The benefits and costs of air pollution control

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The U.S. Environmental Protection Agency estimates that we devote about $150 billion annually to environmental protection. While we can probably afford to spend such a sum on environmental protection, we must spend it wisely. Certainly the magnitude of our environmental expenditures—on the order of 2% of the Gross Domestic Product (GDP)—raises questions about the efficiency and effectiveness of the overall environmental management system. Are we getting good value for our money? Could we do better?

To answer such questions we turn to the field of economics and, particularly, the burgeoning field of environmental economics. Economic analysis can provide an accounting framework for tracking and exploring the implications of environmental decisions. It can serve as a tool for arraying information about the benefits and costs of environmental policies, and as a mechanism for revealing the cost-effectiveness of alternative approaches.

This paper addresses the basic question of how much value we are getting for the resources committed to one particular environmental problem, namely air pollution. The focus is on the aggregate or economy-wide benefits and costs of clean air policies carried out in the U.S. over the past several decades.

1. ECONOMICS AND ENVIRONMENTAL PROTECTION

The great transformation from primitive life to civilized society that occurred over many centuries has altered the environments of entire continents, as humans converted forests into farms and domesticated plants and animals. More recently, our ability to use and adapt the environment has increased dramatically with the development of new polluting technologies, e.g., chlorofluorocarbons. Rising human population and per-capita consumption levels have further contributed to the speed by which we are currently able to alter the environment. The environmental impacts of our newly acquired powers are forcing us to recognize that the environment consists of scarce, even exhaustible resources, e.g., clean air. That is where economics enters, for economics is the science of allocating scarce resources among competing ends.

Economic analysis of environmental programs and policies can serve multiple purposes. It can help allocate our resources more efficiently, encourage transparency in decision making, and provide a framework for consistent data collection and identification of gaps in knowledge. Economic analysis also allows for the aggregation of many dissimilar effects, e.g., improvements in health, visibility, and agricultural output, into one measure of net benefits expressed in a single currency. The challenge for environmental policy is to determine when public intervention in the affairs of firms and individuals is desirable for environmental reasons, and which policies are most appropriate in various circumstances. Economic analysis can help policy makers identify interventions that generate more benefits than costs and assist them in choosing the best intervention from among those that do.

1.2. Environmental benefits and costs

Environmental policies can improve human health, increase output of forests and other natural resources, reduce corrosion or soiling of economic assets, and enhance recreational and other environmental assets. A taxonomy, incorporating broad categories of environmental benefits, is shown in Table 1. Some environmental benefits, e.g., increased output of forests, are measured in commonly used indicators of economic activity like the gross domestic product (GDP). Other benefits are the non-market, welfare-enhancing type that typically are not represented in the GDP, e.g., improved human health or greater biodiversity. It is estimated that more than 90% of the environmental benefits of the Clean Air and Clean Water Acts are of the non-market, welfare-enhancing type not represented in the GDP (Freeman (1982)). Although researchers are trying to develop comprehensive measures of economic activity that capture a broad set of environmental benefits (and costs), e.g., "green GDP", there are, in fact, strong theoretical and practical reasons for excluding such welfare-enhancing benefits from a commonly used measure of economic activity like GDP. Yet, no one doubts that human welfare - rather than GDP - is what societies are ultimately concerned with. The fact that such welfare-enhancing benefits are difficult to value and often involve specialized terminology and measurement techniques does not mean that they are any less valuable than those benefits that are measured by the GDP.

The estimation of costs can be as difficult an undertaking as the estimation of benefits - a fact not often appreciated by even the most knowledgeable practitioners in the field. For example, the most commonly used measure of environmental costs is reported out-of-pocket expenditures for regulatory compliance. However, this is a narrow measure that may either under- or overstate total compliance costs. On the one hand, the omission of items like legal expenses and diverted management focus suggests that reported out-of-pocket expenditures would tend to understate total compliance costs. On the other hand, failure to account for improved worker health or increased innovation tends to overstate total compliance costs. Table 2 contains a taxonomy of environmental compliance costs borne by the private sector, including firms and households, and all levels of government, including the EPA. The reader should note, however, that the cost estimates reported in this paper generally represent reported out-of-pocket expenditures for regulatory compliance. Depending on the importance of the other (often less well measured) cost items listed in Table 2, reported compliance costs may under or overstate total compliance costs.

