NATURAL RESOURCES JOURNAL

Volume 23
Issue 3 *Symposium on Environmental Management: The Policy Perspective*

Summer 1983

Benefits Analysis and Air Quality Standards

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INTRODUCTION

The process of setting ambient air quality standards offers important lessons to students of policy analysis. The Clean Air Act's lofty goals of protecting public health with an adequate margin of safety quickly become muddled by troublesome issues such as what does and does not constitute an adverse health effect of concern, who are the sensitive groups, and what is an adequate margin of safety. While the Clean Air Act does not mention costs as a consideration in meeting these goals, an Executive Order of the President specifically requires that comparisons be made of costs and benefits prior to the promulgation of major regulations.

Ideally, air quality standards would be set to maximize net social benefits. However, the Clean Air Act appears to be more concerned with distributional issues than with economic efficiency. Thus, it is not surprising that the courts have ruled that costs should not be considered in setting primary ambient air quality standards. Were economic efficiency to be used as the key criterion in setting air quality standards, however, only a very broad range of air quality could be identified due to present uncertainties in the measurement of economic benefits.

Despite difficulties encountered in assessing the precise benefits of an air quality standard, economic analysis can still prove highly useful for several reasons. First, the act of conducting a benefit analysis provides a review, independent of the standard setting process, of the underlying scientific information. Second, economic analysis, as called for in Executive Order 12,291, provides a different focus for the review of scientific information. For example, rather than seek threshold air pollution levels where health effects occur, a benefits analysis weighs in economic terms the consequences of health risk and population exposures. To illustrate this last and perhaps most important use of economic analysis, this paper focuses on the national ambient air standard for particulate matter (PM), currently undergoing review by the Environmental Protection Agency under the authority of the Clean Air Act.

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†This work represents the views of the authors and should not be interpreted as either the policy or position of the Environmental Protection Agency or the American Petroleum Institute.

Background

The Clean Air Act calls upon the Administrator of the Environmental Protection Agency to publish and periodically revise a list of air pollutants that may reasonably be anticipated to endanger public health or welfare.[1] For each pollutant so listed, the Administrator must issue air quality criteria (a "criteria document") reflecting the latest scientific information useful in identifying public health and welfare effects.[2] Based upon information contained in the criteria document for each air pollutant, the Administrator must propose and subsequently promulgate national primary ambient air quality standards to protect the public health, and secondary ambient air quality standards to protect the public welfare.[3] These standards are to be reconsidered every five years and revised if necessary.[4]

The Clean Air Act requires that primary air quality standards be set to protect the public health with an adequate margin of safety.[5] The legislative history of the Act suggests this to mean the protection of "a representative sample of persons comprising the sensitive group rather than a single person from such a group."[6] As interpreted by the courts, the Act prohibits the EPA from considering compliance costs in setting primary ambient air quality standards, forcing the EPA to focus exclusively on protecting public health.[7]

In the periodic review of the PM standard, at least two important issues are under contention: the appropriate levels for the primary and secondary standards, and the desirability of basing the primary standard solely on the small particles believed to cause adverse health effects, rather than on total suspended particulates as the regulation now reads. In addition, the PM standard is the first ambient air standard to require a Regulatory Impact Analysis (RIA) under Executive Order 12,291.[8]

Review of the PM standard is interesting in at least one other respect. Some industry sectors have pressed hard for relaxation, arguing that marginal control costs were rising much faster than benefits for the last several percent removal required by the existing regulations on PM. At least one trade association has recommended a relaxation of the PM standard to approximately twice its current level.[9]

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1. 42 U.S.C. §7408(a)(1) (Supp. I 1977).
2. 42 U.S.C. §7408(a)(2) (Supp. I).
3. 42 U.S.C §7409(a) (Supp. I 1977)
4. 42 U.S.C §7409(d).
5. 42 U.S.C §7409(b)(1).
S. REP. NO. 1196, 91st Cong., 2d Sess. 10 (1970).
7. *See, e.g.*, Portland Cement Ass'n v. Ruckelshaus, 486 F.2d 375 (D.C. Cir. 1973), *cert. denied*, 417 U.S. 921 (1974).
8. Exec. Order No. 12,291, 46 Fed. Reg. 13,193 (1981).
9. The American Iron and Steel Institute in private discussions and in correspondence has taken the strongest position in urging relaxation of the PM standard.

