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Volunteering for Market-Based Environmental Regulation: The Substitution Provision of the SO2 Emissions Trading Program

by

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Abstract

In this paper we explore the practical and welfare implications of a system of voluntary compliance within a market-based environmental regulation. The Substitution Provision of the SO2 emissions trading program allows the owner or operator of an affected electric utility unit to voluntarily designate a non-affected electric unit to become subject to all compliance requirements of affected units and to receive SO2 traceable emission permits (allowances). We find that although the Substitution provision has had a rather small effect on the overall of the SO2 emissions trading program and on SO2 emissions reductions, there has been a significant participation, with more than half of the "affected" electric utilities using this voluntary option to reduce compliance costs. This provides further evidence to the notion that, in general, electric utilities are choosing cost-effective strategies to comply with SO2 limits. Consistent with that is our finding that transaction costs associated to the Substitution provision have been relatively low.

In another result, we show that non-affected units have opted in, largely because their actual unrestricted emissions (i.e. emissions in the absence of regulation) are below their historic omissions and hence their allowance allocation. Other units have opted in because they have low marginal control costs, say, below allowance prices. While the latter effect reduce today's aggregate cost of compliance by shifting reduction from high cost affected units to low cost units (the flexibility effect), the first effect increases today's emissions and emissions in the future (the adverse selection effect). An ex post cost-benefit analysis suggests that the adverse selection effect dominates, in part because of low allowance prices from an ex ante perspective however, we show that this result may not hold.

Volunteering for Market-Based Environmental Regulation:
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1. Introduction

Despite the cost-effectiveness properties of market-based environmental policy instruments such as traceable permits and taxes, there are only few cases where they have been used as an alternative to traditional command-and-control instruments such as emission or technology standards. In recent years however, we have witnessed a significant increase in the attention given by policy makers to market-based instruments. The SO2 emissions trading program under Title IV of the 1990 Clean Air Act Amendments (CAAA) constitutes the largest experiment in the use of traceable permits ever implemented.[2] Furthermore, it is the first emissions trading program to include a voluntary compliance program- the Substitution Provision - within the trading scheme.[3] In this paper, we explore the welfare properties of this voluntary compliance provision and its implications for the overall performance of the SO2 emissions trading program based on actual data after 1995 the first year of compliance with Title IV.

Title IV of the CAAA imposed a reduction of SO2 emissions from electric utilities to be achieved in two phases. In Phase I, 1995 through 1999, only the "dirtiest" 263 electric utility units[4] are required to comply with SO2 limits, while about 2000 units remain unregulated with regard to SO2 limits until year 2000, that is when Phase II begins. Congress established the Substitution provision as a voluntary compliance option to increase affected units' compliance flexibility and reduce their overall costs of compliance in Phase L The Substitution provision allows the owner or operator of any of these 263 affected units to reassign units' emissions reduction obligations to a designated non-affected unit (hereafter substitution unit) under the owner's or operator's control. Upon EPA's approval, the substitution unit receives SO2 tradeable emission permits (allowances) approximately equal to its historic emissions. We expect that a Phase II unit opts in as long as the revenue from selling allowances exceeds the combined emissions control costs and costs of using the Substitution provision.

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[1] I would like to thank Denny Ellerman Paul Joskow and Richard Schmalensee for numerous comments, participants in EC/OECD/IEA Energy Externalities and MIT Energy Policy workshops, the EPA's Acid Rain Division Group specially Larry Montgomery and Joe Kruger, and the MIT Center for Energy and Environmental Policy Research for financial support. Errors and omissions ate mute.

[2] For the theory and practice of traceable permits see, for example, Tietenberg (1985) and Hahn "d Hester (1989).

[3] Note that voluntary compliance programs are not totally uncommon in US environmental policy (see Stoughton, 1995 for an evaluation of six voluntary programs implemented by EPA, including the 33150 Program). These ate very different in nature and scope to the voluntary program we study here.

[4] A unit, which is defined as a Fossil-fuel-fired combustion device" in 5 402 of the CAAA, corresponds to a single generator and associated boiler A generating plant can house one or several units, which may be of different sizes, vintages, type or fuel input.

Since the passage of the CAAA in November 1990, questions have been raised about the functioning of the SO2 allowance market and the cost-effectiveness of electric utilities' compliance strategies.[5] Less attention has been paid to the practical and welfare implications of a phase-in design and the possibility for non-affected sources to voluntary opt in and receive SO2 Allowances We believe that an analysis of a voluntary compliance program represents a interesting case study of issues that can arise in attempts to implement traceable permit schemes in practice. This is particularly important if we believe that phase-in or less than fully comprehensive trading systems are likely to be the rule rather than the exception in future environmental policy. A salient example is provided by current emissions trading proposals in dealing with global warming that call for early carbon dioxide restrictions on OECD countries with substitution possibilities with the rest of the world (Tietenberg and Victor, 1994). Although the results of our empirical analysis are specific to Title IV and the SO2 trading program, there are aspects that may apply to future trading programs as well.

Our first result indicates that overall, the voluntary compliance program of Title IV has not had a significant effect on the performance of the SO2 allowance market. The total SO2 emissions reductions and "net" allowances (those not used to cover SO2 emissions in 1995) from substitution units are relatively small compared to the total figures. However, we have observed significant participation, with more than half of the "affected" electric utilities using this voluntary program to reduce compliance costs, which provides further evidence supporting the notion that, in general electric utilities are choosing cost-effective strategies to comply with SO2 limits. Consistent with that is our finding that transaction costs associated to Substitution provision has been relatively low.

In another result, we show that non-affected units have opted in, largely because their actual unrestricted emissions (i.e. emissions in the absence of regulation) are below their historic emissions and hence their allowance allocation. Other units have opted in because they have low marginal control costs, say, below allowance prices. While the latter effect reduce today's aggregate cost of compliance by shifting reduction from high cost affected units to low cost units (the flexibility effect), the first effect increases today's emissions and emissions in the future (the adverse selection effect). An ex post cost-benefit analysis suggests that the adverse selection effect dominates, in part because low allowance prices. However, an ex post analysis may not say much about whether implementing the program is efficient from an ex ante perspective. Using data on units that withdrew from the Substitution provision, we carry out an ex ante cost- benefit analysis and show that expected net benefits can be substantially higher than ex post figures.

The paper is organized as follows. The next section provides a brief overview of Title IV of the CAAA and the SO2 emissions trading program and the implementation aspects of the substitution provision. Because they are relevant to the implementation aspects of Substitution provision, we also include a brief description of the NOx requirements of Title IV and the Reduced Utilization Provision. Section 3 examines the empirical evidence on voluntary compliance after the first year of compliance with Title IV, which is 1995 ant its effects on the performance of the SO2 trading program Section 4 explains the trade-off between flexibility and adverse selection and presents an econometric analysis to estimate the relative magnitude of each effect. Section 5 presents a logit motel to disentangle the importance of these effects in the decision to opt in a non- affected unit. We also include a discussion of possible transaction costs of using the Substitution provision for compliance. In section 6 we carry out an ex post cost-

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[5] See, for example, GAO (1994)

benefit analysis associated exclusively to the implementation of the Substitution provision. In section 7 we carry out an ex ante analysis. Concluding remarks are in section 8.

2. Voluntary compliance with Title IV

The design and implementation of the Substitution provision of Title IV has been far from trivial. In fact, a large part of EPA's administrative efforts has been spent on this and closely related programs/provisions.[6] To understand the practical implications of the Substitution provision for electric utilities' compliance strategies, we briefly explain Title IV and the implementation of the SO2 trading program, and related aspects such as the Reduced Utilization provision and the NOx compliance requirements.