Table 1
Taxonomy of environmental benefits

To Individuals
Mortality
Morbidity (acute, chronic)
To Production/Consumption
Crops/Forests/Fisheries
Water-Using Industries
Municipal Water Supply
To Economic Assets
Materials (corrosion, soiling)
Property Values
To Environmental Assets
Recreation
Other use values (visibility)
Nonuse (passive use)

2. BENEFITS AND COSTS OF THE CLEAN AIR ACT: AGGREGATE ANALYSIS

Given this brief introduction to environmental benefits and costs, we now may turn to our basic question, namely, what do we know about the overall health, welfare, ecological and other economic benefits of the Clean Air Act and how do these benefits compare with estimated costs? Can we apply an economic framework to determine whether we are getting value for our money?

2.1. Early Research

In a major study Freeman developed the first and - until quite recently - the only comprehensive benefit-cost analysis of the Clean Air Act (Freeman, 1982). His study was controversial upon publication because it involved a great many assumptions - some would say 'leaps of faith' - and attempted to reduce a complex set of issues to a few numbers. One of the key issues in such studies is the question of the baseline: what would ambient air conditions have been in the absence of federal legislation? Ideally, one would compare environmental quality levels with and without the federally mandated controls, holding all other things constant, including the patterns of production, technology, and demand for goods and services which, in turn, determine the generation of pollutants. Such a measure should compare an observed outcome resulting from the policy with a hypothetical or counter-factual position reflecting the same underlying economic conditions and differing only with respect to the impact of the environmental policy. Unfortunately, data and resource limitations prevented Freeman from making such a comparison in his original study. Instead, he measured the benefits of air pollution by examining the actual improvements in air quality observed between 1970 and 1978. As Freeman notes, such measures are likely to underestimate the true benefits because they fail to account for the significant economic growth over the period.

Table 2
Taxonomy of environmental costs

Government Administration of Environmental Statutes and Regulations
Monitoring
Enforcement
Private Sector Compliance Expenditures
Capital
Operating
Other Direct Costs
Legal and Other Transactional
Shifted Management Focus
Disrupted Production
Offsetting Benefits
Resource Inputs
Worker Health
Increased Innovation
Economy-Wide Effects
Product Substitution
Discouraged Investment
Retarded Innovation
Transition Costs
Unemployment
Obsolete Capital
Social Impacts
Loss of Well-Paying Jobs
Economic Security Impacts

Source: Adapted from Jaffee, et al.(1995), page 139.

Table 3 presents Freeman's results for air pollution benefits and costs in 1978 (converted to 1995 dollars). Total benefits of the air pollution program range from $12.3 to $123.3 billion with what Freeman calls a 'most reasonable' point estimate of $49.1 billion. Overall, more than 75% of the benefits are health related. Costs of the air pollution program are estimated to be $35.0 billion. Freeman concludes that, taken as a whole, it is highly likely that air pollution control has been worthwhile on benefit-cost grounds.

Table 3
Air pollution control benefits and costs in 1978 (in billions of 1995 dollars)

Category	Range	Most Reasonable Point Estimate
Benefits		
Health		
Mortality	5.9 - 59.5	29.3
Morbidity	0.6 - 26.2	6.5
Soiling and Cleaning	2.1 - 12.7	6.3
Vegetation	0.2 - 0.8	.6
Materials	1.6 - 5.3	1.5
Property Values	1.9 - 18.8	4.9
Total	12.3 - 123.3	49.1
Costs		35.0

Source: Freeman (1982), page 128.

Drawing on the sizable body of research conducted in the intervening years, a recent EPA study expands on Freeman's original work. Like Freeman's estimates, the new study synthesizes and integrates a large body of information derived from the scientific and economics literatures. The EPA study, which was mandated by Congress as part of the 1990 Air Act Amendments, assesses the benefits and costs of the Clean Air Act, 1970-1990. It was developed by EPA in conjunction with a Congressionally mandated panel of distinguished economists and scientists.