While some groups believe the evidence supports relaxation of the current standard, others interpret the evidence differently. The California Air Resources Board, for example, recently proposed a PM standard for California that is approximately one-third of the current federal standard.[10]

Based upon the development of the PM criteria document, and its review by the Clean Air Scientific Advisory Committee (CASAC), a 1982 EPA staff paper recommended to the Administrator a new measure of PM restricted to particles capable of penetrating the thoracic regions.[11] Thoracic-penetrating particles are less than 10 microns in diameter, and have been termed "PM10." The staff paper also indicated a range of possible standards for consideration. Because the paper recommends an arithmetic rather than the current geometric measure of pollutant concentration and a statistical measure of exceedances, precise comparisons with the existing standard for total suspended particulates (TSP) are difficult. The consensus of the EPA and its consultants is that the CASAC recommendation represents a 20 to 30 percent relaxation of the current standard at the lowest value proposed, and a greater relaxation at the upper end of the proposed range of interest.

The standards that EPA ultimately sets will be based upon a synthesis of the scientific community's peer reviewed, published literature. Primary standards will be based on the health effects literature on PM. Secondary standards, if promulgated, will be based on an assessment of the so-called "welfare" effects: visibility, soiling and the like. This paper will focus on issues relating to the establishment of the primary standards. Thus, health rather than welfare effects are the principal concern.

Measurement of Health Effects

In its literature review for the criteria document, EPA found that the health effects of most concern at present PM exposure levels included respiratory mechanics and the aggravation of existing respiratory and cardiovascular diseases.[12] At higher levels of exposure, risks of mortality become a definite concern. The EPA staff paper notes: "The data do not . . . show evidence of clear population thresholds but suggest a continuum of response with both the risk of effects occurring and the magnitude of any potential effect decreasing with concentration."[13] Given the wide range of effects, the substantial variation in response within and among

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10. *See* California Air Resources Board, Research Division, Ambient Air Quality Standard for Particulate Matter, i–v (1982).

11. EPA OFFICE OF AIR QUALITY PLANNING AND STANDARDS, REVIEW OF THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR PARTICULATE MATTER 450/5-81-001 (1982).

12. *Id.* at xi.

13. *Id.* at xiii.

subgroups, and the acknowledged absence of clear thresholds for effects, the EPA Administrator will have great difficulty identifying a standard that protects all sensitive subgroups against all measurable effects of particulates and at the same time is economically achievable.

As a tool to help select the appropriate standard, the EPA Office of Air Quality Planning and Standards summarized the effects of PM on health. At the lowest levels of exposure, effects are deemed unlikely or not serious. At higher exposures effects become progressively more serious. One problem with such a depiction of effects is that it does not reveal the population at risk. The exposure of a hundred million individuals to a small risk is certainly quite different from the exposure of a few hundred individuals to the same risk. But even knowledge of the number of people exposed to different PM levels and the resultant effects does not tell one whether the indicated effects are of consequence. Imagine, for example, the indication that one million people would experience mild eye irritation ten days per year. Or that another million individuals would have a two percent reduction in lung function. Should the EPA Administrator protect against such effects or are they so trivial that they can be ignored?

Ferris and Speizer have ventured their opinion as to when effects are serious enough to merit attention. They suggest defining adverse health effects as medically significant changes that are generally characterized by permanent damage or incapacitating illness to the individual.[14] Such a definition would rule out of consideration as adverse health effects such outcomes as temporary damage to or irritation of individuals. Ferris and Speizer would, however, make some allowance for increased hospital admissions as an indicator of adverse health effects, even when patients recovered fully.

The difficulty with the Ferris and Speizer approach should be quite apparent to students of economics. Results of pollution that are cast aside as not constituting adverse health effects worthy of regulation may have significant adverse impacts on individual welfare and on economic well being. Likewise the permanent damages that are noted and used as the basis for standard setting may have only minor implications for economic well being. Economists would prefer to ask how the various effects are valued by individuals and society before deciding some should have zero weight and others extremely high weight in setting standards to protect health.

Preliminary results of economic benefits analysis do not indicate that net benefits would be increased by a relaxation of the PM standard.[15]

14. Ferris and Speizer, Criteria for Establishing Standards for Air Pollutants, consultants' report prepared for the Business Roundtable (1980).