Title IV of the CAAA imposed a reduction of SO2 emissions from electric utilities, by the use fully tradeable emission permits, called allowances. SO2 is the primary precursor of acid rain and other acidic deposition, and the SO2 control measures imposed by Title IV are designed specifically to effect a substantial reduction in those depositions.[7] Allowances convey the right to emit one ton of SO2 in the year of issuance or any later year and are issued to affected electric generating units based upon a series of formulas heavily dependent on historic fuel use (see Joskow and Schmalensee, 1996). Each allowance specifies a particular year, its "vintage", in which it is first available to be used to cover SO2 emissions. Allowances are fully tradeable in that allowances of any vintage can be traded to any party (e.g. another utility, broker, individual' etc.) and can be banked for future use, but can not be brought forward for use in an earlier year. At the end of each year, affected sources in the program are required to hold allowances in amounts equal to or greater than the total amount of SO2 emitted in that year. To control for that, the CAAA requires each affected source to have continuous emissions monitoring (CEM) equipment on each stack to measure actual SO2 emissions and to report those emissions to EPA.8

To accomplish the SO2 emissions reduction intended by Congress, Title IV mandated an aggregate cap on SO2 of approximately 8.9 million tons by year 2000, approximately half of the 1980 emissions, to be achieved in two phases. Phase I, that covers the period 1995~1999, affects the 263 dirtiest large generating units at 110 power plants whose emissions must be reduced to an average of 2.5 lbs. of SO2 per million Btu (hereafter #/mmBtu) times their baseline, which is the average 1985-87 heat input. Units affected in Phase I were designated by Table A of the legislation; and with few exceptions, Table A included all units of 100 MW of capacity or greater with average emission rates above 2.5 #/mmBtu. Hereafter we refer to these units as Table A units. Phase II, which begins in 2000, applies to all fossil fuel plants and further limits emissions to roughly the lesser of 1.2 #/mmBtu or the 1985 emission rate times the baseline.

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[6] Brian McLean personal communication, September, 1996.

[7] Discussion of the benefits of SO2 reduction by Title IV can be found in EPA (1995b)

8 A unit that fails to hold sufficient allowances to cover its emissions is subject to significant financial and legal penalties The penalty for non-compliance is $2000 for each ton of SO2 emitted that is not covered by an emission allowance designated for that source. In addition, the subsequent yeses allocation will be reduced by the tonnage subject to the penalty.

9 9 A Phase I unit is said to be underutilized if, in any year in Phase 1, the total annual utilization of fuel at the unit is less than its baseline

Title IV includes two provisions under which Phase 11 units - those units that are not mandatorily affected until year 2000 - can voluntarily opt-in into Phase I: the Substitution and Reduced Utilization provisions. For the purpose of this paper we will refer to Phase I units as any unit that is affected in Phase I, which will include all Table A units and any Phase II unit that opted-in under either of these two provisions.

Let us first briefly explain the Reduced Utilization provision. There are administrative complications associated with a phase-in program, in which many sources remain outside the trading program and emissions compliance requirements. Because electric utilities can choose how to dispatch their electricity, the incentive structure created by Phase I encourages utilities to shift generation and emissions from Phase I to Phase II units. To account for possible shift in emissions through reduced utilization or underutilization of Phase I units,9 Title IV originally required the submission of a reduced utilization plan for any Phase I unit that is planned to be utilized below its baseline as a method of compliance with the SO2 emissions limitations. The plan must either (1) designate Phase II units (referred to as compensating units) to which generation was shifted, (2) account for the reduced utilization through energy conservation or improved unit efficiency measures, or (3) designate sulfur-free generators (e.g. hydroelectric or nuclear generators).

However, the reduced utilization plan is not required if the underutilized Phase I unit (including substitution and compensating units) surrender allowances in proportion to the reduced utilization, or if there is overutilization at other Phase I units in the same dispatch system, or if there is a decrease in the dispatch system sales. Thus, the surrender of allowances does not become effective if the total heat input from all Phase I units in the relevant dispatch system is equal or above the total baseline heat input of such units.

Let us now explain the main features of the Substitution provision. A complete description is in the Appendix. As mentioned above, Title IV includes the Substitution provision as a compliance option to increase units' compliance flexibility and reduce their overall costs of compliance in Phase I while still achieving the same emissions reductions intended by Congress under Title IV. Upon approval, the substitution unit becomes subject to requirements for Phase I units with regard to SO2 and nitrogen oxides (NOx) and receives allowances. Allowances are given to substitution units wording to fairly complicated rubs that were tightened after claims brought by environmental groups trying to prevent excess allowances, that are allowances "in excess" to the SO2 emissions that otherwise would have been observed.

In an attempt to allocate allowances closer to unrestricted emissions and hence prevent excess allowances, the final rule for allowance allocation is based on the lesser of three emissions rates for the unit in question: (I) 1985 actual SO2 emissions rate (or 1985 allowable SO2 emissions rate); (2) the greater of 1989 or 1990 actual SO2 emissions rate; or (3) the most stringent Federal or State allowable SO2 emissions rate applicable in 1995-99 as of November I5, 1990. The substitution unit's allowance allocation is then calculated by multiplying the lower of the above rates by the baseline, which reflects 1985-87 utilization. Note that the original allocation rule only considered (1). There is no restriction to designate substitution units other than having a common operator or owner with a Table A unit.'ø Likewise, there is no restriction to opt in new substitution units or withdraw existing ones in any subsequent year during Phase I.

