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Research Triangle Park NC 27711

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Air

Benefit Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates

Volume VI

FINAL ANALYSIS

BENEFITS ANALYSIS OF ALTERNATIVE SECONDARY NATIONAL AMBIENT AIR QUALITY STANDARDS FOR SULFUR DIOXIDE AND TOTAL SUSPENDED PARTICULATES

VOLUME VI

BENEFITS ANALYSIS PROGRAM
ECONOMIC ANALYSIS BRANCH
STRATEGIES AND AIR STANDARDS DIVISION
OFFICE OF AIR QUALITY PLANNING AND STANDARDS

U.S. ENVIRONMENTAL PROTECTION AGENCY

RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

AUGUST 1982

FINAL ANALYSIS

BENEFITS ANALYSIS OF ALTERNATIVE SECONDARY NATIONAL AMBIENT AIR QUALITY STANDARDS FOR SULFUR DIOXIDE AND TOTAL SUSPENDED PARTICULATES

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August 1982

PREFACE

This report was prepared for the U.S. Environmental Protection Agency by MATHTECH, Inc. The report is organized into six volumes containing a total of 14 sections as follows:

Volume I

Section 1: Executive Summary
Section 2: Theory, Methods and Organization
Section 3: Air Quality and Meteorological Data

Volume II

Section 4: Household Sector
Section 5: Residential Property Market
Section 6: Labor Services Market

Volume III

Section 7: Manufacturing Sector
Section 8: Electric Utility Sector

Volume IV

Section 9: Agricultural Sector

Volume V

Section 10: Extrapolations
Section 11: Bibliography

Volume VI

Section 12: Summary of the Public Meeting
Section 13: Analysis of Pollutant Correlations
Section 14: Summary of Manufacturing Sector Review

The analysis and conclusions presented in this report are those of the authors and should not be interpreted as necessarily reflecting the official policies of the U.S. Environmental Protection Agency.

ACKNOWLEDGMENTS

This report and the underlying analyses profited considerably from the efforts of Allen Basala, who served as EPA Project Officer, and V. Kerry Smith, who served as a reviewer for EPA. Allen provided the initiative and on-going support to conduct an applied benefits analysis. Kerry's technical insights and suggestions are reflected in nearly every section of the report.

James Bain and Tom Walton of EPA, and Jan Laarman and Ray Palmquist, who served as reviewers for EPA, also contributed substantially to individual report sections through their advice and comments during the course of the project. Also providing helpful comments and assistance were Don Gillette, Fred Haynie, Neil Frank and Larry Zaragosa, all with EPA.

Several other members of the Mathtech staff contributed to the project during various stages of the work. They included Robert J. Anderson, Jr., Neil Swan, John Keith, Donald Wise, Yaw Ansu, Gary Labovich, and Janet Stotsky.

The production of the report was ably managed by Carol Rossell, whose patience remained intact through countless drafts and deadlines. Carol was assisted by Sally Webb, Gail Gay, and Deborah Piantoni.

Finally, we extend our appreciation to the many dozens of individuals, too numerous to list here, who provided advice, suggestions, and data during the course of the project.

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SECTION 12

SUMMARY OF THE PUBLIC MEETING

INTRODUCTION

On July 27 and 28, 1981, a public meeting was held at the Sheraton Crabtree Inn in Raleigh, North Carolina. The purpose of this meeting was to provide an opportunity for public comment on the study and to receive comments from a panel of experts in the field of environmental benefits analysis. In addition to this panel of experts, the major participants at the meeting included staff and consultants from the Office of Air Quality Planning and Standards (OAQPS) for the Environmental Protection Agency (EPA), and staff and consultants from Mathtech, Inc. Other interested individuals also particpated. A copy of the notice for this meeting as it appeared in the Federal Register, the agenda for the meeting, and a list of those attending the meeting are contained in Appendix A of this volume.

SUMMARY OF PUBLIC MEETING

The meeting was opened by James Bain, Chief of the Economic Analysis Branch of OAQPS who stated that the purpose of the meeting was to present, discuss, and receive feedback regarding the benefits analysis done by Mathtech.

An overview of the general approach used for estimating the benefits of alternative secondary national ambient air quality standards (SNAAQS) and a summary of the results of the study were given in a slide presentation by Ernest Manuel of Mathtech. This was followed by individual slide presentations by members of the Mathtech staff for each of the economic sectors analyzed in the study. Comments and questions from the panel of environmental experts were made after each slide presentation. Following the panel's comments, comments and questions were received from members of the audience. General comments and recommendations regarding the study were made at the conclusion of the two-day meeting.