The new EPA study updates the Freeman methodology by developing and comparing two scenarios as a basis to evaluate progress under the Clean Air Act: 'control' vs 'no-control'. The 'no control' scenario essentially freezes federal, state, and local air pollution controls' at levels of stringency and effectiveness which prevailed in 1970 and attributes the benefits and costs of all air pollution controls from 1970-1990 to federal law. In all likelihood, state and local regulation would have required some air pollution controls even in the absence of the Clean Air Act. Certain states, e.g., California, might have required very tight controls. It is also likely that industry would have acted on its own to reduce at least some of its emissions. If one assumed that state and local regulations would have been equivalent to federal regulations then a benefit-cost analysis of the federal clean air act would be a meaningless exercise: the incremental benefits and costs of any federal initiatives would equal zero. On the other hand, any attempt to predict how states' and localities' regulations or voluntary efforts would have differed from the Clean Air Act is extremely speculative. Thus, the freezing of emissions at 1970 emission rates is a reasonable, albeit unrealistic, assumption. Both the 'control' and 'no control' scenarios are evaluated by a sequence of economic, emissions, air quality, physical effect, economic valuation, and uncertainty models to estimate the benefits and costs of the Act. The analytical sequence incorporating these various steps is shown in Figure 1.

The air quality modeling involves a number of key issues worthy of mention. For sulfur dioxide, nitrogen oxides, and carbon monoxide, improvements in air quality under the control scenario are roughly proportional to the estimated reduction in local area emissions. In contrast, differences in estimated ground level ozone concentrations vary significantly from one location to another, because of local differences in the relative proportion of VOC's and NO_x, and weather conditions. Many pollutants contribute to ambient concentrations of particulate matter and, in fact, specific sources vary according to region, urban vs. rural, and other factors. From a human health standpoint, fine particles which can be respired deep into the lungs are the greatest concern. Many of these fine particles are formed in the atmosphere through chemical conversion of gaseous pollutants. They are referred to as secondary particles. The three most important secondary particles are (1) sulfates, which derive primarily from sulfur dioxide emissions, (2) nitrates, which derive primarily from nitrogen oxides emissions, and (3) organic aerosols, which can be directly emitted or can form from volatile organic compound emissions.

Overall, estimated improvements in air quality across the country compared to baseline were substantial: 40% reduction in sulfur dioxide, 30% reduction in nitrogen oxides, 50% reduction in carbon monoxide, 15% reduction in ozone and about 45% reduction in particle concentrations (including both directly emitted and secondary particles). Human health effects or benefits are derived by combining air quality improvements with estimates of dose-response functions derived from the scientific literature. (The EPA study conducted a comprehensive literature review. See study for details.) Table 4 presents selected health benefits of the Clean Air Act 1970-1990, in thousands of cases reduced per year. The mid-range estimates of reduced mortality, for example, show that in 1975 the air pollution controls in place reduced premature deaths attributable to airborne particles (PM_{10}), ozone, sulfur dioxide, and lead by an estimated 20,000 cases. By 1990 the corresponding number of premature deaths avoided stood at 79,000. Similarly, the mid-range estimate for heart attacks avoided rose from 1,000 in 1975 to 18,000 in 1990, largely due to the reduction of lead in the environment.

To develop estimates of economic benefits it is necessary to translate these physical effects into dollar terms. This is often the most contentious aspect of any benefit-cost analysis. Table 5 displays the economic values, drawn from the economics literature, used in the EPA study. Heart attacks and reduced IQ points, for example, are valued at $587,000 per case, and $5500 per point, respectively. In the case of mortality it is not possible to "value" the lives of victims in a benefit-cost sense. One can, however, determine the compensation required for individuals to accept relatively small reductions in mortality risk. Typically, they are inferred from observed behavior, for example, sales of safety devices such as smoke detectors, or wage differentials associated with high risk occupations. For expository purposes this valuation is expressed as "dollars per life saved" even though the actual valuation is really based on small changes in mortality risk. The estimate of $4.8 million per life saved represents an average value from the literature.

The total monetized economic benefit attributable to the CAA was derived by applying the valuation estimates discussed above to the complete stream of physical effects calculated for the 19701990 period. In developing these estimates, steps are taken to avoid the double counting of benefits and costs. EPA reports that the estimated benefits of the Clean Air Act realized during the period from 1970 to 1990 range from $5.6 to $49.4 trillion, with a central estimate of $22.2 trillion.