Some Phase II units may not find it profitable to opt in because they are required to comply earlier than otherwise with the NO% limits of Title IV, which includes NOx emission performance standards for coal-fired generating units. Electric utilities are a major contributor to NOx emissions nationwide, and approximately 85% of electric utility NOx comes from coal- fired power plants. Title IV specifies a two-part strategy to reduce NOx emissions from coal- fired plants. The first stage will affect only Phase I units with Group I boilers and reduce annual NOx emissions by 400,000 tons (from 1980 levels) between 1996 and 1999." The second stage, which begins in year 2000, will reduce emissions by 2.0 million tons annually by: (I maintaining the same standards for Phase I, Group I boilers, (2) establishing more stringent standards for Phase II, Group I boilers, and (3) establishing new standards for Group 2 boilers.12 Title {V includes some provisions that allow Phase II units with Group I boilers to comply early with the NOx requirements of Phase I and avoid the more costly standards of Phase II. Like all Table A units, substitutions units that opted in by January 1995 are never subject to revised NOx emission limitations. This is commonly known as the "NOx grandfathering." Note however, that these units must incur the extra costs associated with early compliance starting in January 1996. The other substitution units that are opting in after January 1995 are not subject to revised NOx emission limitations until the year 2008 and must start complying with Phase I NOx limits by January 1997. This latter is the NOx early election provision, which in fact applies more broadly allowing any Phase II unit to comply early with NOx limits and cut some of the costs of future compliance without the need to become a substitution unit. Because the NOx early compliance provision is always a possibility, the "NOx benefits" of early compliance as substitution units should be thought only in terms of the NOx grandfathering. Other small electric utility units and industrial sources of SO2 that are excluded from the mandatory requirements of Title IV, may elect to enter the SO2 trading program under the Opt- in Program and receives allowances approximately equal to their historic emissions (EPA, 1995 Unlike the Substitution provision, it seems that the combined emissions control costs and costs in participating in the Opt-in program has exceeded the revenues from selling allowances for potential sources. Only three industrial sources have The only exception is under the control-by-contract clause, where the owner (or operator) of the substitution unit commits to make reductions and deliver the allowances to the owner (or operator) of the corresponding Table A unit. Allowances arc issued equal to 70% or less of the amount under the regular rule. " Boilers of coal-fired units can fall in either Group I or 2. Group I includes tangentially fired boilers and dry bottom wall-fired boilers other than units applying cell burner technology. Group 2 includes wet bottom wall-fired boilers cyclone boilers, boilers applying cell burner technologies, vertically-fired boilers, arch-fired boilers and any other type of utility boiler (such as fluidized bed or stoker boiler) that is not a Group I boiler. 12 There are five options for compliance with NOx: standard emission limitations, emissions averaging, alternative emission limitations, phase I extensions. and early election. There are some restrictions that apply. 6 found it profitable to opt in, two of Which have already obtained approval and received allowances.13 Although it would be interesting to see whether transaction costs, uncertainty about approval, and/or low allowance prices are hindering participation in the Opt-in program, in this paper we focus exclusively on the empirical evidence on voluntary compliance from the Substitution provision. We turn to that now. 3. Evidence on voluntary compliance 3.1 The data and eligible units The data we use in our empirical analyses was obtained as follows. First, from the EPA's Acid Rain Division. The data is in Pechan (1993 and 1995 and two large data system: the emissions tracking system (ETS) and the allowance tracking system (ATS). The NOx control cost data was obtained from EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park (EPA, 1991). The second source is the Federal Energy Regulatory Commission Form 423 (FERC423) that contains monthly data on the cost and quality of fuels delivered to electric power plants. Finally we complement this data with the MIT-CEEPR Title IV Questionnaire and personal communications with electric utilities staff (CEEPR, 1996). Additional sources are explained as we progress. To understand the practical implications of the Substitution provision and the extent to which electric utilities are using it to reduce their compliance costs requires cross sectional studies comparing units that opted in from those that did not. In establishing the scope of the Substitution provision we first need too identify those Phase II units that were eligible to opt in, or what we call hereafter eligible units. Because the only restriction to opt in a Phase II unit is that of common owner or operator with a Table A unit, we have included in our eligible units sample both (1) all units that actually opted in, and (2) all those Phase II units either in operating utilities with at best one Table A unit or in holding companies with at least one Table A unit.14 Phase II units with common operators and/or owners with Table A units are identified wording to the operating utilities list of Pechan 1995 sod the holding companies list of the FERC423 and the US Electric Utility Industry Directory. Thus, our eligible units sample reduces to 629 units." 3.2 Voluntary compliance and SO2 emissions trading Because the Substitution provision rules have been subject to changes and controversies, we would anticipate a rather low participation. That is not the case. A total 13 These are Alcoa units in Indiana and DuPont boilers in Tennessee. In total they received 95,882 allowances (Clean Air Compliance Review, Nov. 4, 1996). 14 In our analysis we do not include any potential substitution unit under the control-by-contract clause because we do not have a good estimate of the corresponding allowance allocation. 15 We eliminate 23 units that were conditional compensating units that under the new rules were not eligible to opt in as compensating units and neither as substitution units because they were originally in a reduced utilization plan. 7 of 42 operating electric utilities are using the voluntary compliance program. Among them, 31 (out of 61) are "affected utilities" or utilities with at least one Table A unit.16 More specific, there are 182 Phase II units that have voluntarily opted-in and have become subject to Phase I requirements under the Substitution provision. Strictly, seven of these are compensating units that voluntarily became affected under the Reduced Utilization provision. Because the designation of compensating units is entirely optional. for analytical and practical purposes they can be treated as substitution units, and we will do so in what follows. Table 1 shows the statistics of Table A and substitution units. Substitution units are on average cleaner than Table A units, and account for a 47% increase in Phase I affected capacity. Table 1 also includes bask statistics on eligible Phase II units that did not opt in. We believe that this large participation can be attributed to low transaction costs and electric utilities choosing cost-effective strategies. We come back to the issue of transaction costs later. Despite this significant participation, the Substitution provision has had a rather small effect on the overall performance of the SO2 trading program. We first observe from Table I that most of the difference in SO2 emissions from Phase I units between 1993 and 1995 comes from Table A units (96%). This suggests that most 1995 SO2 emissions reductions are from Table A units.17 Furthermore, based on the large emissions reduction observed at Table A units we conclude that the original emissions reduction goals of Title IV has not been compromised at all by the Substitution provision; contrarily to what has been argued by some parties." In addition, we observe that only IS% of the allowances banked for future use (i.e. 1995 allowances not used to cover 1995 SOz emissions) come from substitution units. This figure suggests that probably the equilibrium pace would have been a bit higher without this provision. But provided the large allowance pace fluctuation during, for example, the period March 95 - March 96 (from $133 to $70), we conclude that the substitution provision has not had any significant effect on allowance prices and hence on the development of the SO2 allowance market. There are other market elements that can explain price fluctuations and lower than expected allowance prices such as change in coal economics (Ellerman and Montero, 1996), and the "fixity" of control cost investments and the integration of allowance and coal markets (Montero et al., 1996). 4. SO' _ and the adverse selection problem Although substitution units have not had a significant impact on the allowance market and the total SO2 emissions reductions, it is interesting to explore the extent to which these units are reducing emissions or changing utilization (generation or heat input) as a result of being affected in Phase I. Title IV expressly states that in approving a substitution plan, EPA should ensure that the substitution plan result in total emission 16 The other l I utilities are either with a holding company with a Table A unit (4), brought in under the control-by-contract clause (6), or have compensating units (1). 