With respect to the overall study, three general observations were made by the panel of environmental experts. The first observation was related to the study's overall quality. Each member of the panel and various members of the audience agreed that the Mathtech study was a high quality piece of research and represented "state-of-the-art" economics. It was emphasized that the methodology used to estimate the economic benefits of alternative SNAAQS was based on conventional economic theory. In addition, several comments were made commending the use of sound and sophisticated econometric techniques throughout the analysis. In fact, several members of the panel suggested that shortened versions of some of the sector analyses should be submitted to economic journals for publication.

The second general observation was concerned with the quantity and quality of the data used in the empirical estimation of the sector models developed in the study. A few members of the panel pointed out that although the models developed were theoretically sound, less than optimal data were available for the estimation of some of the models. It was acknowledged, however, that this was not a problem specific to the Mathtech analysis, but rather a problem that beset all analyses of this type. Specific comments were raised regarding the appropriateness of using data from air quality monitoring stations as proxies for ambient exposure to certain pollutants and the omission of pollutants such as ozone and nitrogen dioxide from the estimated models. The general concern of the panel was directed toward how these data limitations and omissions might affect the conclusions that could be drawn from the study. It was suggested that the implications of these data limitations should be examined with respect to the Mathtech study and with respect to the needs of future research.

The discussion of the data limitations encountered in the study prompted a third general comment from the panel members -- the plausibility of the benefit estimates. For the types of benefits measured in the study, the panel felt that the benefit estimates presented at the meeting were the best estimates currently available. The panel members and others attending the meeting acknowledged that because of the conservative assumptions employed throughout the study, the estimates reported in the study were most likely lower-bound estimates of the benefits of attaining alternative SNAAQS in the economic sectors analyzed. It was also pointed out that the estimated benefits did not reflect all of the benefits of attaining SNAAQS since the estimation of other welfare benefits were not part of the Mathtech analysis (e.g., aesthetics, recreation, other economic sectors). In addition, it was mentioned that any health benefits that might occur as a result of the implementation of a secondary standard were not included in the benefit estimates presented at the public meeting.

Several members of the panel expressed concern that only the point estimates of the benefits were reported in the analysis. It was suggested that it would have been more appropriate to report a range of benefit estimates based on the confidence intervals that are associated with these point estimates. It was explained, however, that because of the complexity of the econometric models used in the benefit estimation, it might not be possible to develop rigorously such confidence intervals.

The remainder of the comments were specific to each economic sector and will be discussed according to the agenda followed at the public meeting. It should be mentioned that since copies of the written comments made by the panel of environmental experts are given in Appendix B of this volume, only the major comments regarding these sectors will be discussed in this section. Those interested in obtaining further information regarding the comments made at the public meeting should refer to Appendix B.

HOUSEHOLD SECTOR

The comments specific to the household sector analysis focused on two major points: 1) the coverage of the economic benefits accruing to households that was provided by the household expenditure model, and 2) the comparability between the benefits estimated by the household expenditure model and the benefits estimated by the residential property value and wage studies. With respect to the first point, several panel members praised the innovative approach taken in the household sector analysis. It was felt that since many of the actions that households might undertake as a means of mitigating the effects of air pollution were capable of being reflected in the household expenditure model. Consequently, the model provided more realistic coverage of the economic benefits accruing in this sector. This was considered to be a significant improvement in the field of environmental benefits analysis.

A few panel members noted, however, that the effects of all air pollutants were not measured in this model. It was also mentioned that all of the mitigative actions available to households were not reflected in the model. For example, it was noted that neither household location decisions nor labor-leisure decisions were reflected in the consumer expenditure model. In addition, the possibility that the household may have a "pure" utility increase as a result of reduced air pollution exposure was not captured by the model. One panel member explained that any effects of air pollution that do not result in a change in the household's market behavior were not "picked up" in the consumer expenditure model. This panel member further explained that the omission of non-market adjustments and some of the mitigative actions available to the household would result in an underestimate of the benefits of reductions in air pollution. There was a general concurrence among those attending the meeting that the household sector estimates were lower-bound estimates of the household sector benefits of attaining SNAAQS. Robert Horst of Mathtech acknowledged that Mathtech was aware of this issue and hoped to examine how the model could be modified to incorporate other mitigative actions.

The second comment regarding the comparability between the benefits estimated by the household expenditure model and the benefits estimated from the property value and wage studies was directly related to the comment about the amount of benefit coverage provided by the household expenditure model. It was observed by several panel members that the benefits estimated from the household expenditure model were much less than those estimated from the property value and wage studies. One reason for the disparity between these estimates was the fact that the household expenditure model was not designed to estimate the health and aesthetic benefits that may result from implementation of a secondary standard. Another reason for the differences between these estimates was the exclusion of the previously mentioned mitigative actions from the household expenditure model.

