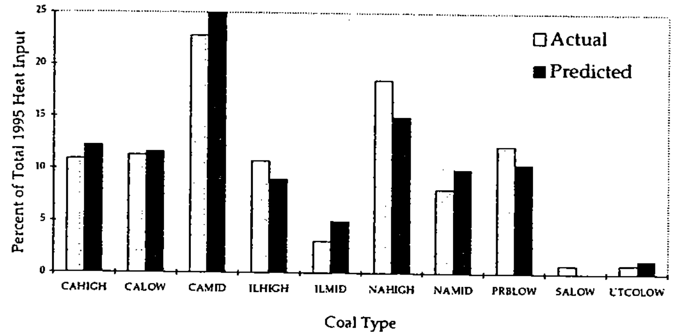
The first conclusion to be drawn from Fig. 2 is that in present value terms, all variants of Title IV are more cost effective than command-and-control. We estimate that Title IV without banking (Intra-trading) saves about $0.65 billion dollars in present value terms, a savings of approximately 6% over command-and-control. When banking is allowed (Intra-trading and Banking), the cost savings of $2.8 billion represents a 26% savings compared to the C&C case. Thus, the incremental cost savings of banking relative to intra-utility trading without banking is $2.2 billion in total net present value. On an annualized basis, this is a savings of $0.30 billion/yr, relative to $0.10 billion/yr saved without banking (compared to command-and-control).

Our estimate of $0.87 billion for the compliance cost borne by utilities in 1995 under "intra-trading and banking" closely agrees with the $0.84 billion figure recently given in USEIA (1997). While the latter estimate is based on a post-facto analysis using 1995 data, our estimate derives from a predictive optimization-based model that does not rely upon actual compliance data. This suggests that utilities have done a good job at extracting the cost-savings obtainable through intra-utility trading and banking.

However, the gains from inter-utility trading are potentially even greater. We estimate that if utilities engaged more

Table 2. Sulfur Premium ($/ton) for Five Scenarios

Scenario (Sulfur Premium)	Sulfur Content of Coal (lb/MBtu)			
	≤1.2		1.2 – 2.5	
	Phase I	Phase II	Phase I	Phase II
Zero	0	0	0	0
Small	2	4	1	2
Medium	4	6	2	4
Moderate	6.50	8	4.50	6
Large	8	12	6	8



Nomenclature for Mining Regions and SO_2 Content (lb/MBtu)					
CA	=	Central Appalachian	HIGH	=	> 2.5 lb/MBtu
IL	=	Illinois Basin	MID	=	1.2–2.5 lb/MBtu
NA	=	Northern Appalachian	LOW	=	< 1.2 lb/MBtu
PRB	=	Powder River Basin			
SA	=	Southern Appalachian			
UTCO	=	Utah/Colorado			

Figure 1. Predicted vs. Actual Coal Use for 1995 for the "Moderate" Sulfur Premium Scenario

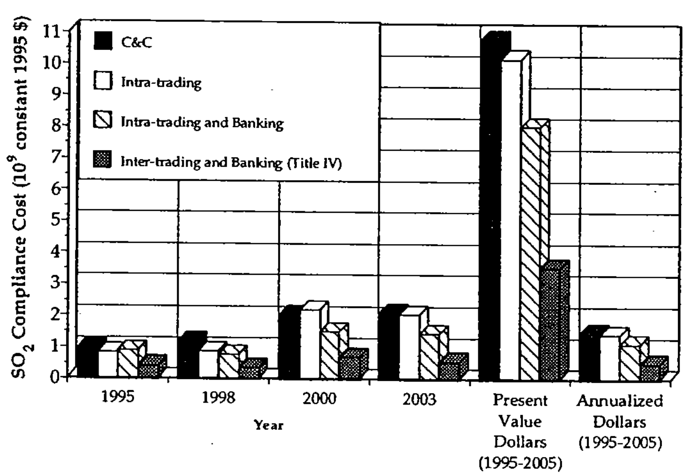


Figure 2. Estimated Compliance Cost Under Four Regulatory Policies

extensively in inter-utility trading, an additional $4.5 billion could be saved (in present value terms) compared to the "intra-trading and banking" case. In annualized terms, this translates to approximately $0.44 and $0.84 billion per year in Phase I and Phase II, respectively. These estimates suggest that state and federal efforts to encourage more active utility participation in the allowance market during in Phase II could have significant returns. Note, however, that inter-utility trading could lead to different spatial and/or temporal patterns of emissions, whose local (air quality) impacts need to be accounted for when assessing the net benefits of inter-utility trading.

Another result of our analysis relates to the temporal nature of compliance costs. Results for 1995 and 2000 show that compliance costs under "intra-trading" and "intra-trading and banking" can exceed the cost under command-and-control in an *individual* year. However, the added flexibility of intra-utility trading opens the door to economies of scale by scrubbing large units that bear a larger share of the abatement burden. In the intra-trading case, the stringent abatement requirements in 2000 are met with more intensive scrubbing compared with C&C. In the latter case, the benefits of scrubbing at any one unit do not offset reduction requirements elsewhere, so there is *less* scrubbing overall.