17 This number is confirmed by Montero et al. (1 996). 18 See Environmental Defense Fund vs. US Environmental Protection Agency, and Alabama Power Company et al., vs. US Environmental Protection Agency. 8 reductions at least equal to the total reductions that otherwise would have been achieved by these Table A and substitution units without such substitution plan. If were the case, we would say that the difference between the 1995 allowance allocation and the 1995 actual SO: emissions at substitution units represents a net of emissions reductions that were shifted from high cost Table A units to substitution units via (spatial) trading and/or banking. In this section we will show that only part of the difference between 1995 allowances and emissions at substitution units can be attributed to Title IV, and that an important part of it is due to "reductions" prompted by economic or other reasons that would have taken place even in the absence of Title IV. 4.1 Adverse selection in voluntary compliance Like any regulatory practice, a voluntary compliance program with environmental regulation is subject to imperfect infornnation.19 In a world with perfect information and no transaction costs, a regulator would issue allowances to substitution units equal to their unrestricted emission, in each period. In practice however, the regulator (and sometimes the firm) cannot anticipate the level of unrestricted emissions. Yet he (she) must establish an allowance allocation rule in advance, which cannot be easily changed in the future even if the arrival of new information would suggest so. Since the regulator cannot extract all the information rents, we must recognize that a voluntary compliance program is subject to an adverse selection problem in that sources that are reducing emissions below their historic emissions will receive allowances above their unrestricted emissions (i.e. emissions that would prevail in the absence of regulation). Inevitably, in setting the allocation rule, the regulator faces a trade-off between extracting information rents and providing flexibility for low cost outside sources to opt in. A too restrictive allocation rule may (inefficiently) leave many low cost sources outside the program (Montero, 1996). In the Substitution provision, the regulator set the allowance allocation equal to historic emissions (based approximately on 1988 emissions) five years before compliance. The adverse selection problem stands in that all those eligible Phase II units that for economics reasons have reduced emissions before compliance in 1995 may find it profitable to opt in without making any further reduction, since they would receive allowances above their unrestricted emissions. In other words they would have excess allowances. Conversely, those units that are increasing their emissions above the allowance allocation may not opt in, even if they have low compliance costs, since they have to costly reduce emissions to first get to the allowance allocation. In aggregate, SO: emissions would be higher than without the Substitution provision because of the excess allowances; nevertheless the aggregate cost of compliance would be lower than otherwise because of both low control cost units opting in and excess allowances. We come back to this issue in section 6. Figure 1 shows the difference in emissions for substitution units and eligible units that did not opt kin. In that figure we can also see that the 1995 aggregate allocation is approximately equal to 1988 emissions. There is a char difference in the emission trends 19 For a complete treatment on the "new regulatory economics" see Laffont and Tirole (1993). 9 that supports our notion that units with unrestricted emissions below historic levels are more likely to opt in. Lower SO2 unrestricted emissions can be explained by either changes in emissions rates, heat input (utilization), or both. We find that most units that have reduced emission rates before 1993 are because of coal switches (blending) from Midwestern to western low sulfur coal suppliers in either Powder River Basin, in Wyoming, or Colorado/Utah. These "switches" were prompted by lower coal prices and usually after expiration of a long-term contract with high sulfur coal Midwestern suppliers. A second reason for the reduction in emissions rates is that a few states have enacted state laws or amended State Implementation Plants (SIPs) under the pre-CAAA to require reductions in SO2 by 1995 or before. A unit can also have lower emissions if its utilization (generation) has decreased as a result of dispatch considerations. According to the surrender of allowances rule, it can be profitable to opt in an underutilized Phase II unit if its underutilization is covered by overutilization of other Phase I units in the same dispatch system We can observe from Table 1, that at the aggregate level underutilization of Phase I units should not be an issue since 1995 heat input levels are 11% and 4% above the baseline for substitution and Table A units respectively. In fact, only 3,426 allowances were surrendered because of underutilization according to the Reduced Utilization provision (EPA' 1996). A peon, having low unrestricted emissions seems to be an important element in explaining the large participation. In the next section we carry out econometric analyses to pursue these issues further and to estimate how much of the reduction observed in 1995 can be associated to the Substitution provision. 4.2 Testing for changes in utilization and SO2 emissions rates In order to estimate the individual and aggregate 1995 SO2 emissions reductions by substitution units, we need first to establish what 1995 emissions would have been in the absence of the Substitution provision, or what will be called hereafter, the counter factual. In Figure 2, we compare actual SO2 emissions, the 1995 emission cap (i.e. aggregate allowances) and the EPA's forecast of emissions in the absence of Title IV for Phase I units. As indicated by the figure, SO2 emissions continued to decline after 1990 instead of increasing as had been projected. Earlier research (Ellerman and Montero, 1996) has addressed the reasons for this unanticipated decline and found that the continuing reduction was caused largely by changes in the economics of coal choice, rather than Title IV. Based on their analysis and on the fact that only by the second half of 1993 early applications for substitution units would be approved, 20 we assume that none of the reduction observed in substitution units by 1993 can be attributed to early compliance with the Substitution provision. For the purpose of this paper we use 1993 as the base year against which we test changes in utilization and emissions rates in 1995 due to the Substitution provision. This approach implicitly assumes that all changes (if any) in emission rates and utilization between 1993 and 1995 are caused by the Substitution provision. Although some of these 20 Application for substitution units was open in February 1993. EPA required at least six month before approving the application. 10 changes may not be due to the Substitution provision, we expect them to be minimum since 1993 is close to the compliance year. We are also interested in estimating the extent to which 1993 figures differ from those used to set the allowance allocation, namely the baseline heat input and emissions rates in the period 1985- 90. To establish our 1995 counterfactual we analyze changes in utilization and emissions rates separately rather than change in emissions - which is the product of heat input and emissions rates. In other words, we treat utilization and emission rates as independent decision variables. Let us first to test for the change in utilization in 1995. Our objective is to compare utilization in 1995 with that in 1993, and then with that in the period 1985-87. We use a simple linear specification that relates unit-specific heat input in a determined period to unit characteristics. Thus, our equation for the ith unit in period, say, 1995 is (1) (ht95/namecap)i = i30 + A x, + E, where ht95i is heat input in 1995 (in Btu), namecapi is the name plate or installed capacity (in MOO). We also work with (ht93/namecap)i and (basc8587/namecap)i as dependent variables (basc8587 is the average heat input during 1985-87 or baseline). The error term is &, and X, is a vector of unit-specific characteristics that includes (we omit the index i) subs dummy variable equal one if unit is a substitution unit coal dummy variable equal one if unit is a coal-fired unit scrub90dummy variable equal one if unit has a scrubber installed before CAAA was passed, which corresponds to new source performance standards (NSPS) scrubbers blryonl the year in which the boiler went on line namecap name plate capacity of the unit (MOO) taplant dummy variable equal one if unit is in a power plant with at best one Table A unit retire dummy variable equal one if unit is said to be retired according to Pechan 1995 We define utilization as the ratio between the heat input and the installed capacity for two reasons. First it gives all units the same weight regardless of their size, and second, it can capture other factors affecting utilization such as aging.21 If the latter were the case, we should observe 90 to be negative (positive) and increasing (decreasing) with time. Our specification allows us to test for changes in utilization associated with designation as a substitution units, while controlling for several other factors, by comparing 1993 and 1995 regression results. If there were no discernible change in unit-specific utilization between 1993 and 1995, all coefficients would be the same. If there were a uniform change across units, all coefficients would be the same except for 40; which would be either higher or lower. If we expect that substitution units had changed

