The Effects of Trading and Banking in the SO_2 Allowance Market

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Abstract

The 1990 Clean Air Act Amendments initiated a dramatic reduction in emissions of sulfur dioxide and nitrogen oxides by electric power plants. This paper provides an evaluation of the environmental and public health consequences of the trading and banking provisions of Title IV. A sizable shift in the geographic location of emissions under Title IV (in some states of over 20 percent of emissions after Title IV is implemented) is attributable to trading and/or to banking. There has been considerable concern that this shift in emissions would cause harm to downwind areas due to long-range transport of pollution. We find the resulting change in atmospheric concentrations and deposition of pollutants, and the change in monetized health benefits, are most unfavorable in the regions where emissions increase. In the East and Northeast including New York State, an area of particular concern, health benefits increase and deposition of sulfur decreases slightly as a result of trading. In the aggregate, trading results in health related benefits nationally of nearly $570 million in 1995 and about $125 million in 2005. The reason is that the geographic shift in emissions away from more populated areas leads to a decrease in exposure to harmful particulates. Meanwhile, cost savings from trading represent about 13 percent of compliance costs in the No Trading scenario in 1995, and about 37 percent in 2005. Banking has the anticipated effect of changing the timing of emissions. Banking causes a reduction of up to 20 percent in 1995 in some states and a commensurate increase in 2005. The geographic pattern of emission changes as a consequence is varied; some states reduce emissions in 2005 as a result of banking. These changes are small compared to the overall reduction in emissions, sulfur deposition, and human health benefits expected to result from the program.

Key Words: acid rain, sulfur dioxide, trading, benefit-cost analysis, Clean Air Act

JEL Classification Numbers: H43, Q2, Q4

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THE EFFECTS OF TRADING AND BANKING IN THE SO_2 ALLOWANCE MARKET

Dallas Burtraw and Erin Mansur*

INTRODUCTION

Title IV of the 1990 US Clean Air Act Amendments (CAAA) regulates emissions of sulfur dioxide (SO_2) from electric generating facilities. The program sets an annual cap on average aggregate emissions by electric generators. The cap is set to fall ultimately to a level equal to about one-half of the amount emitted in 1980. Firms are required to surrender one emission allowance for each ton of sulfur dioxide they emit.[1]

The widely acknowledged innovation of Title IV is the SO_2 emission trading program that is designed to encourage the electricity industry to minimize the cost of reducing emissions. Firms may transfer allowances among facilities or to other firms. In addition, the emission cap accommodates an allowance bank. In any year, aggregate industry emissions must be less than the number of allowances allocated for the year plus the unused surplus that has accumulated from previous years.

This paper provides an evaluation of the environmental and public health consequences of the trading and banking provisions of Title IV. We adapt and exercise an integrated assessment computer model called the Tracking and Analysis Framework (TAF) to evaluate these consequences. We account for changes in emissions of SO_2, atmospheric concentrations of sulfates and deposition of sulfur, and public health benefits from reduced exposure to SO_2 and particulate matter under these alternative scenarios. We evaluate these changes from a geographic and temporal perspective (at the state level) and compare them with estimated costs that result from trading and banking.

The environmental consequences of trading have been the subject of considerable speculation and acrimony, especially in the Northeast, which is widely thought the recipient of pollution emitted by power plants in the Midwest. In 1993 the Attorney General of New York sued the EPA to restrict allowance sales to guarantee protection of the state's resources.

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[1] In general, 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.

Subsequently, legislation passed the New York State Assembly to constrain allowance trades between in-state utilities and other entities. In April of 1998 the State of New York announced an agreement with Long Island Lighting Company (LILCO) to preclude sale of emission allowances from LILCO to other utilities for use at plants in 15 states thought to cause acid rain in New York.

Similarly, the environmental consequences of banking are ambiguous. To build up a bank, lower emissions occur in the near-term leading to greater environmental benefits in the early years of the program. "Over-compliance" to date has been trumpeted by the Environmental Protection Agency as a measure of success for the program. However, beginning in 2000 annual emissions are expected to exceed allowance allocations due to draw-down of the allowance bank, and this is likely to ignite unfavorable opinions from environmental advocates.

The SO_2 program now serves as an international model as a way to reduce the costs of compliance with environmental goals. In September 1998, the EPA announced another substantial trading program for NO_X emissions by electric utilities in 22 eastern states that is explicitly based on the "success" of the SO_2 program. Despite the acrimony about its environmental consequences and the enthusiasm for potential cost savings, there exists little analysis of the actual effects of allowance trading and banking.

In brief, this analysis finds a sizable shift in emissions due to trading and banking in 1995 and 2005, the years examined in this study, with changes in some states of over 20 percent of emissions under Title IV. Trading leads to an increase in emissions in the Midwest and a decrease in the East and Northeast. However, the geographic consequences are not consistent with the fears of program critics. The changes in atmospheric concentrations of pollutants and in monetized health benefits are most unfavorable in the regions where emissions increase. Health benefits actually increase in the East and Northeast due to trading. In the aggregate, trading results in health related benefits nationally of nearly $570 million in 1995 and about $125 million in 2005. The reason is that the geographic shift in emissions away from more populated areas leads to a decrease in exposure to harmful particulates. Deposition of sulfur in the eastern regions also decreases by a slight amount as a result of trading, even in New York State, an area of particular concern.

Meanwhile, cost savings from trading represent about $97 million, or 13 percent of compliance costs in the No Trading scenario in 1995. In 2005 cost savings attributable to trading total $531 million, or about 37 percent of compliance costs in the No Trading scenario.

Banking has a predictable effect on the timing of emissions and the benefits of emission reductions, with emission changes of up to 20 percent in 1995 and 2005 in some states. The geographic pattern of emission changes is not simple; some states actually reduce emissions in 2005 as a result of banking. However, in 1995, emission reductions due to banking lead uniformly to decreased concentrations and deposition, and emission increases in 2005 lead uniformly to increased concentrations and deposition.

BACKGROUND

For years, economists have urged that policy makers use market-based approaches such as emission permit trading to control pollution (taxes or tradable permits). The motive is that trading should limit SO_2 emissions at a lower cost than traditional command-and-control approaches. Rather than forcing firms to emit SO_2 at a uniform rate or to install specific control technology, trading emission allowances enables firms operating at high marginal pollution abatement costs to purchase SO_2 emission allowances from firms operating at lower marginal abatement costs. This provides a means of compensating firms with relatively lower marginal abatement costs for assuming a relatively greater share of the costs of emission reductions. The lower cost firms are expected to expand their abatement efforts until their marginal costs rise to meet those of higher cost firms. By equating marginal costs throughout the industry, the total costs of emissions reductions would be minimized.