ELECTRIC UTILITY SECTOR

The major comment that was raised in reference to this sector concerned the multicollinearity among the variables used in estimating the cost functions for these utilities and how this collinearity would affect the estimated relationship between air pollution and the utilities' costs. It was mentioned that variables such as age of plant, stack height, sulfur content of fuel, and air quality that were included in the cost functions were likely to be highly correlated with one another. It was noted that although this collinearity would increase the standard errors of the estimated coefficients for these variables, it would not bias the coefficient estimates.

AGRICULTURAL SECTOR

The one comment that seemed to pervade the panel's discussion of the agriculture sector analysis concerned the lack of data. Kathleen Brennan of Mathtech mentioned that estimation of the crop yield equation was extremely difficult since county level data on the use of many of the farm inputs used to produce specific crops could not be obtained from the agriculture sector analysis. Because of the lack of data, the question was raised whether the results of controlled field experiments could be used in place of economic studies in order to approximate the economic benefits of reductions in sulfur dioxide. Reservations about using the results of controlled field studies were expressed because these studies do not replicate the actual conditions under which agricultural crops are grown. It was felt that the agricultural analysis emphasized the need for the collection of better and more data.

Several panel members expressed concern about the omission of relevant pollution variables such as ozone and nitrogen dioxide from the agricultural crop yield equation. It was suggested that the impact that these omissions might have on the estimated relationship between agricultural crop yield and sulfur dioxide be investigated.

Another comment raised by the panel focused on the inability of the model, as currently developed, to take into account some of the actions that a producer might undertake to offset the effect of sulfur dioxide on agricultural crops. Cultivar and crop substitution were two mitigative actions specifically mentioned. It was acknowledged that because producers had probably adjusted to the effects of air pollution through cultivar and crop substitution and because these adjustments were not incorporated into the model, the estimated benefits were likely to be lower-bound estimates of the economic benefits of SNAAQS.

MANUFACTURING SECTOR

The format followed for the manufacturing sector discussion differed somewhat from that published in the agenda. After Ernest Manuel of Mathtech completed the manufacturing sector slide presentation, comments were received from representatives of the American Iron and Steel Institute (AISI). (Written copies of the comments provided by the AISI representatives can be found in Appendix C.) Comments and questions were taken from the panel of environmental experts and general audience following Mr. Manuel's reply to AISI's comments.

The major comment from the representatives of AISI was that the study's finding of a statistically significant relationship between air pollution and manufacturing costs could not be construed to mean that air pollution caused manufacturing costs to be higher. The representatives cited several urban factors that they felt were the "true" causes of higher production costs: age of plant, wage rate, tax rates, and older labor force. Since these factors tend to be correlated with air pollution, the representatives asserted that the relationship observed between air pollution and manufacturing costs was due to correlation and not causation. Mr. Manuel replied that variables reflecting age of plant and the labor costs were included in the manufacturing model and hence the effects of these factors could not be attributed to air pollution. Mr. Manuel felt that the problem of other omitted urban variables such as the age of the labor force and tax rates was minimized somewhat since the majority of the manufacturing data were for establishments located in relatively urban areas. He stated further that although no statistical analysis outside of controlled laboratory conditions could ever "prove" a cause-and-effect relationship, he felt that the manufacturing sector analysis adequately controlled for the other factors influencing production cost so that the relationship observed between air pollution and production cost in the study suggested a cause-and-effect relationship.

The panel members also commented about the omission of "urban" variables from the production cost functions that were estimated for the industries in the manufacturing sector. It was mentioned that the omission of these variables might bias the coefficients of the air pollution variables because these excluded variables tend to be correlated with air pollution.

The other comment raised by the panel of environmental experts dealt with the benefits estimated for the fabricated structural metal products sector. Questions were raised as to why the benefits estimated for this particular industry were so large relative to the benefits estimated for the other manufacturing sectors. The sensitivity of the inventories and welding operations in the fabricated structural metal products industry to dust, and therefore to particulate matter, were given as two possible reasons for the magnitude of these benefits. It was suggested, however, that the reasons for the magnitude of the benefits estimated for this industry be investigated further.

In general, the panel members praised the manufacturing sector analysis. Both the careful and sophisticated research undertaken in this sector were highly commended. The panel members acknowledged that based on the conservative assumptions employed throughout the analysis and the fact that only 4 percent of the manufacturing sector was covered in the analysis, the estimates reported for this sector were clearly lower-bound estimates of the benefits of implementing SNAAQS.