21 We experimented with other specifications (such as hr95 on hr93 with similar. results

utilization as a result of being designated as such, a structural change test would indicate that the coefficient in subs for 1993 and 1995 are different. One might also argue that significant and negative coefficient in subs in either 1993 or 1995 could indicate that a unit with low utilization is more likely to be designated as substitution unit. The latter remains a possibility since a unit could have been withdrawn from the provision until November of 1995 if utilization was much higher than the baseline. We include several variables and dummy variables to control for special unit characteristics. We expect namepcap to be positive in that large units are run as baseload units. We expect the coefficient of blryonl to be positive, in that newer units are expected to be utilized more. We include taplant to test whether a unit in a plant that has at least one Table A unit is likely to be dispatched differently- if anything more. We also can test whether coal-fired plants are being utilized more over the years relative to gas-oil units. It would be the case if the coefficient in coal increases overtime. Finally, we include retire to control for units that are planned to be retired and (expectedly) being used less intensively before they are completely shut down. We work with two samples to test for changes in utilization. The first or full sample, includes all Phase II and substitution units. The second sample, is the eligible units sample. Results are in

Table 2 for the full sample and Table 3 for the eligible units sample. Dependent variables are basc85871namecap, ht93/namecap and ht95/namecap respectively. Although heteroskedasticity does not appear to be a problem, based on White's general test, we include heteroskedastic-consistent estimates for the standard errors. Results are similar so we focus our analysis on Table 2. If compare results in the last columns (ht93/ht9S/namecap)namecap and ht95/namepcap) we find that subs units are more likely to be underutilized in either of those years. The first column however, shows subs to be positive and significantly different from zero. Tests of structural change (Green, l 993, pp.203- 228) for the subs coefficient show both (1) that substitution units are underutilized in 1993 compare to 1985-87 levels, and (2) that there is no significant change in utilization between 1993 and 1995 This is consistent with statistics in Table 1, that show that eligible units not opting in have increased utilization above the baseline in a larger proportion relative to substitution units. Our results also indicate that units in plants with Table A units, regardless whether they opted in or not, are more likely to be overutilized than otherwise in 1995 compared to previous years. A test of structural change confirmed that the coefficient of taplant is greater in 1995 Based on this analysis we conclude that the substitution provision did not affect the utilization and dispatch of substitution units in 1995 but they were ceteris paribus underutilized compare to previous levels. Thus, in calculating our counterfactual we use actual 1995 heat input levels as the heat input level that would have prevailed in the absence of the Substitution provision. Let us now test for the reduction in emission rates in 1995 due to the Substitution provision. We follow Ellerman and Montero (1996) and use a simple linear specification that relates unit-specific emission rates in 1995 to emission rates in 1993 and to unit characteristics. Our equation for the ith unit is (2) rte95i = yO + y, Y. + u, 12
where rte95i 1995 emission rate (in rate (in #/mmBtu), ui is an error terns and Y. is again a vector of unit-specific characteristics that includes besides subs, scrub90, and taplant (we omit index i) rte93 emission rate in 1993 subrte93 subs*rte93 unitlim dummy variable equal I if unit is affected by SO2 State limits other than Title IV As before, our specification allows us also to test for changes associated with designation as a substitution units. If there were no discernible change in unit-specific emission rates between 1993 and 1995 all coefficients would be zero except for the coefficient on rte93, which would take the value of unity. To test for changes in rates due to the Substitution provision we use subs and subrte93 . We expect the two coefficients to be jointly significant. We use the same two samples as before and present the results in Table 4. Coefficients of subrt393 are significantly different from zero and negative, which strongly suggest that substitution units are reducing emissions as a result of being subject to Title IV. One might also argue that these results suffer from an endogeneity problem in that units reducing emissions between 1993 and 1995 for reasons other than Title IV are more likely to be opting in. This is the same as to suggesting a downward emissions trend affecting only some units. There is no reason to believe that the downward emissions trend takes place only after 1993. Rather we should observe a similar trend sometimes before that. Our specification (2) allows us to test for changes in emission rates relative to the rate used to calculate individual allowance allocation for substitution units, what is approximately the 1988 rate (see Table 1). To test for changes in emissions rates between 1993 and 1988 we regress rte93 on rte88.22 If there were no discernible change in unit-specific emission rates between 1993 and 1988 for substitution units, the coefficients of subs and subrte88 (subs*rte88) would be jointly not significantly different from zero. We use the same two samples as before and present the results in Table 5. We do not find evidence supporting the argument for a downward trend affecting only some