Banking is thought to offer similar opportunities for cost savings by affording firms flexibility in timing their investment for compliance. Title IV is implemented in two phases, and the second phase is significantly more stringent and affects a greater number of facilities. With the opportunity to bank unused emission allowances, a firm may decide to invest in a relatively greater level of abatement at one facility during Phase I and create an allowance surplus that can be used to delay further investments at the same or other facilities in Phase II.

The first phase of Title IV began in 1995 and affected about 110 facilities, mostly large coal-fired power plants. The second phase will begin in 2000 and will tighten average emission rates at Phase I facilities and also will affect about 700 additional facilities including coal and oil-fired plants. Total emission reductions are expected to be about one-half of emissions measured from a baseline. However, the full effect of the emission reductions will not be felt until after 2010, when the allowance bank built up in Phase I is largely depleted.

The SO_2 program places no controls on the regional pattern of trading. The program operates under the fiction that SO_2 is a uniformly mixing pollutant, meaning that where damage from pollution occurs is independent from where emissions occur. In fact, environmental damage does vary with the source of emissions and an early version of the legislation would have divided the nation into two trading regions, divided roughly by the Mississippi River, in order to preclude broad geographic shifts in the pattern of emissions. The decision not to divide the nation in this way in the final legislation was a policy choice intended to expand the market and the opportunity for cost savings by affected facilities.

Few studies have examined this issue of trading and none have explored the geographic impact of banking. EPA (1995) offered a comparison of sulfur deposition for a set of scenarios for the year 2010 including one that analyzed the effects of trading. NAPAP (1991) offered a hypothetical illustration of changes in emissions and deposition that could result from a trading program, but the scenario was not linked to an economic model of compliance costs or trading. A comparison of these studies with our results is presented in the sections that follow.

More recently, EPA (1998) find that most allowances used for compliance in 1995 and 1996 were used in the same state as they were allocated, indicating little geographic sifting of emissions due to trading. However, several authors have suggested that the amount of allowance trades realized to date has been less than necessary to capture fully the potential gains from trade (Bohi and Burtraw, 1997; Rose, 1997; Ellerman et al., 1997). Two papers have compared the actual pattern of trading activity to the joint cost minimizing allocation of emission abatement activities identified in various optimization models, and found that potential cost savings are not fully realized in the early years of the program (Carlson et al., 1998; Solomon, 1998).

In this analysis we follow in the tradition of solving an optimization model to identify the pattern of trades that would minimize costs. The results in this analysis deviate from actual trading patterns and from emissions for 1995. However, over time one can expect the increasingly competitive forces in the electric utility industry to impose discipline on the market and lead to an increase in trading activity converging on the least-cost solution we identify. Indeed, Kruger and Dean (1997) find the amount of economically significant trading activity has virtually doubled every year and this trend continues to the present.

One of the subtle aspects of the implementation of Title IV is the comparison of potential compliance activities, especially the choice between construction of a flue gas desulfurization equipment (scrubbers) as a means of compliance versus switching to lower sulfur coal. Failing to anticipate these investments is another way in which modeling results could differ importantly from reality. In this analysis we have taken Phase I scrubber investment decisions as given in the examination of trading. Potential further investments in scrubbers in Phase II are determined endogenously in the investment algorithm. These investments are considered within the model, in order to isolate their contribution to the banking of allowances in Phase I for use in compliance in Phase II.

THE TRACKING AND ANALYSIS FRAMEWORK

The Tracking and Analysis Framework (TAF) is used to conduct this analysis.[2] TAF is a nonproprietary and peer-reviewed model constructed with the *Analytica* modeling software (Bloyd et al., 1996).[3] TAF integrates models of electric utility emissions and costs, pollutant transport and deposition (including formation of secondary particulates but excluding ozone), visibility effects, effects on recreational lake fishing through changes in soil and aquatic chemistry, human health effects, and valuation of benefits. All effects are evaluated at the state level and changes outside the U.S. are not evaluated. The estimation of effects is amenable to modeling at a less centralized level, and the model uses probabilistic methods to represent variations in sources of emissions, geography and population density

[2] The entire model is available at http://www.lumina.com/taf/index.html.

[3] Each module of TAF was constructed and refined by a group of experts in that field, and draws primarily on peer reviewed literature to construct the integrated model. TAF is the work of a team of over 30 modelers and scientists from institutions around the country. As the framework integrating these literatures, TAF itself was subject to an extensive peer review in December 1995, which concluded that "TAF represent(s) a major advancement in our ability to perform integrated assessments" and that the model was ready for use by NAPAP (ORNL, 1995).

within states. The considerable uncertainty in parameters in each of the modeled domains and in the underlying scientific and economic literature is partly captured through Monte Carlo simulation, and has been explored in other papers (Sonnenblick and Henrion 1997; Shannon et al., 1997; Small et al., 1998; Burtraw et al., 1998).

Burtraw et al. (1998) utilized TAF to compile a cost-benefit analysis of Title IV. They find 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.

In this analysis we limit our focus to the human health mortality and morbidity effects of Title IV in estimating monetary benefits. We also evaluate changes in atmospheric concentrations of sulfates and deposition of sulfur, which proxy for other environmental effects of interest. The model calculates benefits as estimates of the willingness-to-pay by society to avoid the health effects that are modeled. The benefits are totaled to obtain annual health benefits for each year modeled.

Health effects are characterized as changes in health status predicted to result from changes in air pollution concentrations. Impacts are expressed as the number of days of acute morbidity effects of various types, the number of chronic disease cases, and the number of statistical lives lost to premature death. The health module is based on concentration-response (C-R) functions found in the peer-reviewed literature. The C-R functions are taken, for the most part, from articles reviewed in the U.S. Environmental Protection Agency (EPA) Criteria Documents (see, for example, EPA 1995). The Health Effects Module contains C-R functions for PM_{10}, total suspended particulates (TSP), sulfur dioxide (SO_2), sulfates (SO_4), nitrogen dioxide (NO_2), and nitrates (NO_3). The change in the annual number of impacts of each health endpoint is the output that is valued. In this exercise inputs consist of changes in ambient concentrations of SO_2, demographic information on the population of interest, and miscellaneous additional information such as background PM_{10} levels for analysis of thresholds.