CONCLUDING REMARKS

During the general comment period, James Bain of OAQPS asked the panel members to comment on the potential usefulness of the Mathtech study in the standard setting process. Everyone concurred that the study could be extremely useful in helping policy makers make environmental decisions. Because of the conservative assumptions and the limited number of sectors covered in the study, it was stressed that the benefits estimated in the study were lower-bound estimates of alternative SNAAQS. It was mentioned, however, that the current regulatory process required that the study appear in the Criteria Document before it could be considered in the standard setting process.

It was emphasized that although the study was a significant advancement in the field of environmental benefits analysis, there were still other benefit categories, not considered in the Mathtech study, that have not been adequately examined. It was suggested that in order to comply with Executive Order 12291, the study's estimates should be combined with the "best available" estimates of the benefits accruing in other economic sectors in order to approximate the total benefits of SNAAQS implementation.

RECOMMENDATIONS

At the close of the meeting, two recommendations were made regarding the Mathtech study. The first one was to examine the correlations between the excluded air pollution variables and total suspended particulates (TSP) and sulfur dioxide (SO_2). This was suggested in order to find out whether the exclusion of these variables might bias the coefficients of TSP and SO_2.

The second recommendation was to investigate whether it is feasible to report a range of benefit estimates based on the confidence intervals associated with the point estimates reported in the study.

APPENDIX A

Federal Register Notice, Agenda for Public Meeting, and

List of Participants

The above notices of determination were received from the indicated jurisdictional agencies by the Federal Energy Regulatory Commission pursuant to the Natural Gas Policy Act of 1978 and 18 CFR 274.104. Negative determinations are indicated by a "D" before the section code. Estimated annual production (PROD) is in million cubic feet (MMCF). An (*) before the Control (JD) number denotes additional purchasers listed at the end of the notice.

The applications for determination are available for inspection except to the extent such material is confidential under 18 CFR 275.206, at the Commission's Division of Public Information, Room 1000, 825 North Capitol St., Washington, D.C. Persons objecting to any of these determinations may, in accordance with 18 CFR 275.203 and 275.204, file a protest with the Commission on or before July 15, 1981.

Categories within each NGPA section are indicated by the following codes:

Section 102-1: New OCS lease
- 102-2: New well (2.5 mile rule)
- 102-3: New well (1000 ft rule)
- 102-4: New onshore reservoir
- 102-5: New reservoir on old OCS lease

Section 107-DP: 15,000 feet or deeper
- 107-GB: Geopressured brine
- 107-CS: Coal seams
- 107-DV: Devonian shale
- 107-PE: Production enhancement
- 107-TF: New tight formation
- 107-RT: Recompletion tight formation

Section 108: Stripper well
- 108-SA: Seasonally affected
- 108-ER: Enhanced recovery
- 108-PB: Pressure buildup

Kenneth F. Plumb,
Secretary.

[FR Doc. 81-19223 Filed 6-29-81; 8:45 am]
BILLING CODE 6450-85-M

ENVIRONMENTAL PROTECTION AGENCY

[AD-FRL-1869-8]

Benefits Analysis of National Ambient Air Quality Standards for Sulfur Oxides and Particular Matter; Meeting

AGENCY: Environment Protection Agency (EPA).

ACTION: Notice of public meeting.

SUMMARY: EPA's Office of Air Quality Planning and Standards is conducting a public meeting to solicit input on a contractor's technical report containing a benefits analysis methodology for National Ambient Air Quality Standards for sulfur oxides and particulate matter under Section 109 of the Clean Air Act, 42 U.S.C. 7409. A panel of experts in the field of environmental benefits analysis will critically discuss the analysis of various economic sectors. Questions and comments from the general public will be also be discussed. The meeting will be from 9:00 a.m. to 5:00 p.m. on both Monday, July 27, and Tuesday, July 28, 1981. It will be held in the Governor's Room of the Sheraton-Crabtree Inn, U.S. 70 West, Raleigh, NC 27612.

FOR FURTHER INFORMATION CONTACT: Janet Scheid (919) 541-5611/(FTS 629-5611) of the Ecnomic Analysis Branch, Strategies and Air Standards Division, Office of Air Quality Planning and Standards. The mailing address is: Economic Analysis Branch (MD-12), U.S. Environmental Protection Agency, Research Triangle Park, 27711.

Dated: June 24, 1981.

Edward Tuerk
Acting Assistant Administrator for Air, Noise, and Radiation.

[FR Doc. 81-19182 Filed 6-29-81; 8:45 am]
BILLING CODE 6560-26-M

[AMS-FRL-1871-2]

Fuel Economy Retrofit Devices; Announcement of Fuel Economy Retrofit Device Evaluation for "FUEL-MAX"

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice of Fuel Economy Retrofit Device Evaluation.