15. Mathtech, Benefit and Net Benefits Analysis of Alternative Primary National Ambient Air Quality Standards for Particulate Matter, EPA Contract No. 68-02-3579 (1983).

However, several considerations suggest that the range of uncertainty surrounding the benefits estimate could be large. One issue concerns the determination of which studies are the most relevant for the measurement of benefits, apart from the parallel need to identify the exposure limit that protects health, as required by the Clean Air Act. A second set of issues concern the endpoints, or effects measured in the studies; the quality of exposure data; possible mitigating behavior by exposed populations; and the extent to which the separate effects of different pollutants were actually measured. The next section will examine these issues in greater detail and also will suggest how economists can focus future research efforts in this area to increase the probability that their work will be used as an input in the regulatory process.

Measuring Benefits: Mortality

Concern for controlling air pollution grew after the occurrence of severe episodes in London, England in the 1950s. As a result of these episodes, a number of scientific investigations estimated functional relationships of short-term exposure to air pollution and mortality.[16] Martin and Bradley found a statistically significant relationship existed between daily readings of both PM (measured as British Smoke) and sulfur dioxide and daily mortality (measured as deviations from a 15 day moving average) during the London winter of 1958–59.[17] This result was confirmed by multiple regression analysis which demonstrated that a linear or quadratic dose-response function fit the data equally well.[18]

Several problems exist with this analysis and the underlying data. First, the high degree of correlation between PM and sulfur dioxide precludes a determination of the impact of either pollutant alone. Second, in combining 14 years of data, the model is plagued with omitted variable bias. Although trend and seasonal variables were included in the analysis, no explicit account is made for changes in health habits, income, or the chemical composition of PM. Third, there are some methodological problems in the analysis.[19] Fourth, difficulty arises in converting the air pollution measurement used (British Smoke) to PM10. Finally, a threshold (no effects) level was suggested by the authors although no explicit anal-

16. A review is provided by Ware, Thibodeau, Speizer, Colome, & Ferris, *Assessment of the Health Effects of Atmospheric Sulfur Oxides and Particulate Matter: Evidence from Observational Studies*, 41 ENVIRONMENTAL HEALTH PERSPECTIVES 255 (1981).

17. Martin & Bradley, *Mortality, Fog and Atmospheric Pollution—An Investigation During the Winter of 1958–1959*, 19 MONTHLY BULL. MINISTRY HEALTH AND THE PUBLIC HEALTH LAB. SERV. 56 (1960).

18. Mazumdar, Schimmel, & Higgins, *Relation of Daily Mortality to Air Pollution: An Analysis of 14 London Winters, 1958/59—1971/72*, 37 ARCHIVES ENVTL. HEALTH 213 (1982).

19. Pitcher, H., Note on the Statistical Methodology Used in Mazumdar, Schimmel, and Higgins, mimeo, U.S. EPA (1983).

ysis was conducted on the issue. Subsequent efforts by Ostro demonstrated, by fitting a piecewise linear regression to the data, that no threshold was discernible from the data and that adjustment for autocorrelation of the residuals did not seem to alter the results.[20] A number of important questions that are amenable to statistical inquiry still remain. For example, the possibility of a complex lag structure needs to be examined, as well as the impact of averting or mitigating behavior.

Economic analysts have concentrated more on the effects of long-term (chronic) exposure to air pollution. Beginning with the pioneering work of Lave and Seskin, a number of studies have used regression analysis to determine the relationship between aggregate mortality rates (i.e., city- or county-wide) and ambient levels of PM.[21] These estimates probably include both the effects of short-term exposure cited above, as well as longer-term effects. The degree of overlap will remain unknown in the absence of information on the "true" relationship between air pollution exposures and health.

In these studies, the analysis typically involves a regression of area-wide mortality with a number of area-wide independent variables, including socioeconomic variables, population density, and weather and environmental characteristics. These so called "macroepidemiologic" studies have both advantages and disadvantages. Advantages include the reduced reliance on extrapolation from controlled laboratory studies or animal experiments, more accessible sources of data to serve as cross checks on results, and the typically larger sample size. The studies also include people with varying behavioral responses, lifestyles, exposures, and occupations, making the results more "generalizable" for the assessment of benefits.