The TAF estimates of costs and an algorithm for determining compliance activities at different facilities were developed by Argonne National Laboratory, based on their unit inventory called GECOT. Compliance options for SO_2 reductions include scrubbing, fuel switching (including plant modifications), fuel blending, retirement and replacement of plants. The module ranks compliance options on a unit cost ($/ton reduction) basis, with the most-cost-effective units being implemented first, until the emission reduction requirements are satisfied. Emission allowance trading is modeled implicitly by allocating compliance in a cost-effective way.

THE EFFECTS OF TRADING

Legislative debates about acid rain in the 1980s had a sharp regional character. Since acid deposition typically occurs away from the source of emissions, which were largely concentrated in the Ohio Valley, many observers claimed that emissions from these power plants were contributing to environmental degradation in the Northeast.

To explore the regional effects of trading, we constructed alternative scenarios for comparison in TAF. One is a "Baseline" scenario intended to represent compliance with Title IV as it is taking shape.[4] The alternative is a "No Trading" scenario for the years 1995 and 2005. This comparison could be constructed in a variety ways.

One approach that we rejected would be to define the No Trading case such that individual facilities emit at less than or equal to the allowance allocation for that facility, absent the opportunity to trade. This approach has the disadvantage that aggregate emissions would likely be less in the No Trading case. The reason is that, absent the flexibility to trade allowances, plants are restricted to a self-sufficient compliance strategy. In addition, compliance technologies usually provide a discrete rather than continuous range of options for emission reduction. Hence, in order to be self-sufficient, an individual facility would be expected to choose the least expensive option that met or was below its emission allowance allocation, and often this option would lead to emissions that are less than the allowance allocation for that facility. Under the Baseline (with trading), over-compliance at one facility is rewarded through the opportunity to sell excess emission allowances to another facility that can then exceed its allowance allocation, keeping aggregate emissions constant. However, absent the ability to trade, over-compliance at an individual facility leads to lower emissions in the aggregate (Oates et al., 1989).[5]

Our primary interest is the influence of trading on the geographic pattern of emissions and their environmental effects. To model this, we chose a different approach. We chose to constrain aggregate emissions in the No Trading scenario to approximate those in the Baseline. This is achieved by artificially raising the allowance allocation for individual facilities in the No Trading scenario above the level corresponding to the allocation for each facility in the Baseline.[6]

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[4] The Baseline is described in detail in Bloyd et al. (1996). One constraint on the investment algorithm is that facilities that chose to scrub in Phase I of Title IV are assumed to scrub in the Baseline scenario. The reason for imposing this constraint is that given the prices of various compliance options that obtained over the nineties, many of the decisions to install retrofit scrubbers appear uneconomic *ex post* (Carlson et al., 1998), and would not be chosen given the prices of these compliance options reflected in the model.

[5] We find annual SO_2 emissions are 11.86 million tons in 1995 and 9.99 in 2005 in the Baseline. They would be 10.8 in 1995 and 8.8 in 2005 were allowance allocations fixed and aggregate emissions allowed to vary.

[6] We repeatedly solved the model to find the allocations that approximate aggregate emissions in these two scenarios. By construction, aggregate emissions are within about one percent in both scenarios for the years 1995 and 2005 that are the focus of the evaluation of trading. In other years the levels vary by a greater amount. Individual emission allocations are systematically higher in the No Trading scenario. Under Title IV, allowance allocations in Phase I are based on a historic utilization rate for each facility and an emission rate of 2.5 (lb. SO_2 per mmBtu heat input) and in Phase II allocations are based on a rate of about 1.2. In the Baseline scenario the 2.5 rate can be achieved by blending and the 1.2 rate can be achieved by switching. In the No Trading scenario allowance allocations are increased, based on rates of 3.2 in Phase I and 1.6 in Phase II. Absent the opportunity to trade, all units affected in Phase I must at least blend fuels, if not switch or scrub, in order to achieve compliance. In Phase II blending fuels is not sufficient and facilities must fuel switch or scrub to meet their allowance allocation.

To isolate the geographic effect of trading from the inter-temporal effects of banking, we take as given in the No Trading scenario the Phase I retrofit scrubbing installations in the Baseline scenario. In both scenarios, other facilities solve the inter-temporal investment algorithm to minimize net present value of compliance decisions. The result is that 15 additional facilities choose to scrub in the No Trading scenario in addition to those that scrub in the Baseline. At these facilities, scrubbing is less costly than fuel switching or blending, given their location and the transportation costs associated with alternative fuel choices. In the Baseline, these units were purchasers of allowances, but this option is not available in the No Trading scenario.

Emissions Changes from Trading

The results are reported in Table 1. The first two columns of numbers list changes in emissions as a result of the ability to trade. The total change is approximately 1 percent of aggregate emissions in the Baseline. The goal to hold aggregate emissions constant in both scenarios is difficult to achieve given the inter-temporal investment algorithm. However, the fact that emissions are slightly lower in the aggregate under Trading is a bias against the benefits of trading. Nonetheless, this bias does not seem to undermine the qualitative results regarding deposition and health benefits that are discussed below.

Figures 1 and 2 present the changes in emissions in a graphic manner, reporting the percent change in emissions from electricity generating stations attributable to trading for each state for 1995 and 2005, respectively. The figures indicate that emissions increase in the Ohio Valley, but not in a uniform way. For instance, in 1995 the effect of trading is to reduce emissions from Illinois, while they increase in 2005, in percentage terms. The effect of trading on most states outside the Ohio Valley is to reduce emissions.

Deposition Changes from Trading

The middle set of columns in Table 1 report changes in the annual sum of wet and dry sulfur deposition as a result of the ability to trade. The result is similar for 1995 and 2005 in that midwestern states experience increases in deposition. This increase in deposition aligns with the increase in emissions from some of these states, but the pattern of deposition changes is more widespread because of atmospheric dispersion and transport. The results are the converse across the northeastern, eastern and southeastern states. In both years, these regions are predicted to experience decreases in deposition as a result of the spatial flexibility of the trading program. Figures 3 and 4 display this information in graphic form as the percent change in deposition attributable to trading for 1995 and 2005.

In previous investigations, EPA (1995) projected the changes in deposition attributable to trading in the year 2010 would be less than 10 percent, usually much less, especially in the Adirondack region of New York. However, they concluded that most areas would experience a slight increase due to trading in the cases that were examined (p. 78).