SUMMARY: This document announces the conclusions of the EPA evaluation of the "FUEL-MAX" device under provisions of Section 511 of the Motor Vehicle Information and Cost Savings Act.

Background Information

Section 511(b)(1) and Section 511(c) of the Motor Vehicle Information and Cost Savings Act (15 U.S.C. 2011(b)) requires that:

(b)(1) "Upon application of any manufacturer of a retrofit device (or prototype thereof), upon the request of the Federal Trade Commission pursuant to subsection (a), or upon his own motion, the EPA Administrator shall evaluate, in accordance with rules prescribed under subsection (d), any retrofit device to determine whether the retrofit device increases fuel economy and to determine whether the representations (if any) made with respect to such retrofit devices are accurate."

(c) "The EPA Administrator shall publish in the Federal Register a summary of the results of all tests conducted under this section, together with the EPA Administrator's conclusions as to—

(1) the effect of any retrofit device on fuel economy;

(2) the effect of any such device on emissions of air pollutants; and

(3) any other information which the Administrator determines to be relevant in evaluating such device."

EPA published final regulations establishing procedures for conducting fuel economy retrofit device evaluations on March 23, 1979 [44 FR 17946].

Origin of Request for Evaluation

On January 18, 1980, the EPA received a request from FIDCO, Fuel Injection Development Corporation, for evaluation of a fuel saving device termed "FUEL-MAX." This device is an air bleed device that replaces the EGR valve. It is claimed to conserve fuel.

Availability of Evaluation Report

An evaluation has been made and the results are described completely in a report entitled: "EPA Evaluation of the FUEL-MAX Device Under Section 511 of the Motor Vehicle Information and Cost Savings Act." This entire report is contained in two volumes. The discussions, conclusions and list of all attachments are listed in EPA-AA-TEB-511-81-10A, which consists of 18 pages. The attachments are contained in EPA-AA-TEB-511-81-10B, which consists of 120 pages. The attachments include correspondence between the Applicant and EPA, all documents submitted in support of the Application and the EPA testing of the device.

As a part of its evaluation EPA has actually tested the FUEL-MAX device. The EPA testing is described completely in the report "Emissions and Fuel Economy of FUEL-MAX, a Retrofit Device," EPA-AA-TEB-81-15, consisting of 8 pages. This report is contained in the preceding FUEL-MAX 511 Evaluation as an attachment and can be obtained separately or as part of the attachment package.

Copies of these reports may be obtained from the National Technical Information Service by using the above report numbers. Address requests to: National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, Phone: Federal Telecommunications System (FTS) 737-4650, Commercial 703-487-4650.

Summary of Evaluation

EPA fully considered all of the information submitted by the Device manufacturer in the Application. The evaluation of the "FUEL-MAX" device

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Public Meeting
Benefits Analysis of Secondary National Ambient Air Quality Standards
for SO_2 and TSP

July 27-28, 1981

AGENDA

Monday, July 27

9:00 a.m.	Introduction	Jim Bain, Chief Economic Analysis Branch U.S. EPA
9:15 a.m.	Project Overview	Ernest Manuel, Project Manager Mathtech, Inc.
9:45 a.m.	Household Sector Analysis	Robert Horst Mathtech, Inc.
10:00 a.m.	Household Sector Discussion and Comments	
12:00 noon	Lunch	
1:00 p.m.	Utility Sector Analysis	Ernest Manuel, Project Manager Mathtech, Inc.
1:45 p.m.	Utility Sector Discussion.and Comments	
5:00 p.m.	Adjournment	

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Public Meeting
Benefits Analysis of Secondary National Ambient Air Quality Standards
for SO_2 and TSP

July 27-28, 1981

AGENDA

Tuesday, July 28

9:00 a.m.	Introduction	Jim Bain, Chief Economic Analysis Branch U.S. EPA
9:15 a.m.	Agricultural Sector Analysis	Kathleen Brennan Mathtech, Inc.
9:45 a.m.	Agricultural Sector Discussion and Comments	
11:00 a.m.	Manufacturing Sector Analysis	Ernest Manuel, Project Manager Mathtech, Inc.
12:00 noon	Lunch	
1:00 p.m.	Manufacturing Sector Discussion and Comments	
3:00 p.m.	Overall Conclusions & Recommendations	Jim Bain, Moderator
5:00 p.m.	Public Meeting Adjournment	

MAJOR PARTICIPANTS

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APPENDIX B

Comments from Panel of Experts in the Field of Environmental Benefits Analysis

Comments Prepared On:

BENEFITS ANALYSIS OF ALTERNATIVE SECONDARY NATIONAL AMBIENT AIR QUALITY STANDARDS FOR SULFUR DIOXIDE AND TOTAL SUSPENDED PARTICULATES

For Review

July 27-28, 1981
Raleigh, North Carolina

Gardner M. Brown, Jr.
University of Washington

"Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates," is an exceptional piece of research. The theoretical underpinnings of the applied economic analysis are at the forefront of the profession. The analytical model used by Mathtech appeared in the best economics journals only six years ago.

