An Assessment of US Air Quality Policy: Past, Present and Future*

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ABSTRACT

It is accepted in current literature that market-based pollution reduction methods are more effective that conventional command and control policies. This paper examines the current trends in air quality levels in the US and the projected effects of the EPA's Clean Air Interstate Rule (CAIR) to develop a benefit-cost model to analyze the potential effectiveness of the cap and trade programs developed in this program. The model adopts a marginal benefit of pollution abatement from the literature and uses actual and projected market-based prices for annual SO2 and seasonal NOx allowances. The results show that the benefits of pollution reduction in both markets far exceed the costs.

INTRODUCTION

This paper will present a brief cost-benefit study on the efficiency of the proposed CAIR cap-and-trade air quality programs. There has been a significant amount of ex post analysis on Title IV of the Clean Air Act Amendments (CAAA) of 1990 presenting empirical data that states the benefits of reducing SO2 emissions from EGUs across the country far outweigh the costs. Citing Title IV as an example, it has been accepted in the literature that cap-and-trade programs relating to air pollution reduction are more environmentally and economically effective than alternative "command-and-control" programs. The following section will discuss both the environmental and economic benefits of using a cap-and-trade program, describe the current state of benefit-cost models as they relate to air quality policy, and present a concise, up-to-date model that forecasts the market efficiency and net benefits of CAIR programs with respect to SO2 and seasonal NOx emissions reductions.

ENVIRONMENTAL EFFECTIVENESS

The environmental effectiveness studies that have been done have largely focused on the success of the Title IV acid rain trading program. These results can be generalized to predict the results of similar programs for pollutants other than SO2. Ellerman (2003a) argues the acid rain trading program's environmental effectiveness is due to four features: (1) a large reduction in emissions was actualized relatively quickly after implementation; (2) the use of allowance banking significantly accelerated emission

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reduction; (3) no exemptions or exceptions from the program's requirements were granted; and (4) the pollutant-ridden "hot spots" that opponents of cap-and-trade programs cite as a result of allowance trading have not yet appeared.

Since the main air pollution reduction policies involving a cap-and-trade program implemented are designed almost identical to the ARP, these policies should achieve similar results. Ellerman's first three environmentally effective features should transfer to other programs in at least some magnitude. There were fears that a lone national market for SO2 would result in an increase in pollutant concentrations in the Northeast from EGUs in the Midwest where it is more costly to reduce emissions. These fears, however, have proved to be ungrounded as the entire eastern seaboard has received benefits due to the patterns of trading coupled with a national decrease in emissions (Burtraw et al. 2003). Ellerman (2003b) also points out that sources in the Midwest provided about 80% of the emissions reduction achieved in the acid rain program. This pattern is also expected to be seen as a result of the CAIR reduction programs which, by title, are devoted to reducing the pollution that traverses state borders.

ECONOMIC EFFECTIVENESS

In the early nineties, when the acid rain program was promulgated, there were very few estimates of the economic benefits of air pollutant reduction, namely SO_2. Burtraw et al. (2003) claims that the only economist who presented an opinion the issue in 1990 estimated the benefits and costs of the acid rain program to be approximately equal. It is now well known that the benefits of SO_2 reduction far outweigh the costs. This is, in part, due to the increasing valuation of health and ecological benefits from pollution reduction as pollutant monitoring and analysis technology has improved as well as the lower than expected aggregate abatement costs provided by allowance trading.

Burtraw et al. (1998) compares the estimated costs of command-and-control legislation proposals for SO_2 reduction in the eighties to the realized costs of the cap-and-trade ARP. The Sikorski/Waxman bill proposal in 1983 had a range of estimated costs from $7.9 to $11.5 billion dollars per year (1995 $). Another bill proposal, H.R. 4567 in 1986, targeted similar environmental improvements at an estimated rate of $7.5 billion per year. Burtraw et al. (1998) compile a list of eight studies that estimate long-run (2010) costs of the ARP between $.9 billion to $3.7 billion, with the more recent studies (circa 1998) being lower and probably more accurate as they are structured on actual rather than entirely projected data. According to Burtraw et al. (1998), the fact that the price of *ex post* realized allowances are much lower than the *ex ante* estimates of marginal abatement costs demonstrates that the market-based allowance trading system is responsible for reducing the costs of lowering SO_2 emissions.