Table 1: The contribution of trading to emissions, deposition and health benefits

	Change in SO_2 Emissions (thousand tons)		Change in Sulfur Deposition (kilograms/hectare)		Change in Health Benefits (million 1995 $)	
	1995	**2005**	**1995**	**2005**	**1995**	**2005**
AL	-84	-55	-0.3	-0.2	37	13
AR	0	0	0.0	0.1	0	-10
CT	0	0	-0.2	-0.2	23	27
DC	0	0	0.0	-0.3	2	5
DE	0	0	-0.3	-0.4	7	10
FL	-44	-44	-0.2	-0.2	103	88
GA	-101	-68	-0.4	-0.2	82	41
IA	-7	9	0.0	0.1	-2	-12
IL	-59	137	0.0	0.5	-21	-180
IN	114	-16	0.4	0.6	-54	-110
KY	90	261	0.4	0.9	-32	-92
LA	0	0	0.0	0.0	5	-2
MA	-13	-13	-0.2	-0.3	44	51
MD	-25	-25	-0.3	-0.4	51	78
ME	0	0	-0.1	-0.1	4	5
MI	-46	-46	0.0	0.1	-5	-37
MO	71	-5	0.1	0.1	-13	-31
MS	12	-8	0.0	0.0	6	-1
NC	-80	-78	-0.4	-0.3	116	109
NH	-6	-6	-0.1	-0.1	5	6
NJ	-2	-2	-0.3	-0.3	74	84
NY	-19	-11	-0.1	-0.2	62	90
OH	120	-85	0.4	0.2	-95	-74
PA	-60	-7	-0.1	-0.2	46	92
RI	0	0	-0.3	-0.3	8	10
SC	-21	-21	-0.4	-0.2	46	32
TN	18	54	-0.1	0.3	10	-50
TX	-1	32	0.0	0.0	6	-26
VA	-8	-21	-0.1	-0.2	56	79
WI	-8	1	0.0	0.1	0	-25
WV	14	-52	0.3	0.0	-7	0
Total	-152	-53	N/A	N/A	566	124

Figure 1

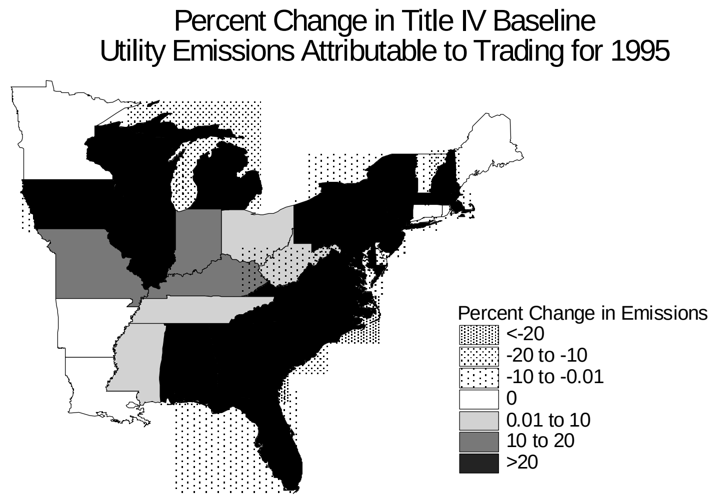


Figure 2

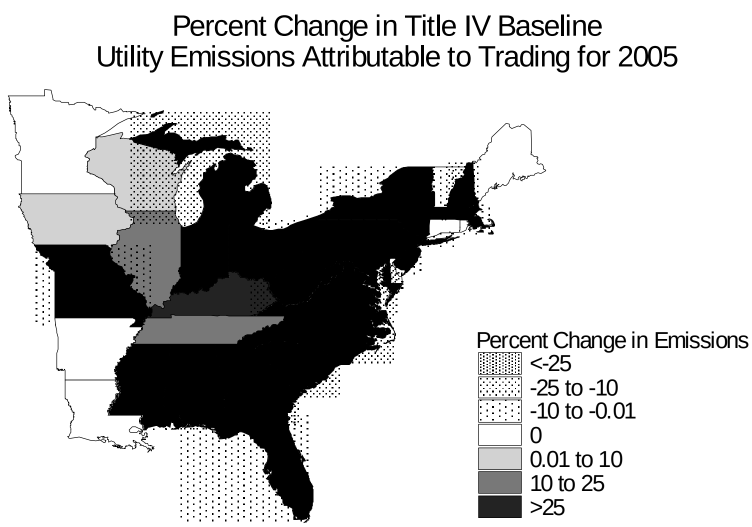


Figure 3

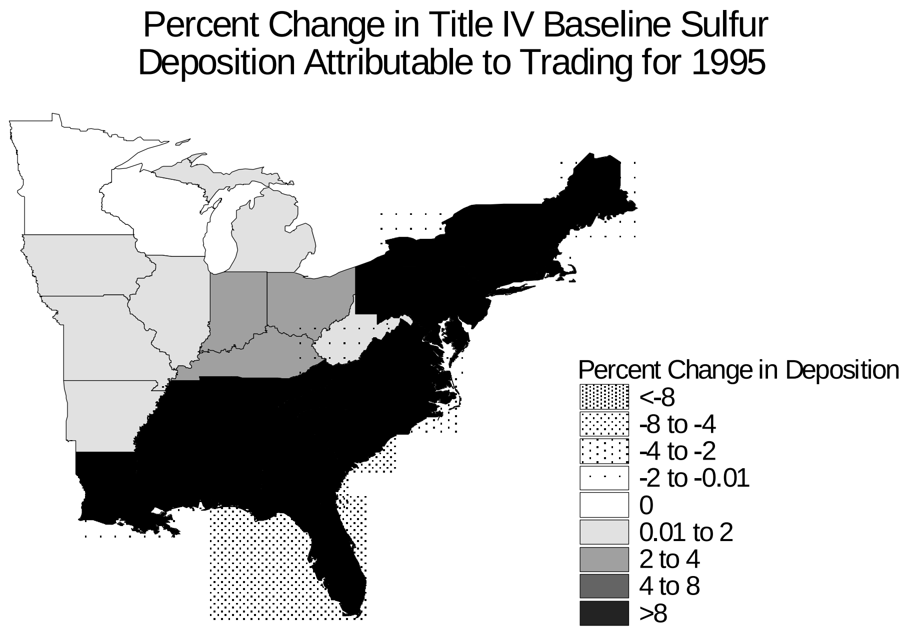
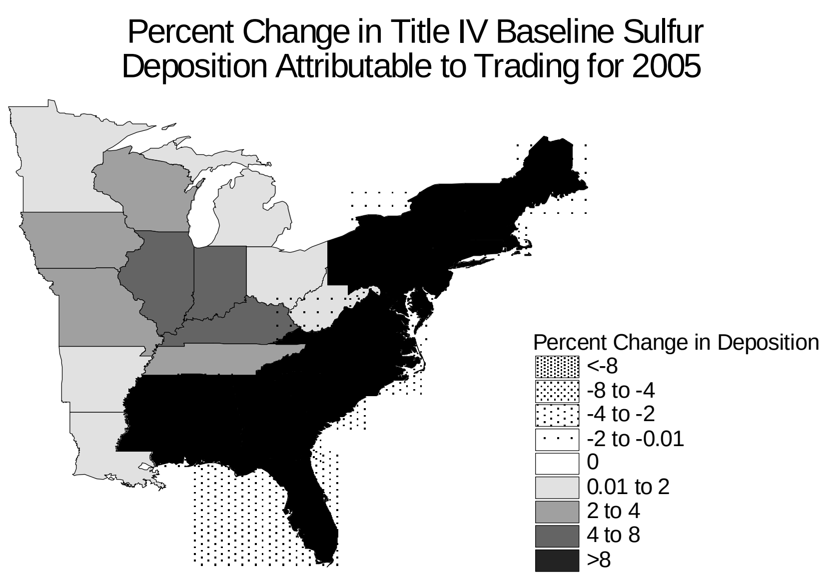