The general presentation is articulate, careful and quite complete. The authors identify the plausible alternative research strategies available at each juncture of the analysis. The explanations given for the models adopted, the behavioral responses captured--and not captured--by the models, the variables included and excluded and the alternative assumptions which might have been made are professionally treated. There is a welcome tone of critical evaluation present, surprisingly more than one finds in professional journals. The results are presented clearly and the statistical features are capably and critically treated as well. The repeated checks for the sensibility of the results are laudable.

It pays to allocate different levels of effort to different tasks depending on the economic importance of the sectors. Such discrimination is evident in the volumes reviewed. As a result the household and manufacturing reflect the highest quality of analysis.

It is apparent from reading the study and from the discussion which ensued at the meetings in Raleigh, at which the study was reviewed, that there are serious data limitations which limit benefit analysis and bring into question the precision of the estimates obtained. This fact prompts a recommendation and a query. The recommendation is for Mathtech to identify the missing data which in its estimation presented the greatest bottlenecks toward reaching accurate answers. The "holes" should be ranked and a brief explanation should be given about the gains to be made if the four or five most highly ranked gaps in data were filled.

In view of the fragile data base would not it have been better to have adopted other modes of analysis, particularly those with less voracious appetites for data? My uncomfortable judgement is no. One alternative is to have done nothing except choose the best estimates gleaned from a literature review. These estimates could not have come from a better data base--it does not exist--and their conceptual foundations are not conceptually superior to the ones adopted, in my judgement.

A second alternative is to have conducted different studies with the existing data base. I do not think the credibility of the results of the alternative studies necessarily would have been better and it well might have been much worse. Other approaches, for example, gain simplicity simply by making even more assumptions than appear in this study. For instance, to assume firms are governed by a Cobb-Douglas production or cost function is to rule out the possibility of interactions, which the Mathtech analysis shows to be statistically significant in their analysis in the manufacturing sector. In short, neither the alternative of doing no further analysis nor the option of doing another type of study has unequivocal attractiveness.

Another perspective is gained by the reader considering the scientific credibility of studies which supported earlier environmental decisions of the same order of magnitude as the secondary standards in question. Is it superior to the credibility of the present study? I think not, although there may be one or two exceptions. Thus, if there must be a benefit analysis of the secondary standards and if there is insufficient time to enhance the data base much beyond the present level, then my conclusion is that the overall benefit estimate found in this study is reasonable. It appears that the authors have taken precautions, perhaps too many, to make their estimate of benefits lower than what reasonably might be expected. One exception to this general conclusion, maybe SIC 344, fabricated structural metal products, in the manufacturing analysis, for reasons given at the meeting in Raleigh.

The comments which follow are directed to particular sections of the study and are more detailed in character.

Volume 1

3-3 If a firm was sensitive to pollution and had to choose a location in within a county, what is the probability it would locate where pollution is measured? I am concerned here and elsewhere in the study that firms will locate where pollution is low, not high, ceteris paribus, and pollution is not being monitored in the low pollution areas, on average. What bias does this create? The study cites Freeman's discussion of bias but I did not find this issue addressed in Freeman.

3-11 Please add a figure exhibiting the discussion on this page.

3-21 What is the correlation of Temp with Sechigas?

Volume 2

4-12 We only have to have perfect information about welfare effects if we want to have an error-free model. A weaker assumption which permits well behaved errors will do.

4-20 Are damage functions related to changes in concentration? Why not add "marginal" damage?

4-24 Can you ask Waddell what he meant rather than assuming what he meant?

4-78 It would be useful to explain what "consistent" means since it pays such an important role in choosing an aggregator.

5-30 The explanations on this page seem strained. Households cannot consistently lag in adjusting to air quality, continuously changing in one direction. Arbitrage prevents this in a competitive framework.

5-31 If there is discounting of environmental improvement, this is testable using lagged relationships.

5-35 When prices are linear in a market, a demand function is estimated by fitting a function from prices obtained in different markets. The cross-section provides the price variability necessary to estimate the price slope for quality. This is explained in G. Brown and R. Mendelsohn, "Hedonic Travel Cost Method," University of Washington.

5-36 Explanation does not make sense. You cannot use the price function to get infra-marginal values.

5-37 This discussion holds when the Polinsky-Shavell assumptions are met. I suggest citing them here.