Concerns with and disadvantages of these studies include: (1) the potential estimation bias due to omitted variables such as occupational exposures, smoking, diet, medical care, exercise, and migration; (2) the omission of important individual characteristics such as age, sex, race and income; (3) the failure to fully consider alternative functional forms; (4) the existence of potentially confounding effects among pollutants or between pollution and other variables characterizing the urban area; and (5) the use of a single urban monitor to represent air pollution exposure for the area residents. The last concern is frequently cited and may most limit the overall acceptability of these economic studies in the scientific community.

These concerns indicate that analysts must be extremely careful in

20. Ostro, A Search for a Threshold in the Relationship of Air Pollution to Mortality in London, mimeo, U.S. EPA (1982).

21. Lave & Seskin, *Air Pollution and Human Health,* 169 SCIENCE 723 (1970); also L. LAVE & E. SESKIN, AIR POLLUTION AND HUMAN HEALTH (1977).

selecting data and methods for benefit analysis. They also suggest the need to determine the existence and extent of any bias in the estimation procedures. Some of the problems, such as random measurement error, may actually bias downward the estimated air pollution effect. Further, Freeman has shown that in certain cases, even if the estimated regression coefficient is biased, it still will give reasonable predictions of the changes in mortality due to changes in air pollution.[22] Despite the potential problems that exist with these studies, replication of the general results through analysis of different data sets using different methods suggests that a relationship does indeed exist between air pollution, measured in annual averages, and mortality.[23] However, these studies have been deemed unreliable by CASAC for determining a threshold level and therefore as a basis for setting the air quality standard.

CASAC has favored studies that exhibit highly specific data on air quality and health effects. These are primarily studies of acute effects where pollution was well measured, and studies of chronic effects in small populations. The studies of acute effects are representative of conditions faced by only a very small subset of the population. The chronic effects studies accepted by CASAC focus on small populations, measure effects that are very difficult to evaluate in economic terms, and typically do not provide dose-response relationships. Chronic studies of large populations, on the other hand, may capture both short and long-term effects from pollution exposures faced by large samples more representative of the entire population. Furthermore, these large-scale chronic studies often study effects that are amenable to economic valuation. Consequently, large-scale epidemiologic studies, though not favored by CASAC, are believed highly relevant to an economic assessment of a proposed PM standard.

The estimated relationship between air pollution and increased risk of mortality is an important determinant of the overall estimate of benefits for alternative air quality standards. To arrive at this benefit estimate, the exposed population and the change in air pollution from baseline must be determined. For area i (be it city, country or nation) the aggregate change in population risk reduction (PR) is the product:

$$\begin{array}{rrcl} & PR_i & & (\Delta A_i) \cdot (Pop_i \cdot M'(A)) \\ \text{where} & \Delta A_i & = & \text{the change in air quality in area i} \\ & Pop_i & = & \text{population in area i} \\ & M'(A) & = & \text{slope of mortality risk function} \end{array}$$

22. A. M. FREEMAN, III, THE BENEFITS OF AIR AND WATER POLLUTION CONTROL: A REVIEW AND SYNTHESIS OF RECENT ESTIMATES 26–28 (1979).

23. *See, e.g.*, Mendelsohn & Orcutt, *An Empirical Analysis of Air Pollution Dose-Response Curves* 6 J. ENVTL. ECON. & MGMT. 85 (1979); and J. SENECA & P. ASCH, THE BENEFITS OF AIR POLLUTION CONTROL IN NEW JERSEY (1979).

Obviously, the assumptions one makes in calculating these terms are crucial and require the analyst to address a number of empirical questions. For example, one must obtain information on the baseline level, the actual change that will result from treatment and control strategies, the actual number of people who will be exposed to the various levels, and the correct functional form and specification for calculating mortality risk.