Figure 4



Our results are consistent with respect to the order of magnitude; all the states in our model experience changes of less than 8 percent attributable to trading. However, we project that the entire eastern region (including New York State) will experience a decrease in deposition. This holds despite the slight bias of greater total emissions under Trading in our model for these years, as described above.

Also, NAPAP (1991) offered hypothetical illustrations of changes in emissions and deposition that could result from a trading program but the scenarios were not linked to an economic model of compliance costs or trading. One illustration involved 250 large plants and imposed disproportionate emission reductions (comparable to the effects of scrubbing) on the 120 facilities with the highest emission rates (p.447). This allocation of emission reductions was to proxy for where reductions might occur under a trading program, and led to no change or a slight improvement in deposition in most of the East including New York State. In another example, the study compared equal percent reductions across all sources to equal emission rates within states but varying among states (p.256). This experiment found slightly higher to moderately lower levels of sulfur deposition to result in the scenario with variation among the states. Our predictions are roughly consistent with the NAPAP illustrations.

Health Benefits from Trading

The third set of columns in Table 1 represent the change in health benefits in 1995 and 2005 due to the opportunity to trade. All values are expressed as 1995 dollars, without discounting. In the aggregate, trading results in net health related benefits in both 1995 and 2005. In 1995 these benefits nationally total $566 million, and in 2005 they total $124 million. The benefits in Table 1 are not discounted either. Trading results in net benefits because the geographic shift in emissions away from more populated areas leads to a decrease in exposure to harmful particulates.

Figures 5 and 6 display the percent change in health benefits attributable to trading for the years 1995 and 2005. These figures show the opportunity to trade has regional implications for the distribution of health benefits under the program. Trading undermines the health benefits of the program in areas closest to where emissions increase as a result of trading.

There has been significant concern that trading might serve to contribute to the transboundary effects of pollution. The fear has been that citizens in New England and along the eastern seaboard might suffer health effects as a consequence of emission increases in the Ohio Valley that result from trading. However, those increases in the Ohio Valley imply decreases in other states that have an equal or greater impact on citizens in the east. As a consequence, it appears that trading actually leads to improvements in air quality in the east.

Figure 5

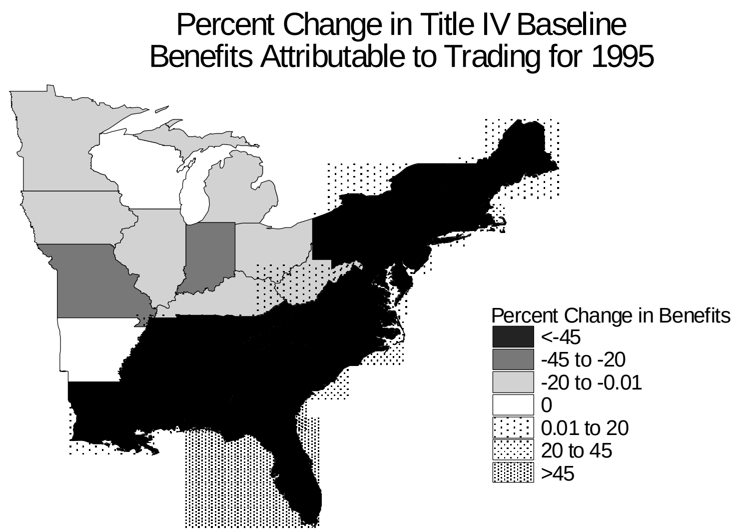
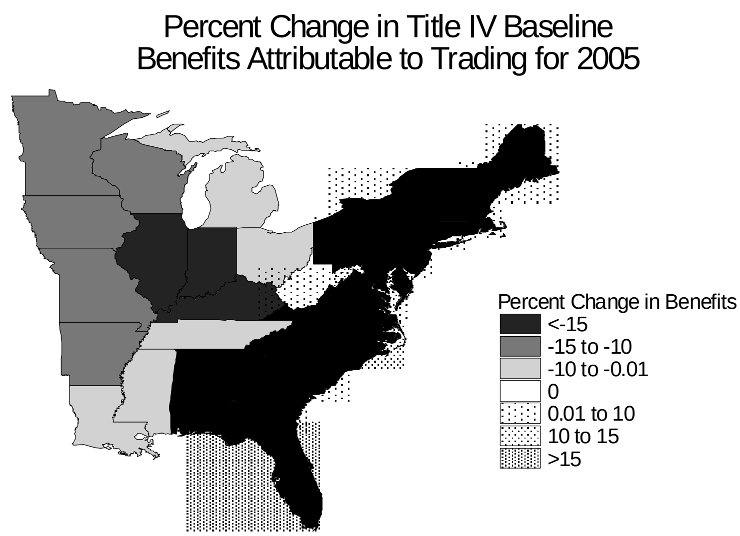


Figure 6



THE EFFECTS OF BANKING

The banking provision of Title IV is expected to result in an accumulated surplus of allowances of nearly 11 million tons by the year 2000, when Phase II of the program begins and the scope of emissions reductions will become both broader and stricter. Beginning in 2000, it is expected that the allowance bank will diminish over a period of several years.