4-8ff The treatment of methodological issues is helpful. The study points out that people can vote with their feet in response to pollution, moving to cleaner areas, incurring some cost, not necessarily captured by wage or property value differentials.

The treatment of separability is very good on the whole. I think it is a strong assumption to separate consumption from leisure and here is a place to be more candid. Moreover, it is possible to test for separability within groups and across groups. Some of the more vulnerable divisions might be tested. Groups 2 and 3 might be aggregated or groups 2 and 4. Drycleaning might be tested for separation from clothes.

In all the sectors, there should be tests for stability at the mean and at the observation points.

4-152 I am troubled that separability and rules of aggregation can lead to a price increase, i.e., produce a result counter to our expectations. Maybe this suggests that the model has problems.

4-160 It is assumed that the primary standard is achieved in 1985 and the secondary standard met two years later. Assumed also that any SMSA below the primary standard in 1978 remains at the 1978 levels to 1985. Cities at secondary levels do not receive any benefits. But what if quality would have deteriorated in the absence? Thus this assumption understates benefits.

4-162 Are the prices implied in the income projections consistent with the prices imbedded in the assumption that relative prices do not change?

Volume 3

7-61 It would have been good to have a bit more explanation about the importance or unimportance of rented capital.

7-61 Is it of any concern that the study use an opportunity cost of 7 percent for the manufacturing sector and a discount rate of 10 percent?

It would be useful to exhibit standard errors and estimated coefficients in the TC and MC functions, at least for SIC 344 which is so critical.

7-46+ 7-98 Assumption 2 assumes a doubling of input prices doubles the output price. The estimated output price equation indicates that a doubling of input prices is not associated with a doubling of the output price for six of the seven industry classifications. The assumptions and facts are eternally inconsistent.

With respect to the discussion of missing data, I suggest an experiment to get some feeling for using sample means for the missing data. Why not remove some observations in Sector 344, say, and put the sample mean in instead? One could then see the effect the change has on the basic results obtained.

7-128ff Why are Ernie's elasticity of substitution estimates with respect to capital, so much smaller than were found in this study?

7-126 Small shares definitely is a problem. I expect it has produced results equivalent to concave (misbehaved) isoquants. There are standard tests for stability which should be made.

7-178 Regional shares of output are assumed to remain constant. Is this assumption the usual one made by federal agencies predicting future regional output and income, and so forth? If not, your study is internally inconsistent.

Section 8--Utilities

This section does not seem to be a vitally important one and I have the sense that it was not done as painstakingly as other sections.

For example, we are treated to a most sophisticated measure of capital in the manufacturing sector, but here the measure of capital is quite simple: capacity, augmented by capacity utilization. Age of plant never is significant and that seems a little odd. One sentence will do about why the elaborate approach is not necessary in this section.

8-17 Sulphur is aggregated across plants in a linear fashion if I understand the statement on 8-17, but the aggregate outcome is entered non-linearly in the analysis. If the stakes were high the aggregation rule should be more carefully constructed. Also if stack heights really mattered, I would think more carefully about the linear rule used. Stacks' height surely is not a constant marginal cost item. Besides it too enters linearly in the regression.

8-44 Investigators used restricted Cobb-Douglas functional form because of too many variables. They could have excluded some variables as was done in other sections. For example, age and wage rate were never significant so could be omitted on a trial basis. Rain and sulphur content also could be removed. Regional benefits assume no relocation of population forever. That is probably a strong assumption. Note that benefits are zero in the Pacific region and positive in the Central regions. If people continue to move to the Pacific region, benefits will have been overestimated.

Volume 4

Agriculture

I have a strong temptation to regard this as a marginal piece of work. If, in response, I was challenged to come up with a better estimate of the benefits to pieces of agriculture from changing SO_2 levels, I doubt I could do it. At least I am not confident I could. Thus, judged against the terribly important standard of doing the best, given reasonable constraints, this is a good study. Suppose, however, I was asked to review an edited version of Section 9 for a journal. I would reject it.

What troubles me most is the inadequacy of the data base. I would have thought yield/acre depended on the level of capital (e.g., machinery) inputs. It is omitted. I would have thought that the marginal produce of labor diminished and depended on the level of other inputs. It does not--not in the equation used for benefit estimation (Tables 9-10, equation 2). Using regional observations for labor in the production of soybeans (used also to produce flax seed) may be the closest one can approximate a representative farmer's decision. It seems like an heroic assumption to me. Regressing yield per acre on labor per region is also a bit curious.

Data for the years 1975, 1976, 1977 are assumed to be drawn from the same population in the yield equations. Is there adequate variability of SO_2 over these years, holding region constant?

Why aren't the estimated costs to Texas cotton and soybean farmers from decreasing SO_2 entered into the analysis and net benefits computed?