BENEFITS ESTIMATES

In the literature, benefits gained from a reduction in pollution are estimated in a variety of ways. Health benefits are the predominant monetary benefit in most studies. Some estimates also assign values for ecological damages including agriculture, visibility, and materials (Banzhaf et. al 1996).

Ostro et al. (1998) describe four distinct components when measuring health benefits: (1) the quantitative relationship between ambient concentrations and the concentration-response functions; (2) the size and identification of susceptible populations; (3) the projected change between current and target air pollutant concentrations; and (4) the economic value of the reduction in health effects incidence. The fourth component differs substantially throughout the air quality literature. Concentration-response, or dose-response, functions assess the "what-if" scenario with respect to an increase in pollution and the accompanying pollution-related health incidents. Ostro et al. (1998) disaggregate health effects related to particulate matter pollution into categories of premature mortality, adult chronic bronchitis, respiratory hospital admission, cardiac hospital admission, emergency room visits, child acute bronchitis, restricted activity days, asthma symptom days, and acute respiratory symptom days—each with a particular range of dollar values. Banzhaf et al. (1996) disaggregate monetary health, as well as agricultural, effects by damages done by each of the six criteria pollutants in a study on electricity generation in the Midwest. Muller et al. (2007) annualize monetary damages by the effects of six different pollutants in the following categories: mortality, morbidity, agriculture, timber, visibility, materials, and recreation. Ultimately, every benefits analysis contains different benefit criteria and a different range of monetary benefits, so, as would be predicted, the aggregate benefits of reducing pollution differs substantially across the literature.

METHODS

This paper aims to build upon prevalent knowledge and analyze the effectiveness of current air quality policy in the U.S. in order to predict an estimate of the efficiency of the CAIR program which is scheduled for implementation in 2009 and 2010. The focus of this model centers on two pollutants, SO_2 and NO_x, and their effects. Banzhaf et al. (2004) provide the results of a simulation model designed to estimate efficient emission fees for SO_2 and NO_x in the national electricity sector. The model presented in that study provides satisfactory values for marginal benefits of both SO_2 and NO_x abatement—that is, the social dollar value of one less ton of a pollutant in the air. These values—\$3,000/ton$_{SO2}$ and \$900/ton$_{NOx}$—are adopted for this paper's model. Burtraw et al. (2001) and Burtraw et al. (1998) confirm the NO_x estimation of Banzhaf et al. (2004) in four separate models with NO_x reduction benefits ranging from \$647 to \$755.

Additionally, most of the air quality benefit-cost studies use an estimate of program implementation, monitoring, and new technology installation costs to calculate the aggregate costs of a program or policy. Alternatively, this paper will apply actual and EPA-projected market-based allowance prices at different levels of abatement as an aggregate marginal cost. Burtraw (1998) explains that allowance prices in a given year should reflect marginal abatement costs in that year and provides this example: “Imagine instead that allowance prices were less than a firm’s marginal costs. Then the firm could decrease its compliance activities and purchase allowances in the market as an alternative means of compliance, earning positive net revenues.”

This model focuses on the market efficiency of annual SO_2 abatement and ozone season NO_x abatement. This paper does not address the annual ozone NO_x reduction program because that program is the first of its kind and has no current data available for analysis. The annual ozone program does, however, limit the projections of market prices for the seasonal ozone program since the two programs overlap, while restricting emissions of the same pollutant, during five months of the year. This model, therefore, can only estimate the projected allowance prices by the trend in known data and the expected future level of abatement.

Using the allowance price data, this model is designed to approximate a marginal cost curve at different levels of pollution abatement. The allowance price data is regressed exponentially to form a marginal cost curve. For SO_2, the derived curve held the equation: $y = 144.54e^{0.0000003872x}$, where $y =$ annual SO_2 allowance price and $x =$ tons of SO_2 abatement. For NO_x, the derived curve held the equation: $y = 447.17e^{0.000002833x}$, where $y =$ seasonal NO_x allowance price and $x =$ tons of NO_x abatement. The marginal benefit curves are simply horizontal lines at the particular dollar value per ton of pollutant abated.