To explore the environmental consequences of banking, we employed TAF to compare the Baseline scenario to a "No Banking" scenario. In the latter scenario, allowances can not be banked, so emissions in each period must be less than or equal to allowance allocations in that period. Trading of allowances among facilities is one way of meeting this constraint. In this exercise, we compare the pattern of emissions that are predicted for two years, 1995 and 2005, in the presence and absence of banking.

Two features distinguish the choice of compliance activities in the Baseline and No Banking scenarios. One is the role of scrubbing. The installation of 21 retrofit scrubbers at existing facilities in the Baseline reduces their emissions far below the allowance allocation in Phase I, but at a significant cost. An important attraction of scrubbing is that the "over-compliance" in Phase I enabled contributions to the bank to accumulate for use in Phase II. Absent the opportunity to bank allowances, there would have been insufficient incentive to install scrubbers at these facilities. Compliance options at these and many other facilities are affected as a result. This is reflected in the No Banking scenario.

A second feature that distinguishes these scenarios is the role of the 3.5 million bonus allowances that were awarded in Phase I to facilities that chose to scrub as a means of compliance. These allowances would have had little value were it not for the opportunity to bank them for future use because the relatively moderate emission reductions required in 1995 and 1996, when the bonus allowances were allocated, were relatively easy to obtain through fuel switching and blending. In the Baseline scenario the bonus allowances are all banked for use in Phase II. In effect, these were surplus allowances in Phase I. Constraining their use to 1995 and 1996 in the No Banking scenario while enabling their use in Phase II in the Baseline would lead to a poor evaluation of banking *per se*.

Therefore, for the evaluation of the No Banking scenario, we reallocate the bonus allowances to the years in which they are used for compliance in the Baseline scenario. This is accomplished by solving the inter-temporal investment and compliance algorithm for the Baseline, with and without the bonus allowances, and noting the difference in emissions on an annual basis. This difference is added to total allowance allocations each year for the No Banking scenario.

Emissions Changes from Banking

The result of this comparison is reported in Table 2. The first two columns of numbers in the table represent the change in SO_2 emissions at selected states in 1995 and 2005 due to the opportunity to bank in the program. As expected, emissions fall or stay constant in 1995 compared to the default. However, in 2005 emissions increase in most states and in the total.

Table 2: The contribution of banking to emissions, deposition, and health benefits

	Change in SO_2 Emissions (thousand tons)		**Change in Sulfur Deposition (kilograms/hectare)**		**Change in Health Benefits (million 1995 $)**	
	1995	**2005**	**1995**	**2005**	**1995**	**2005**
AL	0	11	-0.3	0.2	68	-34
AR	0	0	-0.2	0.2	22	-21
CT	0	0	-0.7	0.2	83	-26
DE	0	0	-0.9	0.2	23	-7
DC	0	0	-1.1	0.2	22	-6
FL	0	0	-0.1	0.1	110	-55
GA	0	0	-0.4	0.2	133	-61
IA	0	5	-0.1	0.1	15	-18
IL	0	93	-0.4	0.5	182	-195
IN	-106	3	-1.0	0.7	173	-133
KY	-122	268	-1.4	1.0	161	-112
LA	0	0	-0.1	0.1	24	-22
ME	0	0	-0.4	0.1	18	-7
MD	0	0	-0.8	0.2	162	-51
MA	0	0	-0.6	0.2	129	-42
MI	0	0	-0.4	0.3	138	-96
MS	0	0	-0.2	0.1	30	-18
MO	0	4	-0.2	0.2	47	-49
NJ	-3	-4	-0.9	0.2	260	-77
NY	-18	-1	-0.8	0.3	493	-172
NC	0	0	-0.7	0.2	199	-74
OH	-19	-1	-1.0	0.5	377	-205
PA	-129	74	-1.2	0.4	460	-159
RI	0	0	-0.6	0.2	22	-7
SC	0	0	-0.4	0.2	80	-32
TN	-299	-52	-1.1	0.3	187	-76
TX	0	78	0.0	0.1	34	-78
VA	0	0	-0.9	0.3	227	-79
WV	-164	-72	-1.3	0.4	75	-27
WI	0	0	-0.1	0.2	35	-37
Total	-860	455	N/A	N/A	4067	-2116

These results are illustrated in a qualitative way in Figure 7, which displays the percent change in emissions from electricity generation attributable to banking in the year 1995. Figure 8 displays the same information for the year 2005. These figures illustrate the inter-temporal shift in emissions from 1995 to 2005.

Deposition Changes from Banking

The second two columns of numbers in Table 2 report the change in the sum of wet and dry annual sulfur deposition. Though not every state is shown with a decline in emissions in 1995 due to banking, every state is shown to have a decline in sulfur deposition due to the atmospheric transport of the pollutant. In the year 2005, the converse holds, and every state is shown to have an increase in sulfur deposition. Figures 9 and 10 display this information in graphic form as the percent change in deposition attributable to banking.

Health Benefits from Banking

The third set of columns in Table 2 represent the change in health benefits at selected states in 1995 and 2005 due to the opportunity to bank in the program. All values are expressed as 1995 dollars. As expected, health benefits increase in 1995 compared to the Baseline without banking. However, in 2005 the emissions increase in most states leads to a decrease in health benefits at all states. In the aggregate, we project the additional health related benefits to be $4 billion in 1995. These are offset by additional health related costs of over $2 billion in 2005.

The evaluation of environmental benefits depends on whether there are threshold effects in environmental or public health responses and at what level of exposure those are achieved. The dominant view in health epidemiology regarding exposure to particulates is that the concentration-response function is linear over the range in which changes will occur. Hence, at least with respect to public health, there is a fairly equal trade off of exposure in the later years for less exposure in the near term. The issue is complicated by population growth that implies that greater numbers of people potentially will be exposed in the future due to the banking provision. However, from an economic perspective, benefits achieved sooner are viewed as superior to benefits achieved later, due to discounting. Note that none of the benefits in Table 2 are discounted.

Figures 11 and 12 illustrate the percent change in estimated health benefits attributable to banking in 1995 and 2005, respectively. Banking has caused the realization of health benefits to be accelerated, but the total health benefits are approximately neutral. While the Phase I health benefits are greater, they are realized over a shorter horizon than the health costs of Phase II. The figures also show that there is some minor geographic difference in how states are affected.