Figure 1. Summary of Analytical Sequence and Modeled versus Historical Data Basis

Control Scenario	No-Control Scenario
Compile historical compliance expenditure data	
Develop modeled macroeconomic scenario based on actual historical data	Develop modeled macroeconomic scenario by rerunning control scenario with compliance expenditures added back to the economy
Project emissions by year, pollutant, and sector using control scenario macroeconomic projection as input to sector-specific emissions models	Re-run sector-specific emissions models using no-control scenario macroeconomic projection
Develop statistical profiles of historical air quality for each pollutant based on historical monitoring data (plus extrapolations to cover unmonitored areas)	Derive no-control air quality profiles by adjusting control scenario profiles based on differences in air quality modeling of control scenario and no-control scenario emissions inventories
Estimate physical effects based on application of concentration-response functions to historical air quality profiles	Estimate physical effects based on application of concentration-response functions to no-control scenario air quality profiles
Calculate differences in physical outcomes between control and no-control scenario	
Estimate economic value of differences in physical outcomes between the two scenarios*	
Compare historical, direct compliance costs with estimated economic value of monetized benefits, considering additional benefits which could not be quantified and/or monetized	

* In some cases, economic value is derived directly from physical effects modeling (e.g., agricultural yield loss).

Source: *U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990", Draft Report, April 1997.*

Table 4
Selected health benefits of the CAA, 1970-1990 (in thousands of cases reduced per year, except as noted)

Health Effect		1975	1980	1985	1990
Mortality	High	38	97	124	140
(PM_{10}, O_3, SO_2, Pb)	Mid	20	54	70	79
(thousands)	Low	11	30	40	45
Heart Attacks	High	1	9	19	24
(Pb)	Mid	1	7	14	18
(thousands)	Low	1	5	10	13
Strokes	High	1	5	10	13
(Pb)	Mid	1	4	8	10
(thousands)	Low	1	3	6	7
Respiratory symptoms					
(SO_2)		66	187	165	146
(thousands)					
Respiratory illness					
(NO_2)		1	4	9	15
(millions)					
Hypertension	High	1	6	12	16
(Pb)	Mid	1	5	10	13
(millions)	Low	1	4	8	10

Source: *U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990," Draft Report, April 1997.*

By comparison, the value of direct compliance expenditures over the same period equals approximately $.5 trillion. Comparing central estimates, Americans received roughly $45 of value in reduced risks of death, illness, and other adverse effects for every one dollar spent to control air pollution

A result of this sort stimulates many questions, e.g., what specific regulations account for the most benefits? How do the net benefits of recently promulgated regulations compare to those of older regulations? While the EPA study methodology does not allow one to answer such questions directly, a number of comparisons are possible. Table 6 displays benefits by endpoint category.

Table 5
Central estimates of economic value per unit of avoided effect (in 1995 dollars)

Endpoint	Valuation (mid-estimate)
Mortality	$4,800,000 per case
Heart Attacks	$587,000 per case
Strokes	$587,000 per case
Hospital Admissions	
Respiratory	$7,500 per case
Ischmic Heart Disease	$10,000 per case
Congestive Heart Failure	$8,000 per case
Respiratory Illness and Symptoms	
Upper Respiratory Illness	$18 per case
Lower Respiratory Illness	$10 per case
Acute Bronchitis	$45 per case
Acute Respiratory Symptoms	$17 per case
Work Loss Days	$83 per day
Restricted Activity Days	$38 per day
Asthma Attacks	$32 per case
IQ Changes	
Lost IQ Points	$5,550 per IQ point
Incidence of IQ < 70	$52,700 per case
Hypertension	$682 per year per case
Decreased Worker Productivity	Direct Economic Valuation
Visibility	Direct Economic Valuation
Household Soiling	Direct Economic Valuation
Agriculture (Net Surplus)	Estimated Change in Economic Surplus

Source: *U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990," Draft Report, April, 1997.*

Note that PM mortality alone accounts for three-fourths of the total benefits. Lead mortality benefits are also quite substantial. At first glance this might suggest that control of particulate matter and lead are the most important and, perhaps, the only important actions taken under the Clean Air Act, 1970-1990. Unfortunately, environmental analysis is not that simple. For example, secondary particles, which have been associated with premature mortality, account for a large portion of the total benefits. As noted, these particles are formed in the atmosphere from SO_2, NO_x and VOC emissions which, in turn, are governed by multiple EPA regulations, including those affecting existing as well as new sources. Thus, one cannot say with confidence that the calculated PM benefits derive strictly from regulations explicitly aimed at controlling particles. Some of the calculated PM benefits are clearly associated with these broader control efforts.