Once the impact of air pollution on health is estimated, economic analysis can be used to assign a dollar value to changes in risk. A number of studies have analyzed the relationship between wage compensation and occupational risk in order to infer the willingness-to-pay for a marginal reduction in risk.[24] These valuations can then be applied to the estimated risk reduction due to control of PM to generate crude benefit estimates of alternative air quality standards. Because of the inherent uncertainty in both the mortality studies and the statistical value of life studies, as well as known differences in response to voluntary risks such as occupational accidents and involuntary risks such as air pollution, it is important to perform a careful sensitivity analysis around some of the assumptions. For example, in the benefit analysis for PM, Mathtech considered combinations of the following: (1) alternative estimates of the value of marginal reductions in mortality risk; (2) the upper and lower bound of the confidence interval around the estimated pollution coefficient in the mortality studies; (3) alternative functional forms; and (4) use of coefficients estimated over different subsamples of the data.[25]

Measuring Benefits: Morbidity

Few studies have used economic theory and statistics to estimate the benefits in terms of reduction in illness due to air pollution control. Morbidity effects are an important part of any benefit analysis of air quality standards because there may be a good deal of acute illness that never results in death. In addition, morbidity is a more sensitive indicator of pollution effects, indicating impacts at lower pollution levels than does mortality. Moreover, because of its frequency, morbidity may be easier to capture statistically than the incidence of mortality. However, since a variety of measurable health effects are possible, morbidity may be difficult to describe quantitatively and even more difficult to measure in economic terms.

Epidemiologic research has demonstrated an association between PM and a number of different health indicators such as changes in lung function or capacity, and frequency of symptoms or diseases of the res-

24. Examples include Thaler & Rosen, *The Value of Saving a Life: Evidence from the Labor Market* HOUSEHOLD PRODUCTION AND CONSUMPTION 265–298 (1976); and Brown, *Equalizing Differences in the Labor Market*, 94 Q. J. ECON. 113 (1980).

25. Mathtech, *supra*, note 15.

piratory tract.[26] However, these studies frequently are not suitable for benefit analysis and the economic evaluation of alternative air quality standards. The studies may use health end-points which have not yet been directly valued (e.g., health symptoms such as a cough) or for which the ultimate significance of the clinical health effect is uncertain (e.g., changes in lung function, such as forced expiratory volume in one second). Sometimes the studies consist merely of a comparison of two cities to test whether there is a significant difference in respiratory symptoms.[27] Other studies have looked at a single city over a long period of time or have monitored individuals in expensive case control experiments.[28] Thus, much of the epidemiological evidence to date is of limited usefulness for benefit analysis.

Analysts have recently been engaged in two different types of studies that generate a dose-response relationship and that may be useful inputs for the assessment of benefits. These studies involve the examination of the time-series relationship between acute exposure and hospital admissions, and large scale cross-sectional studies of individuals. Samet, for example, considered the effect of air pollutants on levels of hospital emergency room visits in Steubenville, Ohio.[29] While such studies generate important information regarding health effects, they are of relatively limited use for benefits analysis. For example, they measure only a subset of the potential morbidity effects. Further, hospital admissions are a function of local environmental conditions, demographics, hospital accessibility, and health care characteristics, and may not be representative of the general relationship between air pollution and illness.

Large scale cross-sectional studies of individuals have been completed by Crocker, Ostro and Anderson, and Ostro.[30] The former was an initial

26. Examples include: Bennett, Limitations of the Use of Hospital Statistics as an Index of Morbidity in Environmental Studies, presented at the American Public Health Association Conference, Detroit (1980); Lawther, Waller, & Henderson, *Air Pollution and Exacerbations of Bronchitis*, 25 THORAX 525 (1970); Martin, *Mortality and Morbidity Statistics and Air Pollution*, 57 PROC. ROYAL SOC'Y MED. 969 (1964); and Dockery, Ware, Ferris, Speizer, Cook & Herman, *Change in Pulmonary Function in Children Associated with Air Pollution Episodes*, 32 J. AIR POLLUTION CONTROL A. 937 (1982).

27. Bouhuys, Beck & Schoenberg, *Do Present Levels of Air Pollution Outdoors Affect Respiratory Health?* 276 NATURE 466 (1978).

28. *See, e.g.*, Ferris, Higgins, Higgins, & Peters, *Chronic Non-specific Respiratory Disease in Berlin, New Hampshire, 1961 to 1967, A Follow-Up Study*, 107 AM. REV. RESPIR. DIS. 110 (1973).

29. Samet, Speizer, Bishop, Spengler, & Ferris, *The Relationship Between Air Pollution and Emergency Room Visits in an Industrial Community*, 31 J. AIR POLLUTION CONTROL A. 236 (1981).