Table 1[1]:

Annual SO2 Emissions (tons)	**2008**	**2010**	**2015**	**2020**
Actual (Projected Emissions with CAIR)	8,893,322	6,100,000	5,000,000	4,300,000
Projected Emissions without CAIR	10,034,310	9,700,000	8,900,000	8,600,000
Abatement Level	1,140,988	3,600,000	3,900,000	4,300,000

Seasonal NOx Emissions (tons)	**2007**	**2009**	**2015**	**2020**
Actual (Projected Emissions with CAIR)	1,196,402	1,050,000	960,000	970,000
Projected Emissions without CAIR	1,267,520	1,200,000	1,210,000	1,220,000
Abatement Level	71,118	150,000	250,000	250,000

Allowance Prices	**2008**	**2010**	**2015**	**2020**
SO2	$300	$533	$671	$868
Adjusted for Inflation ($ 1999)	$231	$517	$651	$842
	2007	**2009**		
NOx	$710	$888		
Adjusted for Inflation ($ 1999)	$547	$684		

Marginal Benefits	**SO2**	**NOx**
	$3,000	$900

Discussion and Analysis[2]

Figure 1 illustrates the marginal benefits and costs of SO_2 abatement per annum under current conditions and projections with CAIR. This is an atemporal analysis, despite the yearly labels. The yearly labels simply signify the level of abatement projected for that year under CAIR. As is expected, the level of abatement increases with each phase of CAIR. In 2008, the marginal costs of SO_2 abatement are $231/ton at a level of 1.14 million tons. The net benefits reach $3.3 billion and the benefit-to-cost ratio is 36.4. In 2010, the marginal costs of SO_2 abatement are projected to increase to $517/ton at a level of 3.6 million tons. The net benefits are projected to reach $9.9 billion with a benefit-to-cost ratio of 11.5. In 2015, the marginal costs of SO_2 abatement are projected to rise even further to $651/ton at 3.9 million tons of abatement. The net benefits are projected to rise to $10.6 billion with a benefit-to-cost ratio of 10.6. In 2020, the marginal costs of SO_2 abatement are estimated at $842/ton at a level of 4.3 million tons. The annual net benefits are projected to settle at $11.6 billion and the benefit-to-cost ratio is calculated to be 9.7.

A^*_{SO2} represents the efficient level of SO_2 abatement (7.833 million tons) based on this model—where marginal costs equal marginal benefits. Achieving this level of abatement is not practical under CAIR considering it requires almost total abatement of 2020 emissions levels. It is important to note, however, that this model defines a level of abatement comprising over 91% of total 2020 SO_2 emissions as economically efficient with a benefit-cost ratio greater than 5.

Figure 1:

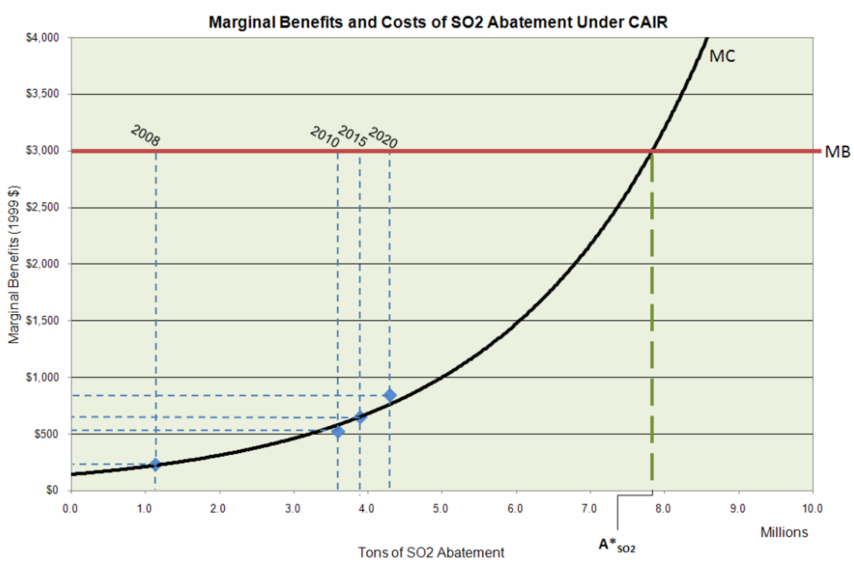

Table 2[3]:

Net Benefits of SO2 Abatement
(millions of 1999 $)

	Total Benefits	Total Costs	Net Benefits	B/C Ratio
2008	3,420.0	93.9	3,326.1	36.4
2010	10,800.0	936.6	9,863.4	11.5
2015	11,700.0	1,099.2	10,600.8	10.6
2020	12,900.0	1,336.3	11,563.7	9.7
A*	23,499.0	4,434.2	19,064.8	5.3

Figure 2, similarly, represents the marginal benefits and costs of seasonal NO_x abatement per annum under CAIR. Using the allowance pricing data from 2007 and 2009 as well as the projected levels of abatement, the marginal cost curve in this model is drawn to illustrate the economic efficiency of CAIR's cap-and-trade program. In 2007, the marginal cost of seasonal NO_x abatement was $547/ton at a level of .071 million tons of abatement. The net benefits reached $62.9 million with a benefit-to-cost ratio of 56.6. In 2009, the marginal cost of abatement is estimated at $684/ton at a level of .15 million tons. According to the model, the net benefits should reach $130 million with a benefit-to-cost ratio of 26.8.

Figure 2:

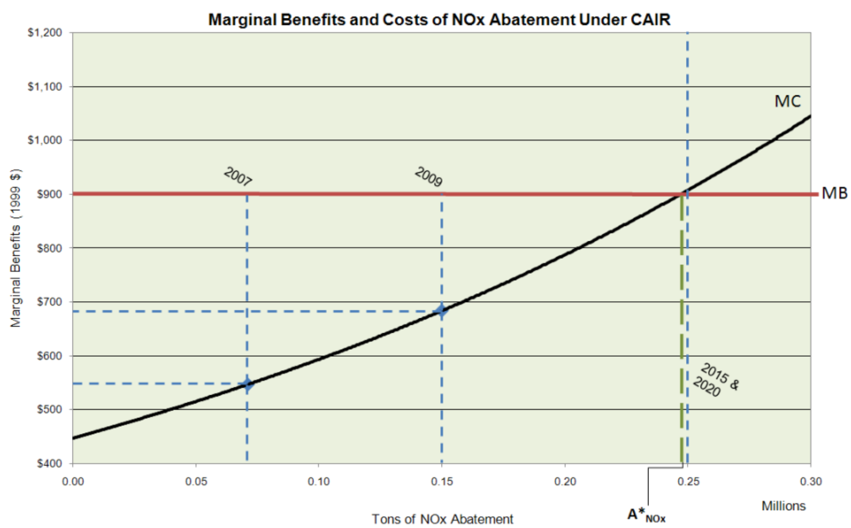

Table 3:

Net Benefits of NOx Abatement (millions of 1999 $)

	Total Benefits	Total Costs	Net Benefits	B/C Ratio
2007	64.0	1.1	62.9	56.6
2009	135.0	5.0	130.0	26.8
A*	222.3	13.6	208.7	16.3

A^*_{NOx} represents the efficient level of seasonal NO_x abatement (247,000 tons) in this model. Even at this level of abatement, the benefit-cost ratio is 16.3. This signifies a substantial social benefit with respect to costs of achieving the abatement level. Under CAIR, projected abatement levels for 2015 and 2020 fall at about 250,000 tons of seasonal NO_x. Since there is an additional annual NO_x allowance trading program under CAIR, reasonable price forecasts for seasonal NO_x could not be used to improve the accuracy of the model. At an abatement level of 250,000 tons, however, the CAIR program falls within 3,000 tons of perfect economic efficiency. Perhaps in assigning phase II caps for the seasonal NO_x emissions requirements, the EPA's air quality model developed similar results as this model and the cap was set in attempt to achieve economic efficiency through CAIR's market based allowance trading program.