A somewhat different approach to estimating benefits and costs of environmental regulations was developed by Hahn (1996). Rather than attempt to integrate all benefits and costs into a single analysis, he examines individual regulations promulgated by EPA between 1990-1995. Using Agency numbers but applying a common discount rate as well as a consistent set of values for reducing health risks, Hahn estimates the present-value benefits and costs of major rules. For all Clean Air Act regulations issued 1990-1995 Hahn calculates benefits at 214.7 billion and costs at $124.7 billion (Table 7).

Table 6
Total monetized benefits by endpoint category for 48 state population for 1970 to 1990 (in billions of 1990 dollars)

Endpoint	Pollutant(s)			Present Value
		5th%	***Mean***	***95th%***
Mortality	PM-10	$2,369	$16,632	$40,597
Mortality	Pb	$121	$1,339	$3,910
Chronic Bronchitis	Pb	$409	$3,313	$10,401
IQ (Lost IQ Pts + Children w/IQ<70	Pb	$271	$399	$551
Hypertension	Pb	$77	$98	$120
Hospital Admissions	PM-10, O_3, Pb & CO	$27	$57	$120
Respiratory-Related Symptoms, Restricted Activity and Decreased Productivity	PM-10, O_3, NO_2 & SO_2	$123	$182	$261
Soiling Damage	PM-10	$6	$74	$192
Visibility	Particulates	$38	$54	$71
Agriculture (Net Surplus)	O_3	$11	$23	$35

Source: *U.S. EPA, "The Benefits and Costs of the Clean Air Act, 1970 to 1990", Draft Report, April, 1997.*

Table 7
Costs and benefits of Clean Air Act regulations 1990-1995 (present value in billions of 1995 dollars)

Number of Regulations	25
Costs	$124.7
Benefits	$214.7
Net Benefits	$90.0

Source: *Hahn, Robert, "Regulatory Reform: What Do the Government's Numbers Tell Us?" in* *Reviving Regulatory Reform,* *(Robert Hahn, ed.), American Enterprise Institute, 1996, page 222.*

Although he expresses serious concerns about the credibility of EPA estimates, he concludes that: "if one takes the Agency numbers at face value...there is reason to be gleeful. They basically say that the [EPA] has done more good than harm in promulgating regulations since 1990."[1b]

3. CONCLUSION

While our understanding of the link between the economy and the environment has clearly advanced in recent years there is still controversy over some of the most basic issues. Some of the controversy stems from the imprecision of the questions themselves, e.g., what do 'value' and 'cost' really mean in the context of environmental health or natural resources? Other controversy stems from differences in methodology of various empirical studies used to quantify the sometimes-abstract concepts involved in applying economic analysis to the environment.

Notwithstanding these controversies, this brief foray into the economics of environmental protection suggests a clear conclusion. Taken as a whole, the benefits of the Clean Air Act since enactment in 1970 clearly outweigh the costs. Several analyses, using different methods and different data sources, conclude that aggregate benefits exceed aggregate

[1b]Hahn (1996), page 240.

costs. As the recent EPA analysis notes, " ...even considering the large number of uncertainties permeating each step of the analysis, it is extremely unlikely that the converse could be true."[2c] One study, finds that benefits exceed costs for rules promulgated 1990-1995. Consistently, the studies show that the health benefits are by far the largest part of the monetized benefits.

To paraphrase Winston Churchill, economic analysis may be the worst approach to environmental policy making except for all the others that have been tried. Indeed, economic analysis is critical to the development of sound environmental policies. If economic analysis is not done explicitly, it almost certainly occurs implicitly. In that case, decision making is driven by public fears, special interest lobbying and bureaucratic preferences. Often, the resulting policies do not reflect the best interests of our citizenry. Future work needs to push beyond the aggregate analyses showcased in this paper and focus on more detailed assessments of individual programs and policies. Such assessments can help assure we get the maximum possible environmental protection for the resources committed.

[2c]EPA (1997), page ES-11.

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