By 2000, the USCPM predicts 45 GW of new scrubbed capacity under the "intra-trading" case compared to 40 GW under the C&C case (see Fig. 3). The extra costs in the year 2000 is $0.15 billion reflecting the added capital requirement for the additional FGD capacity. This result is predicated on the equivalence assumption concerning the coal and FGD markets, as noted earlier, as well as an assumption that state and local-level incentives/mandates to scrub would not be more prevalent under a command-and-control framework. It is worth repeating, however, that all the Title IV variants save money in terms of total present value dollars over the full planning horizon.

The Role of Allowance Banking

The addition of allowance banking adds another dimension to the picture. Banking encourages early abatement. Consequently, costs in 1995 under "intra-trading and banking" are higher than under "intra-trading." The major cost advantage of banking is that the surplus bank carried over into Phase II greatly reduces the abatement required in later years to meet the more stringent Phase II limits. Figure 3 shows that when banking is allowed, predicted FGD retrofit capacity in Phase II is significantly lower relative to policies that do not allow banking.

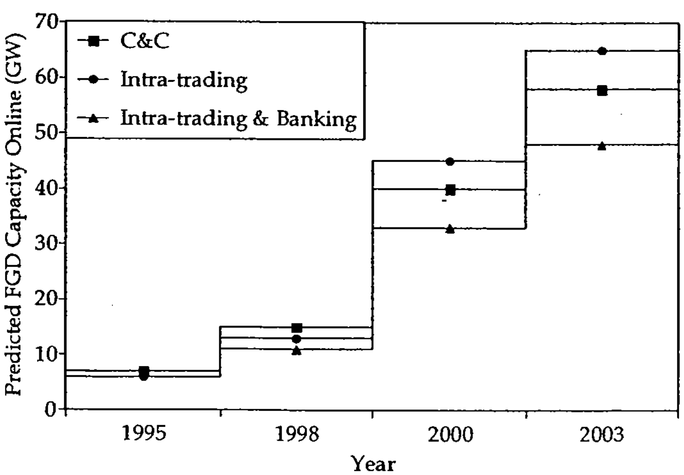


Figure 3. Predicted FGD Retrofit Capacity Online (GW)

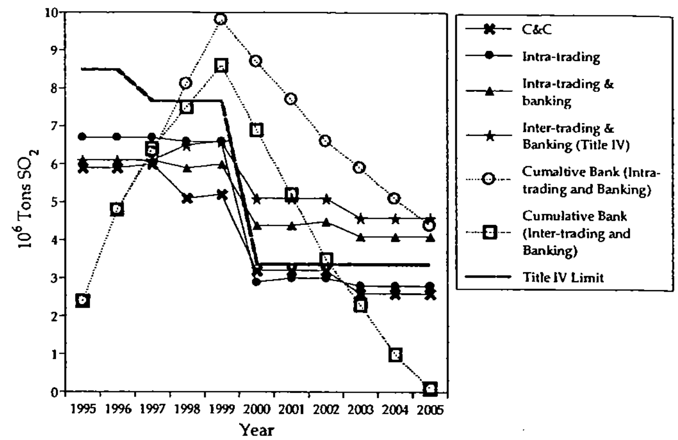


Figure 4. Predicted SO_2 Emissions and Cumulative Allowance Bank for the Four Regulatory Policies

There are potential environmental costs to banking, however. As Figure 4 shows, the Phase II SO_2 cap imposed under Title IV is not achieved until after 2005 under policies that allow banking because over-compliance in early years is followed by under-compliance in the post-2000 period. Although this is permissible under all terms and conditions of Title IV, it points to an implicit tradeoff that regulators face when granting more compliance flexibility. Cost savings may come at the expense of increased uncertainty about when and where emission reductions occur.

CONCLUSIONS AND FUTURE DIRECTIONS

The analysis presented here confirms the cost advantage of the Title IV's flexibility-enhancing provisions for SO_2 compliance. Our results suggest that cost-savings on the order of $0.10 to $0.30 billion per year are achievable without active inter-utility trading in the remainder of Phase I, and for the first five years of Phase II. Additional cost-savings on the order of $0.44 billion/yr in Phase I and $0.84 billion/yr in Phase II are obtainable through more active inter-utility trading. Our inter-utility trading case assumed a perfectly functioning market without any transaction costs, so these estimates can be considered an upper bound estimate. In all cases, the ability to bank SO_2 allowance was a major contributor to overall cost savings.

We also have begun work on extending the capabilities of the USCPM to analyze the cost-savings potential of NO_x trading. An initial case study of 15 boilers engaged in various forms of NO_x trading for Title IV compliance has yielded encouraging results. In some instances, NO_x compliance costs can be cut by a factor of two according to our preliminary analysis (Siegel, 1997). Future work in this area must consider the requirements of Title I related to the attainment of ambient ozone standards.

Finally, we believe that the USCPM modeling tool developed for this analysis represents an improved method for linking engineering-based models, economic theory, optimization methods, and policy analysis. The continued development and application of this tool can better help inform the public policy debate over the benefits and limitations of flexible-based environmental regulatory frameworks.

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