units, especially in the eligible sample. Therefore, we conclude that on average substitution units are opting in because they have low control costs and hence they are making reductions that would have not taken place otherwise. In calculating our counterfactual, we predict the emission rate in 1995 using our specification (2) and coefficient results of Table 4. We turn to that now. 22 We also tried other emissions rates (89,90) and average values with the same results. When we tried rte85 however, subs and subrte85 turn out to be very significant and predicting lower rates for substitution units, which is consistent with claims of some parties about tightening the allocation rules from 85 emissions rates to 88.89 rates. 13 4.3 The counterfactual and SO2 emissions reductions We can now establish our counterfactual, that is emissions in 1995 in the absence of the Substitution provision. We have for the ith unit the counterfactual, S0295hat. is given by (3) S0295hatj =k ht95i rte95hati where rte95hat is the predicted value using specification (2) for rte95 when subs = 0; and k is a conversion factor. Using results in Tables 4.1 and 4.2 we obtain two different estimates for rte95hat. In fact, rte95hat is, on average, slightly higher when we use the eligible units sample. We summarize the actual and predicted emissions, and total reduction in the table below for the two samples: 1995 SO2 Emissions and Emissions Reductions Aggregates Sample 1: Full Sample 2: Eligible SO295853,444 853,444 S0295hat946,953 993,142 SO2 reduction 95 93,509 139,698 Allowances 95 1,329,160 1,329,160 Excess Allow. 95 382,207 336,018 The last row of the Table excess allowances, represents the difference between total allowances in 1995 and predicted emissions in the absence of the Substitution provision. Because of the excess allowances, SO2 emissions in 1995 and in the future will be higher than otherwise. This is the adverse selection effect. In section 6 we come back to this issue about whether the costs associated to adverse selection effect outweighs the benefits of the flexibility provided by voluntary compliance using a cost-benefit framework. S. The decision to opt in We have identifies three reasons to opt in, namely low unrestricted emissions, low control costs, ant the NO,, grandfathering. In this section we use discrete choice econometric models to (1) disentangle the relative importance of these three different factors in the decision to opt in, ant (2) to see whether they ant other "economic" variables can successfully predict electric utilities behavior regarding the Substitution provision. The latter objective is simply an attempt to estimate transaction costs associated to this provision.23 23 For a description of transaction costs in emissions trading programs see Stavins 1995 and Montero (1997). 14 5.1 Model specification We motel the decision opt in an eligible Phase II unit into Phase I as a binary choice. Since the net benefit of opting in a Phase II unit is not observable, we model the difference between benefit and cost as an unobserved variable, subs, such that for the ith unit we have (4) subs = aO + [a~x,~ + v, where we assume that Vi, the error term, has a standard logistic or a normal distribution with mean zero, and x,. are the k characteristics of unit i that affect the decision to opt in. We do not observe the net benefits of opting in, only whether the decision is mate or not. Therefore, our observation is subs = I if subs > 0 subs = 0 if subs S 0 Thus, Our model will predict that unit is a substitution unit if the index function as + ~ Alex`. is greater than zero. The dependent variable, subs, is the probability that a unit opts in as a substitution unit, and it is equal to one when the unit i has actually opted in; or zero otherwise. As we progress we explain the different variables we include in our specification. The benefits and costs of becoming a Phase I unit vary from unit to unit. Let us start with the benefits. First, to capture the benefits of having unrestricted emissions below historic levels and hence below the allowance allocation, we create a variable that captures the difference between the allowance allocation and unrestricted emissions. Unrestricted emissions, which are the predicted emissions in the absence of the Substitution provision, are obtained from the analysis in section 4.3.24 The allowance allocation for each unit is obtained in two forms. For actual substitution units we use the 1995 allowance allocation. For eligible units that did not opt in, we calculate the allowances based on the allocation rule described earlier. The difference between the allowance allocation and unrestricted emissions (exallow) represents the benefits (costs) of low unrestricted emissions at the unit level. However, according to the special provisions for monitoring emissions from common emissions stacks, a Phase II unit with a common stack with a Phase I unit (including substitution units) has to be designated as a substitution unit, unless an additional continuous monitoring system were to be installed. In fact, all 12 Phase II units with common stacks with Table A units were opted in as substitution units. On the other hand, we observe some cases in which not all eligible units under the same "common stack" were opted in. To cope with this issue, we include an additional variable, comstack that for units with single stacks takes the value of zero. For eligible units with common stacks we define comstack as the difference between the aggregate of exallow at the 24 Here we use the eligible sample. IS common stack level minus exallow and divided by the number of units under that common stack.25 For instance, a unit for which exallow is negative can be still opted in if comstack is sufficiently positive such that the costs of additional monitoring are higher than the allowance costs associated with the negative exallow. Needless to say, we expect the coefficient in comstack to be positive. To capture the benefits of having low SO_2 control costs is more difficult since we do not have a direct estimate of compliance costs. As an approximation, we expect for coal-fired units that ceteris paribus the higher the emission rate the lower the compliance costs since more coals are available for compliance. For oil-gas units we do not have a good cost estimate. In our specification we include rte93 as a proxy for SO_2 control cost in coal-fired units. We expect the coefficient to be positive. We also include scrub90 as a proxy for control costs in what we believe units with new source performance standards (NSPS) scrubbers have lower variable cost of compliance. To capture the benefits and costs associated to the NOx grandfathering we must first account for the fact that only coal-fired units with Group I boilers are affected by NOX requirements in Phase I. In addition, we must keep in mind that eligible units can always make use of the NOx early compliance provision without opting in as substitution units. Therefore, the "NOx net benefits" of early compliance as substitution units should be thought only in terms of the NOx grandfathering. The importance of the NOx grandfathering is reflected by the fact that among the 124 substitution units with Group I boilers, 104 are subject to the NOx grandfathering. The other 20 units filed application to opt in after January 1995 We include several variables to account for the net benefits of the NOx grandfathering such as previous NOx emission rates for Group I boilers. To capture the NOx costs of early compliance with Phase I limits we include noxphl that is the difference between the 1993 NOx emission rate (noxrte93) and the Phase I required rate (phlrate) multiplied by a Group 1 dummy variable (group1)). Note that if phl rate > (noxrte93) we make noxphl = 0. For the benefits we include groupl as a first approximation. For the units in which we have control costs data we include marginal cost of compliance with NOx requirements in Phase II for Group I boilers (mcnoxgl). In addition, in order to test whether the NOx grandfathering becomes important only if marginal costs are very high, we create a dummy variable that is equal to I if marginal control costs are above the average mcnoxgl of 867 $/ton of NOx (mchigh). We expect any of the coefficient related to groupl, mcnoxgl and mchigh to be positive There are some costs associated with bringing a