Table 4:

Study	Benefits Estimate (billion dollars)	Comments
Burtraw el al. (1998)	$29.8	Projected Annual Benefits of Title IV in 2010
Muller et al. (2007)	$31.0	Estimate of SO2 and NOx Abatement in 2000
Ostro (1998)	$32.0	Achieving Particulate Matter (2.5) NAAQS from 1994-1996 baseline concentrations
Chesnut (1995)	$35.3	Projected Annual Benefits of Title IV in 2010
EPA (1999)	$110.0	Projected Annual Benefits of Title IV in 2010
Chesnut (2005)	$122.0	Projected Annual Benefits of Title IV in 2010 including benefits to southern Canada and several local benefit studies

In the literature, studies show total annual benefits of SO_2 and NO_x reductions projected to reach roughly $30-35 billion relative to levels of pollution that would be present absent air quality programs from 1990 onward. Two studies, EPA (1999) and Chesnut (2005), projected the total annual benefits of the acid rain program well over $100 billion. The model presented in this paper estimates benefits of CAIR in its initial years of implementation (2009 and 2010) around $10.9 billion without an estimate for annual NO_x reduction. In 2020, the model estimates annual benefits of CAIR around $13.1 billion, again without an estimate for annual NO_x reduction. The EPA projects CAIR to result in $85-100 billion in health benefits and $2 billion in visibility benefits by 2015. Judging by this estimate and the benefits estimates of the acid rain program, it is apparent that the model in this paper is a great underestimate of potential benefits of CAIR.

The low-limit nature of this model provides a useful point of economic analysis. In this study, it is shown that the economic benefits of reducing air pollutants are much larger than the costs of pollutant abatement. With undervalued benefits, the actual benefit-cost ratio is most likely an improvement from the results presented in this model.

FINAL REMARKS

The economic and environmental success of the ARP of Title IV has set the foundation for air quality policy both in the US and worldwide. Critics of cap-and-trade programs for environmental improvements have been silenced by the efficiency of markets—a great victory for economists—as market based programs begin to conquer the world of pollution policy.

This paper is intended to be used as potential framework for future benefit-cost analyses related to market-based air quality policy. With firms actually assigning a dollar value to a ton of pollution abatement, the guesswork on the cost side of analysis is minimized resulting in higher accuracy and better future projections of costs. The benefits of pollution reduction remain vague in the literature. Ambient air quality infiltrates sectors of society in millions of ways that are not, or cannot, be valued and this ambiguity lends uncertainty toward scholarly results. It appears that the literature has begun to narrow the range of health benefits, but skepticism persists.

Ultimately, this paper allows for the understanding, discussion and analysis of air quality policy in the US. The economics of environmental regulation will continue to become a point of interest for those concerned about the human impact on the natural resources. Given that policy provides the opportunity to curb the negative externalities on the environment, it is imperative that research and analysis in this area continues as there is no alternative for clean air.

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ENDNOTES

1.

- The 2008 and 2007 projected emissions without CAIR data for both SO2 and NOx, respectively, were interpolated using a third order polynomial regression of the 2010, 2015 and 2020 EPA estimates as well as actual 2003 baseline levels.

- The 2009/2010, 2015 and 2020 actual (projected emissions with CAIR) data, the 2009/2010 projected emissions without CAIR data, and the actual 2007 seasonal NOx emissions data were gather from the EPA.
- The actual 2008 annual SO2 emissions level was obtained by extrapolating a third order polynomial regression of actual EPA emissions data from 1980 to 2007.
- The 2007/2008 allowance prices are based on Evolution Markets' actual spot-trade pricing. The 2009/2010, 2015 and 2020 data are EPA forecasts. All values are inflation-adjusted to 1999 dollars.
- The marginal benefits are adopted from the Banzhaf et al. (2003) study. These values are in 1999 dollars.

2. It should be noted that all dollar values used in this section of the paper have been adjusted for inflation to 1999 dollars using the BLS inflation calculator.
3. Total costs were calculated by taking the definite integral of the MC function with a lower limit of zero and an upper limit of the level of abatement in the specified year. Hence, total costs are defined as the total dollar value spent by firms on emission allowances.

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