30. T. CROCKER, W. SCHULZE, S. BEN-DAVID, & A. KNEESE, METHODS DEVELOPMENT FOR ASSESSING AIR POLLUTION CONTROL BENEFITS, VOLUME I, EPA-600/5-79-001a, U.S. EPA (1979); Ostro and Anderson, *Morbidity, Air Pollution and Health Statistics*, PROC. OF THE AM. STAT. ASS. (1981); Ostro, *The Effects of Air Pollution on Work Loss and Morbidity*, J. ENVTL. ECON. MGMT. (forthcoming 1983).

exploration of Michigan Survey Research Panel data. In attempting to determine the relationship between annual measures of air pollution and both acute and chronic illness, the study suffered from serious data deficiencies. The sample size was frequently small, usually less than 400 and sometimes as few as 80, and therefore very sensitive to model specification. In addition, a number of important variables were either unavailable or inadequately modeled.

Ostro and Anderson estimated the relationship between annual measures of particulates and sulfates and two different measures of morbidity—work loss or restricted activity. With a data set on individuals—the Health Interview Survey conducted by the National Center for Health Statistics—multivariate analysis was used for a sample of all adults (N = 12,000) and a subset of male nonsmokers (N = 4,500). To explain variations in work loss, the model included demographic characteristics (age, race, sex, marital status) economic characteristics (income, occupation or industry of employment), health status (existence of chronic conditions, cigarette smoking habits), urban factors (population density), and environmental factors (air pollution, temperature, precipitation). Using three different functional forms—linear, logit and Tobit—the results appeared to confirm the hypothesized association between PM and morbidity. Further, the study suggests that merely extrapolating mortality-pollution results to morbidity would result in an underestimation of the benefits of air pollution control. The evidence suggests that the air pollution-morbidity elasticity may be an order of magnitude greater than the air pollution-mortality elasticity.

As in the determination of mortality benefits, the analyst must calculate the aggregate change in morbidity risk due to the change in air quality. These estimated effects can then be quantified by using an estimate of the value of lost work days and the direct medical expenditures incurred, in order to evaluate the impact of choosing alternative air quality standards. Left to future research is the measurement of the cost of averting or mitigating behavior, and the willingness-to-pay to prevent morbidity. Cropper has made some estimates of the latter.[31]

What Have We Learned?

At this time, it is not clear what role economic analysis will play in the determination of a PM standard. Some of the supporting studies have been stigmatized because of their citation by CASAC as inappropriate for quantitative use in standard setting. The literature includes research that is naive in terms of the use of methodology and data, as well as

31. Cropper, *Measuring the Benefits from Reduced Morbidity,* 71 PROC. AM. ECON. A. 235–240 (1981).

other efforts that were merely exploratory in nature. Some studies, however, were carefully conducted statistical analyses that, even with some remaining uncertainties, generate important information and deserve to be considered in the evaluation of benefits of alternative standards.

There are many conflicts and contradictions that cloud the appropriate use of even the best studies. The congressional mandate to choose air standards that protect public health with an adequate margin of safety is difficult to reconcile with evidence that small subsets of the population are sensitive to extremely low levels of certain air pollutants. Furthermore, the requirement that costs not be considered in the standard setting process is juxtaposed with a Presidential executive order requiring a benefit-cost analysis for major regulations such as the PM standard. Economists working in the area of regulatory impact analysis have already made contributions by reviewing and working to determine the economic implications of the health effects literature.

We believe that economic research will continue to contribute to understanding of the effects of air pollution, and that it will help bring focus to many of the issues surrounding the determination of air quality standards. In particular, economists may be able to help fill some of the large gaps that currently exist in assessing the benefits of air quality improvements. Some of the areas where future research should be most productive include: (1) the study of averting and mitigating behavior, (2) improvements in the measurement of willingness to pay to avoid morbidity, (3) research on the benefit of improved visibility, (4) measurement of loss in consumer satisfaction even when no change is observed in behavior (e.g., tolerating dirty paint on a home because painting is done primarily to protect surfaces), and (5) study of aggregation techniques for methods of benefit assessment that overlap to some extent in coverage (e.g., property value studies, wage studies, and health effects).

The upcoming revision of the PM standard will help considerably to delineate the role economic analysis will play in setting air quality standards. The current regulatory climate is more favorable to economic analysis of benefits and costs than at any prior time. Consequently, economic analysis may become a factor in environmental decision making.