The pattern with respect to emissions, deposition and benefits reveals that the harm is less in 2005 than the improvement in 1995. One should not be misled by this comparison. Draw down of the allowance bank is expected to occur over a longer horizon than did its buildup. However, one can conclude that there is a fairly straightforward trade-off between near term and longer term emissions when banking is allowed. In general, the effect is to shift emission reductions toward the present. Absent other scientific or social considerations, this would seem to be a good thing, especially when it allows the emission reductions to be achieved at significantly less cost.

Figure 7

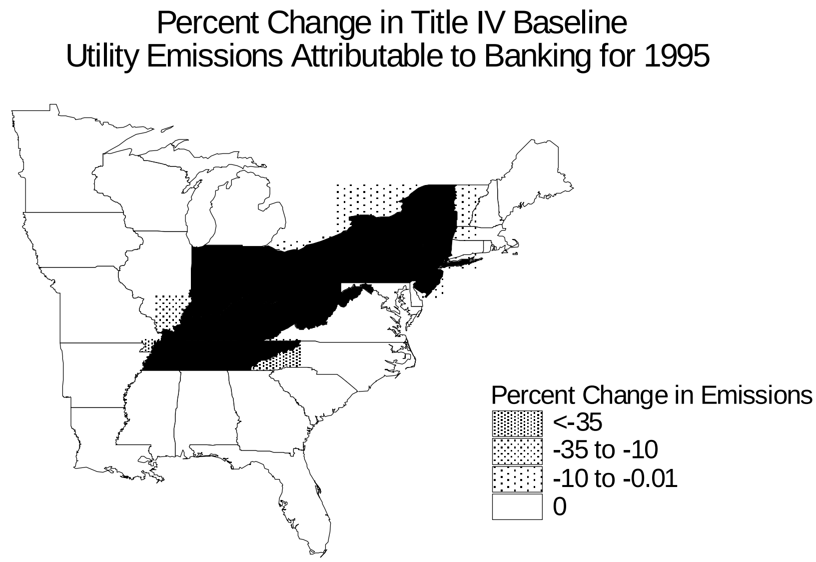


Figure 8

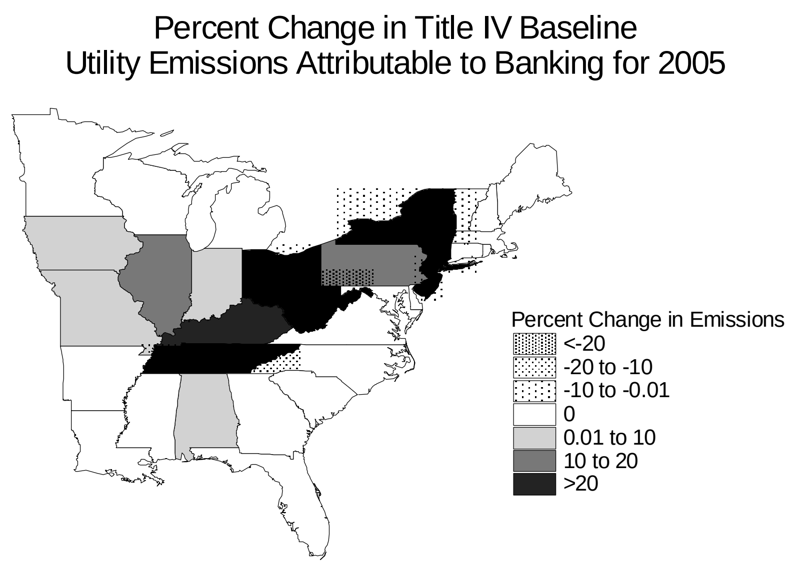


Figure 9

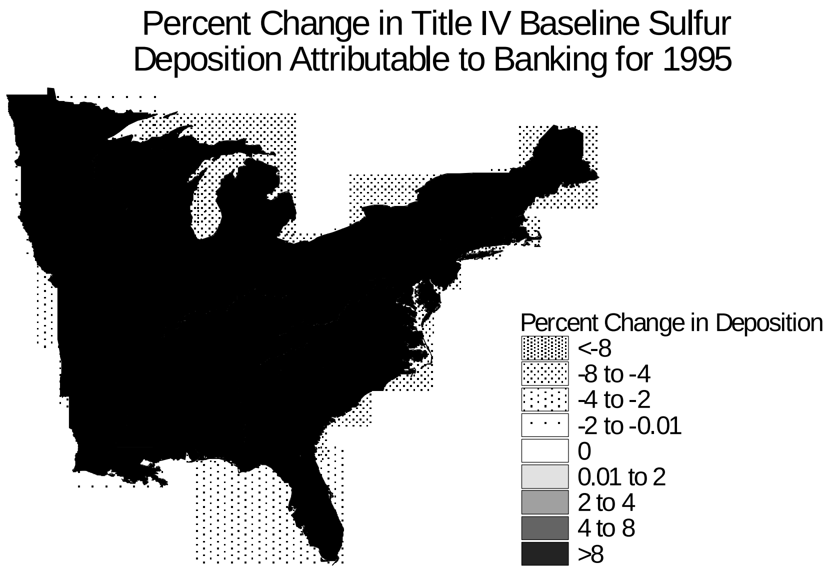


Figure 10

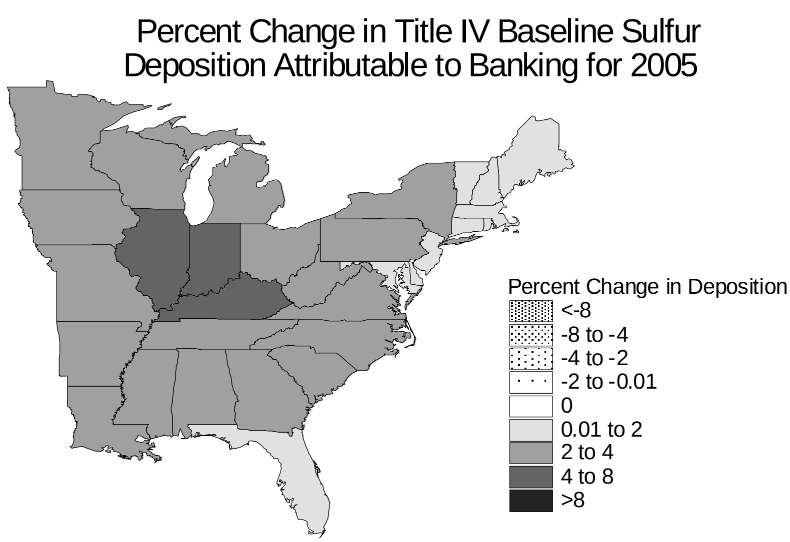


Figure 11

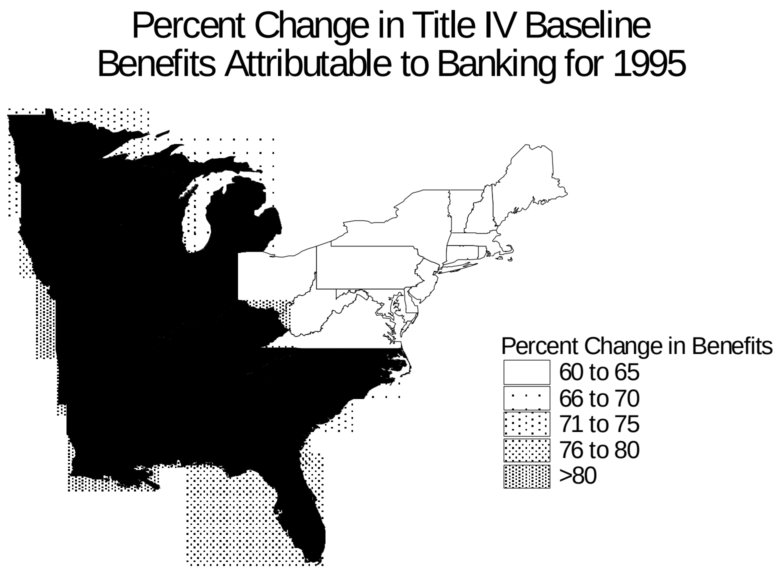
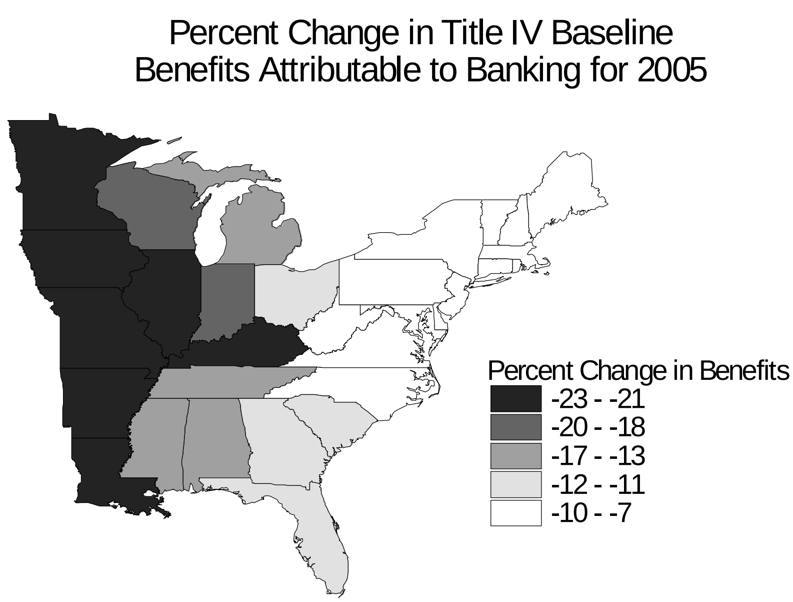


Figure 12



COST SAVINGS FROM TRADING AND BANKING

The point of trading and banking is to reduce the costs of the program. On a state-by-state basis, cost savings can be associated with increases in emissions. The interesting story emerges in considering cost savings in the aggregate.

In the case of trading, aggregate compliance costs of the program are reduced by $97 million in 1995 due to the opportunity to trade. This compares to Baseline costs of $650 million in 1995, according to our model. The gains from trade amount to 13 percent of the costs in the No Trading scenario. In 2005, aggregate compliance costs are reduced by nearly $531 million due to trading. This compares to Baseline costs of $905 million. The gains from trade amount to 37 percent of the costs in the No Trading scenario.[7] The aggregate compliance cost savings complement the aggregate health related benefits that result from trading.

In theory, allowing for banking should decrease costs. However, we find that the opportunity for banking actually led compliance costs to be higher by $651 million in 1995 and $339 million in 2005 in our model. Banking encouraged the construction of scrubbers that appear *ex post* to be cost-inefficient. Given changes in fuel markets subsequent to the planning and construction of these facilities, we calculate that none of the 21 scrubbers that were built in Phase I would have been built if there had not been banking. Whether they should have been built from an *ex ante* perspective (with banking) is suspect and explains why costs increased with banking (Carlson et al., 1998).

CONCLUSION