Phase II unit into Phase I. First, there will be a constraint in generation beyond the baseline. If emissions rates are unchanged from the "allowance allocation rate", additional allowances would be required to cover the extra emissions. Thus, we would expect that ceteris paribus a plant with a large number of Table A units should be less likely to include new units in Phase I. We include in our specification gencnplt that stands for generation constraint at the plant level. 25 The correlation between c > > and comstack is relatively low (0.16). See, for example, Table 6.4 with correlation matrix. 16

It is calculated as the ratio between total "Table A affected" capacity at the plant and the total capacity at the plant. We expect the coefficient gencnplt to be negative.26 On the same line of argument, some electric utility staff have commented that uncertainty about the actual utilization level can be an important factor in the decision to opt in a Phase II unit. We know that if the level of utilization by the end of the year turns out to be larger than the projected utilization at the time the unit was opted in, which implies that the operator must acquire additional allowances to cover for the extra emissions, the operator is free to withdraw the unit from the Substitution program. In doing so, he (she) must incur the apparently non- negligible administrative costs of excluding the allowance costs from the rate base during that year. Therefore we expect that the larger the uncertainty about future utilization the less likely the unit would be opted in. Uncertainty is usually higher in peak units, which are relatively small compare to base load units. Since we find a very high correlation between the variation of heat input over the years and the inverse of installed capacity (see Figure 3), we use invcap = 1/namepcap as a proxy for uncertainty. We expect its coefficient to be negative. Finally, we expect that transaction costs or additional costs of using the Substitution provision not captured by our explanatory variables should be reflected in the constant term, at. We expect this term to be negative. A positive constant term conversely, would suggest additional benefits not captured by our variables. The k characteristics, xik, of unit i that affect the decision to opt in can be summarized as follows exallowexcess allowances (actual or potential allowance allocation - unrestricted > > emissions comstack(sum of "common stack" exallow minus exallow) divided by the number of common stack units; zero for units with single stacks rte93clSO2 emissions rate in 1993 for coal-fired units (- rte93*coal); where rte93 is the 1993 SO2 rate, and coal is a dummy equal on if unit is a coal-fired unit scrub90dummy variable equal one if a scrubber was installed before 1990 noxphl(noxrte93) - phlrate)*groupl; where (noxrte93) is the NOx emissions rate in 1993, and phlrate are NOx emissions rates limits for Group I boilers in Phase I. groupl dummy variable equal one if unit has a Group l boiler mcnoxglmarginal cost of compliance with Phase II proposed limits for Group I boilers zero otherwise mchighdummy variable equal one if mcnoxgl > average mcnoxgl and groupl = 1; zero otherwise gencnpltgeneration constraint at the plant level, the ratio between Table A affected name plate capacity of the plant and the total capacity invcap 1/namepcap. 26 One can argue that if a plant is 100 Table A affected" no unit can be brought in, and ~cnenpl' would be obviously very significant and negative. In our sample however, there are no such cases simply because those plants do not have eligible units. 17
5.2 Econometric Results Because we do not have complete data for all observations, we work with three samples. The first sample includes all eligible units (sample 1). Since we do not have a good estimate for SO2 control cost of oil-gas units, we reduce our second sample to only coal-fired units (sample 2). Furthermore, since we do not have information on NOx control for all Groupl boilers, our third sample reduces to coal-fired units including only those Group l boilers for which we have NOx control cost data from EPA (1991) (sample 3). Table 6 present the

statistical summary of all relevant variables for the three samples, and correlation matrix for sample 3. In Table 7 we present the maximum likelihood logit estimates for samples l, and 2 respectively. Because sample 3 contains a more complete data set, our discussion below will focus primarily on results obtained using this sample. Note however, that results obtained using the other two samples are entirely consistent with our following discussion. Table 8 presents the logit and odds ratio estimates for the third sample. Results in first column of Table 8 confirm closely our previous discussion. Relevant coefficients are significant at the 99* or 95 level and with the expected sign. We first find that the coefficients for exallow and comstack are positive and significant at the 99% level. Similarly, both coefficients controlling for low SO2 marginal control cost (rte93 and scrub90) are significant and with the expected signs. The only exception is the coefficient of scrub90 in the first column of Table 7. The benefits of the NOx grandfathering seems to be well explained by either groupl or mchigh. (We also use mcnoxgl instead mchigh with similar results). On the other hand, the costs of early compliance with NOx (noxphl) seems to be relatively unimportant compared to the NOx grandfathering benefits. Results concerning generation constraints (gencnplt) and uncertainty about utilization invcap are not always significant, but with the right sign when they are. In the first column of Table 8, for instance, both coefficients have the expected sign, but only gencnplt is significant at the 95 significance level. The effect of each independent variable on the probability of observing a unit opting in is presented in the form of odds ratios in the second column of Table 8. An odds ratio greater than one indicates that the odds of a unit being opted in increase when the independent variable increases. For example, for a unit that experiences an increase in 1000 excess allowances, (exallow) the odds of that unit being opted increase by 26%. In other words, if the odds of the event of opting in unit i is I (i.e. probability of opting in equal to 50%)27 a 1000 increase in exallow increases the odds to 1.26 or the probability of opting in to SC%. Similarly, for a unit that experiences an increase of I #/mmBtu in rte93 the odds of that unit being opted in increase by 94%. The effect of the NO,, grandfathering in the decision to opt in is very significant if we analyze the increase in the odds of opting-in of a unit with a Groupl boiler that happens to have a high NO,, marginal cost. This change increases the odds by more than S. that for an initial probability of opting-in of 50% implies that it increases to 84%. This 27 The relation Is: odds of the event occurring . probability event occurs / (I - probability event occurs) 18 result is largely consistent with observations of actual substitution units with very negative exallow but subject to the NOx grandfathering. Because, in order to benefit from the NOX grandfathering it is only required one year of compliance with Phase I, say, 1995, all these units are very likely to withdraw in 1996. The goodness of fit of our logit model is presented in Table 9, which shows how many units are sucessfully predicted. The predicted value for subs takes the value of I (i.e. predicted as a substitution unit) if P(subs > 0) = F(subshat) > 0.5 and zero otherwise, where F is the cumulative logistic distribution and subshat is the predicted value from expression (4). Out of the 316 observations, 258 (81.6%) were successfully predicted either as a substitution unit (77) or not opt-in unit (18l). 5.3 Competing rcasons for opting in Here we estimate the importance of each of the three factors mentioned above (i.e., low unrestricted emissions, low costs and the NOx grandfathering) on the decision to opt in an eligible unit. Using the third sample, we test for three null hypothesis separately: (1) in Mow = a`~t = Q. (2) He: artA3cl S 06en~O = 0 and (3) Ho: aU,xphl = a~rh~h = 0The x2 statistics are 42.92. 17.03 and 21.60 respectively. Besides indicating that the three hypotheses are rejected at the 99% significance level, these numbers suggest that on average having excess allowances (or low unrestricted emissions) has a more significant effect on explaining voluntary compliance than the other two competing reasons. It is important to mention nevertheless, that many units were opted in for more than one reason. In a more intuitive approach we use our specification (4) and sample 3 to predict how many of the 98 predicted positive units (subshat > 0.5) would still be predicted positive if we replace the values of some of their relevant variables by mean values. For example, if for the 98 predicted positive units we make exallow = - 1809 and comstack = 389 (see Table 6.3), while everything else remains the same, we find that only 30 units are still predicted positive. Now, if we make rte93cl = 1.70 and scrub90 = 0.11, while everything else remains the same, we find that 83 units arc still predicted positive. In the case of NOx grandfathering, 76 units arc still predicted positive. These numbers are consistent with the previous results in that having low unrestricted emissions as the most important reason to opt in. 5.4 Estimating transaction costs Transaction costs or additional costs of using the Substitution provision not captured by our explanatory variables seem to be important according to the constant term, which is significant at the 99% level. We can calculate transaction costs in terms of allowances for a typical coal-fired unit with an emission rate of 2.0 #InnnBtu, single stack, scrub90 = 0, groupl = 0, installed capacity of 200 MW, and no generation constraints, that is genenpit = 0. Using the bait coefficients of the first column of Table 8, we find that exallow has to be greater than 1478 for expression (4) to be positive, or for the unit to be 19 > > predicted as a substitution unit. This is a very low number if we compare it to the average compliance cost with Title IV of Phase I units.28 There is no reason to expect transaction costs to be equal across units from different operating utilities. We would except that a eligible unit in a electric utility with a relatively large percentage of generation under Table A face lower transaction costs since there is more incentives to spend a "fixed" amount of effort in understanding the rules. In other words, the marginal transaction costs associated to opting in an extra unit are lower. Thus, in specification (4), we include pertautl (percentage of Table A at the utility level) as the ratio between Table A affected name plate capacity at the utility and the total capacity at the utility. Using sample 3, we find the coefficient of pertautl to be positive and significant (see last column of Table 8). While transaction costs would be the same as before for a unit with pertautl 5 0.24, they would become negligible if pertautl = 0.69. Based on these and above results we conclude that the behavior of electric utilities regarding the Substitution provision can be well explained using "economic" variables and hence transaction costs appear to be relatively low. An important implication from this observation may be that there is no reason to believe that transaction costs associated to the overall SO2 emissions trading program can be that large. This is consistent with the large trading activity reported by Joskow et al. (1996). 6. An ex post c" befit analysis In previous sections we have identified the importance of the adverse selection effect (units opting in because of excess allowances) and the flexibility effect (units opting in to reduce SO2 emissions at costs lower than those of some Table A units). From the analysis in section 3, we concluded that the number of excess allowances is more than twice the number of SO2 tons reduced by substitution units. As we shall see, this observation is neither necessary nor sufficient to claim that the adverse selection effect dominates. In this section we present an ex post cost-benefit analysis that permits us to evaluate which effect dominates from a welfare standpoint. Our analysis is restricted exclusively to the implementation of the Substitution provision. In other words we take all the other provisions of Title IV as given. In addition, we do not include any administrative costs borne by EPA as put of implementing and running the Substitution program, although we know they are not negligible.