This analysis finds a sizable shift in emissions due to trading and banking in 1995 and 2005, the years examined in this study, with changes in some states of over 20 percent of emissions under Title IV. Trading leads to an increase in emissions in the Midwest and a decrease in the East and Northeast.

However, the geographic consequences are not consistent with the fears of program critics. The changes in atmospheric concentrations of pollutants and in monetized health benefits are most unfavorable in the regions where emissions increase. Health benefits actually increase in the East and Northeast due to trading, and in the aggregate for the nation. Deposition of sulfur in the eastern regions also decreases by a slight amount as a result of trading, even in New York State, an area of particular concern. Meanwhile, cost savings from trading represent about 13 percent of compliance costs in the No Trading scenario in 1995, and about 37 percent in 2005.

Banking has a predictable effect on the timing of emissions and the benefits of emission reductions, with emission changes of up to 20 percent in 1995 and 2005 in some states. The geographic pattern of emission changes is not simple; some states actually reduce emissions in 2005 as a result of banking. However, in 1995, emission reductions due to

[7] These costs and cost savings compare favorably with those resulting from an econometric model reported in Carlson et al. (1998).

banking lead uniformly to decreased concentrations and deposition, and emission increases in 2005 lead uniformly to increased concentrations and deposition.

It is important to keep in mind that the emission changes we identify only pertain to the opportunity to bank or to trade allowances. This is only a small part of the story with respect to the overall impact of the SO_2 program. On net, the program will result in dramatic emission reductions of nearly 50 percent. We take these emission reductions as given, and examine the particular features of trading and banking, given the overall emission reductions are otherwise achieved.

Furthermore, it is important to note that the overall emission reductions might not otherwise have been achieved, absent the opportunity to bank and to trade allowances. The flexibility in compliance that is afforded by these aspects of the program led to significant decreases in the cost of the program and made the program economically affordable and politically acceptable. Finally, this analysis leaves aside entirely an evaluation of the proper level of emission reductions and the question of whether environmental resources and public health are adequately protected under Title IV.

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