6.1 A simple model We first develop a simple model that captures the basic trade-off between excess allowances and lower cost emissions reductions. If for simplicity we assume that there is only one period, or equivalently no banking, we can say that all excess allowances will be used during that period. In Figure 4, the horizontal axis of the diagram indicates the amount by which total emissions are reduced below their unrestricted level. The MB 28 Total costs are 836 million (Mortem et al., 1996) that divided > 445 gives 1.87 million > unit. 15 allowance times 100 $/allowance is 8% of that. 20 (marginal benefit) curve represents the marginal social benefit of emissions reduction as a function of the quantity of emissions that are controlled. Curve MCTA (marginal cost) represents the marginal control cost of emissions reduction from originally affected units, that is Table A units. Without the Substitution provision, the optimal control level is obviously Q at which the marginal costs and benefits are equal. Due to information constraints however, the environmental authority, does not necessarily set the emission reduction target at that level, rather she chooses Q. Or equivalently, she sets an aggregate emissions cap of Eo- Q. where Eo is the sum of unrestricted emissions. Aggregate control costs are given by the area under MCTA from 0 to Q. In case the authority implements the Substitution provision (and issues allowances equal to historic emissions), the new marginal control cost curve shifts downward due to the inclusion of low marginal control substitution units. Let MCTAS be the aggregate marginal control costs from Table A and substitution units. If unrestricted emissions of substitution units are equal to historic emissions and hence to the allowance allocations (i.e. no adverse selection), the reduction target remains the same and aggregate control costs reduce to the area under MCTAS from 0 to Q. and savings from the Substitution provision are given by area A + B. In short, there is no adverse selection effect and therefore the flexibility effect dominates. When some substitution units have reduced the unrestricted emissions levels below historic emissions or the allowance allocation the reduction target Q reduces to Q - EA, where EA are the total excess allowances. EA are used to cover SO2 reductions that would have occurred had the Substitution program not been implemented. The adverse selection effect is represented by this shift of the original reduction target to the left. Aggregate control costs are now given by the area under MCT" from 0 to Q - EA. While savings from lower cost reductions are given by area A, savings from "avoided" reductions are given by area B + D. On the other hand, SO2 emissions will be larger than otherwise by an amount equal to EA. The social cost of additional SO2 emissions are given by the area under MB from Q - EA to Q. which is area B + C + D. The total savings or net benefits associated to the Substitution program are given by area A - C. In this case is not clear which effect dominates. It will depend on the slope of the MB and MC curves, how much "reduction substitution" between Table A and substitution units is economically available, and where the original reduction target Q is situated. Note for example, if Q is located to the far right, the adverse selection effect may even be beneficial in that the new equilibrium with the Substitution provision will be closer to the optimum 29 Let us now introduce banking, as in the SO trading program. The cost-benefit calculation complicates somehow: While benefits from shifts in reductions accrue today, benefits and social costs from excess allowances accrue at the time those excess allowances are used to "replace" SO2 reductions that would have taken place otherwise. In 29 It is important to mention that several Table > units have significantly reduced emissions by masons other than Title IV and have, therefore, received excess allowances as well. The implication to our analysis is that the MCTA and MB curves and Q in insure 4 should be interpreted as the actual curves and value that we observe in 1995. For instance, since unrestricted emissions are lower than expected, the actual MB curve has shifted downwards. In addition, the "costly" required reduction is lower than before so Q has shifted left. 21 our case, the latter can be any time between 1995 and the time the bank of allowances runs out. Fortunately, from a dynamic efficiency argument, we know that the net present value of the benefits of avoided reductions from excess allowances is independent of the time of usage.30 We cannot say the same for social costs of additional SO2 emissions. 6.2 Application to the Substitution provision Now, we can use the methodology illustrated in the above model to calculate the ex-post net benefits from the Substitution provision in 1995 We proceed as follows. First, using the results of section 3, we estimate the 1995 reduction from the counterfactual and the 1995 excess allowances, which are 0.14 million tons and 0.34 million allowances respectively.31 Second, using the compliance cost analysis of Montero et al. (1996) and CEEPR (1996) on operating costs of NSPS scrubbers and sulfur premium paid by substitution units switching to low sulfur coat we use an average marginal control cost of substitution units of 55 dollars per SO2 ton removed (hereafter $/ton).32 The control cost savings associated to the 1995 reduction by substitution units can be calculated as the difference between the avoided costs and the marginal costs of substitution units times the SO2 reduction. If we assume that the Substitution provision is a marginal and relatively small part of the SO2 trading program, such as suggested by our analysis in section 3, the avoided costs will be approximately equal to allowance prices. Given the 1995 average allowance prices of $129.33 the savings are equal to 10.4 (- 74*0.14) million dollars. In terms of Figure 4, this would be area A. Third, we calculate the benefits and social costs of excess allowances separately. Benefits, the result of avoided control costs, will be approximately equal to present value of allowances price times the number of excess allowances, which is 43.9 (=129*0.34) million dollars. In figure 4, this would be area D. On the other hand, social costs which will take place when electric utilities decide to use the excess allowances to cover emissions reductions, will be approximately equal to present value of the marginal benefits of SO2 reduction times the excess allowances. Estimates of (annual) marginal benefits of SO2 reductions are clearly above actual allowance prices and vary from 314 to 2326 $/ton.34 One might also argue that the marginal benefit of an extra SO2 ton removed should not be too different from the expected allowance price at the time the reduction target was decided (about $300). In Figure 4, this cost would be area C + D. 30 Because of banking and stricter Phase > limits, allowance prices should increase at some discount rate that discounted to the present ate equal to actual prices. When bank runs out this is not longer true. 31 These are conservative numbers because in reality excess allowances can be larger because part of the reduction is to western coal. 32 This number may be larger if we excluded some of the "economic snitches" to western coal. 33 From Clean Air Compliance Review (several issues). 34 Values ate in 1994 dollars. The 314 figure is the low estimate of Cifuentes and Lavin (1993) and the 2326 figure is from EPA (1995). These estimates only consider human health benefits from SO2 reduction. Because they ate based on linear damage response functions, marginal benefits curve tend to be flat in the relevant ranges, and as a result there is no need to control for the downward shift of the MB curve. 22 Finally, we can perform several net benefits calculations under different assumptions. For example, if we assume that allowances will be used in year 2000, for a marginal benefit of $300 and discount rate of 8%, the latter figures would indicate that the ex-post net benefits of the substitution program arc negative and equal to -15 million dollars (10.3 + 43.9 - 300*0.34*1.08 5). Note that there will be no net benefits if marginal benefits of additional SO2 removal are about $230. Now, if all excess allowances were used in 1995 through spatial trading, the net benefits are 48 million dollars. A further estimate can be attempted with EPA marginal benefit figures. There, the negative net benefits can account for several hundred million dollars, regardless when the excess allowances are used. Although we think that EPA SO2 marginal benefits figures are relatively high, we do not have good reasons to believe that marginal benefits are much lower than previous estimates or the expected allowance prices at the time the CAAA was signed into law that can support a positive net benefits figure. From a methodological point of view is worth explaining that an ex post analysis may not say much about whether implementing the program is efficient from ex ante perspective (i.e. positive expected net benefits). Setting apart legislative and administrative cost of running the program, the fact that allowance prices (and marginal costs) were thought to be much higher than what they are today, tend to favor the implementation of the program in the first place. In fact, Montero (1996) shows that the nigher the expected value and uncertainty about the market equilibrium price for allowances, the more likely a voluntary program would yield (expected) net- benefits. The next section presents an exercise from an ex ante perspective. 6. An hypothetical ex and exercise When the CAAA was signed into law in November of 1990, the expected allowance prices were well above actual paces (around $90 in Dec. 1996). Since then, prices were steadily falling to its lowest level of SOS in the March 1996 auction. We know that the lower the allowance price the less incentive outside sources have to opt in as substitution units and make reductions, therefore, it should not be surprising that actual participation and hence SO2 emissions reductions due to the Substitution provision may be lower than anticipated. Although we do not have any estimate on "expected" participation and emissions reductions > , we have information on several eligible units that filed application with Substitution provision during the Feb93 - Dec94 period and finally decided to stay outside Phase I by Dec 1995 These are 94 conditional units that did not become active substitution units. We use the analysis of section 3 to first predict the amount of SO2 reduction and excess allowances from "additional substitution units" had the allowance prices remained higher. Then, we obtain an ex ante net benefits estimate base on 1993-94 expectations." Allowance prices have been steadily falling to levels significantly lower than previous estimates. In fact, compared to earlier estimates of $300 and above, the average allowance price in the Jan93 - Dec94 period was about $189, and the 1995 average price 35 One may also suggest to extrapolate actual marginal cost curve for substitution units. The only problem is that we can not identify excess allowances. 23 (was only $128.36 That all 94 conditional units would have remained as substitution units had the allowance prices stayed at the 93/94 level is a strong assumption. There are several units that withdrew from opting-in after the allowance allocation rules changed with the settlement agreement. To correct for factors other than price fall in the decision to withdraw from the program, we use our discrete model of section 5 to predict which conditional units would have opted in had the allowance price remained at a higher level. In doing so, we develop a very simple approach. Because most applications involving conditional units were received during 1993 and 1994, and all withdrawal decisions were made during 1995, we assume an ex ante price of $189 (93-94 average) and an ex post price of $128 (95 average), which implies a 32% decline in prices. If we could run our logit model with an explicit higher allowance price of 189 rather than 128, it would predict more units opting in relative to what it actually does. We do not have a price variable in our model, but since we know that the next units opting are the ones with subshat (prediction of subs as the probability of opting in) right below the cutoff point of positive prediction (P = 0.5), we should be able to approximately identify the new opting- units by lowering the cutoff point in the right amount. We have no exact way of determining that amount, so we simply assume that the cutoff point reduces by a proportion equal to the price decline, that is from 0.5 to 0.34. Rather than working with all positive predicted units, as one may reasonably argue, we only work with 28 conditional units that are predicted as substitution units under these new conditions (subslhat > 0.34). Note that 10 of these units were previously predicted positive (subshat 0.5), and that all of them are coal-fired units. For the 28 "additional substitution" units, we calculate the excess allowances and SO2 emissions reduction that we would have observed had these units remained as substitution units. As before, using the analysis of section 4 we estimate emissions reductions and excess allowances equal to 43 thousand tons and 12 thousand allowances respectively. If we sum these quantities to the ones of the 182 actual substitution units and use the 1993-94 average price as the expected avoided costs, the expected net benefits of our previous example increase from-l5 to 19 million dollars. As we go further back in setting our expectations, say, 1990, this amount should become more positive since units with excess allowances opts in first, and possibly regardless of the allowance prices. Although our exercise is far from rigorous and fails to take an ex ante perspective at the time the program was implemented, it helps to illustrate the sort of issues that are important to keep in mind in judging the success or failure of programs of this type. We believe that the expected sharp decline in allowance prices is a main contributor in explaining the slim ex post savings from this program" It is also possible that the low allowance paces are hindering participation in the Opt-in program for industrial sources, which may have higher SO2 control costs compared to electric utility units. 36 Based on early reported private sales and CACR index. Auction paces am not included. 24 7. Conclusions The Substitution provision of the SO2 emissions trading program constitutes the first voluntary compliance program within a emissions trading scheme. We believe that an analysis of a voluntary compliance program such as this represents a interesting case study of issues that can arise in attempts to implement future tradeable permit schemes. In this paper we carried out empirical analyses base on actual data after the first year of compliance with Title IV - which is 1995 - in order to assess the practical and welfare implications of the Substitution provision. Our first result indicates that the Substitution provision has had a rather small effect on the overall performance of the SO2 emissions trading program and on SO2 emissions reductions. Nevertheless there has been a significant participation, with more than half of the "affected" electric utilities using this voluntary compliance option to reduce compliance costs. This observation provides further evidence to the notion that, in general, electric utilities are choosing cost-effective strategies to comply with SO2 limits. Consistent with that is our finding that transaction costs associated to Substitution provision have been relatively low. In another result, we show that non-affected units have opted in, largely because their actual unrestricted emissions (i.e. emissions in the absence of regulation) are below their historic emissions and hence their allowance allocation. Other units have opted in because they have low marginal control costs, say, below allowance prices. While the latter effect reduce today's aggregate cost of compliance by shifting reduction from high cost affected units to low cost units (the flexibility effect), the first effect increases today's emissions and emissions in the future (the adverse selection effect). An ex post cost-benefit analysis suggests that the adverse selection effect dominates, in part because low allowance prices. From an ex ante perspective however, we show that this result may not hold. An interesting area for future research would be to compare the two voluntary compliance options: the Opt-in program and the substitution provision.

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3 3 Note that voluntary compliance programs are not totally uncommon in US environmental policy (see Stoughton, 1995 for an evaluation of six voluntary programs implemented by EPA, including the 33150 Program). These ate very different in nature and scope to the voluntary program we study here.

4 4 A unit, which is defined as a Fossil-fuel-fired combustion device" in 5 402 of the CAAA, corresponds to a single generator and associated boiler A generating plant can house one or several units, which may be of different sizes, vintages, type or fuel input.

5 See, for example, GAO (1994)

6 Brian McLean personal communication, September, 1996.

7 Discussion of the benefits of SO_2 reduction by Title IV can be found in EPA (1995b)

8 A unit that fails to hold sufficient allowances to cover its emissions is subject to significant financial and legal penalties The penalty for non-compliance is $2000 for each ton of SO_2 emitted that is not covered by an emission allowance designated for that source. In addition, the subsequent yeses allocation will be reduced by the tonnage subject to the penalty.

9 9 A Phase I unit is said to be underutilized if, in any year in Phase 1, the total annual utilization of fuel at the unit is less than its baseline.