9-45 Why were past prices used as a proxy for expected prices when futures prices exist for cotton and soybeans?

9-24 Would not the acreage planted be a function of costs as well as prices, unless of course the cost of producing the crop and its substitute are the same? (See 9-24).

Given the present data base and the results of this study, should EPA finance studies of other crops? Or what kind of priority should such studies have in EPA's ranking of studies?

Comments on "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates".

by

Anthony C. Fisher
University of California, Berkeley

Presented at a public meeting put on by the Environmental Protection Agency in Research Triangle Park, North Carolina
July 27-28, 1981

Comments on "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates"

by

Anthony C. Fisher

This five-volume study represents a very significant advance in the theory and method of estimating the benefits from air pollution control.

For some time I have been presenting this topic as involving two basic approaches: 1) estimating (the reduction in) physical damages as a function of a change in air quality and then imputing a value, and 2) estimating in one step the relationship between a change in air quality and a market value, such as property value. To these one could add a third, less widely used: asking individuals what they are willing to pay for designated improvements in air quality. The first is the approach generally taken by non-economists, and as the authors of the present study argue, is likely to be inconsistent with a theoretically preferred approach to benefit estimation (one that gets at willingness-to-pay for a change). Further, it is beset by severe data problems. The second has been used by economists, including the authors of this study. It is consistent with theory, but is perhaps not well suited to the task at hand in this case. The difficulty is that in principle it captures health as well as non-health benefits, and the charge of the present study is to estimate only the benefits of moving from primary to secondary standards, i.e., only the non-health benefits. The third approach has the obvious drawback of depending on response to hypothetical questions, rather than observed behavior.

The great merit I see in the main body of the present work is its development and application of a new approach, one that is consistent with the theory of benefit estimation in that it does get at willingness-to-pay for air quality, discriminates among classes of benefits in such a way that it (in principle) captures only the benefits of moving from primary to secondary standards, and depends on observed behavior in markets for conventional goods and services.

In the more detailed remarks that follow I shall raise a number of questions concerning still (to me) unresolved theoretical issues, and the relationship of the new, "sector" approach to the existing approaches to benefit estimation. The focus is mainly, though not exclusively, on the household sector, because this is where I see the more challenging remaining issues. Also, much of the previous work by economists, such as property value studies, has been in this area, so questions about the relationship of the present work to previous approaches are specially relevant for the household sector.

I want to emphasize, before proceeding, that the questions and comments are offered in a spirit of constructive criticism of a study I regard as making a significant contribution to the field of environmental economics.

One set of questions has to do with the modes of adjustment to pollution by those who suffer from it, and the ways in which adjustment behavior is reflected in the theoretical and empirical analysis. The authors point to their analysis here as important and innovative. I agree, and feel this gives special urgency to unresolved questions.

A first such question I would raise, then, is the following. In treating (as on pp. 2-27 and 2-28) the value of a reduction in pollution as the change in (consumers' and producers') surplus, how do the authors capture the effect of a switch to a different product or, more likely perhaps, a different crop? Figure 2-6, for example, is clearly valid if there is no switch. But if there is, shouldn't one look at the net change in profits, or site rents, either of which might capture the higher value of the new crop? As far as I can tell, this case is not explicitly treated either here (chapter 2) or in the empirical analysis of the agricultural sector (chapter 9, pp. 34-77).

My suggestion, then, is to try the property value approach, relating ambient concentrations of particulates or sulfur oxides to agricultural property values. In the agricultural sector, as opposed to the household sector, comparative property values are not likely to reflect (human) health impacts, and so are appropriate for estimating the benefits of moving from primary to secondary standards.

A related question concerns the ability of the model to pick up benefits in a situation where there is no adjustment by the pollution receiver. Suppose a decrease in sulfur dioxide or total suspended particulates does not lead to a decrease in household demand for laundry and cleaning products; people just live in cleaner surroundings. Does the model pick this up as an increase in utility in the household sector, as it would an analagous increase in output in the agricultural or manufacturing sectors? Or do the authors perhaps underestimate benefit to the household sector for this reason? Another way of putting the issue here is to note that we are getting into esthetics, which the model is not designed to pick up. Of course esthetics might be picked up, but only if people change their market behavior in some fashion.

A related issue is the following, raised on p. 4-11 and perhaps elsewhere. The authors note there that "failure by the analyst to consider the range of adjustment opportunities...can lead to an overstatement of benefits". I believe the outcome is just the reverse. The value of pollution abatement is greater if the receiver is free to make adjustments than it would appear to be if the potential for making these adjustments is ignored. On the other hand, the damages from an increase in pollution would be overstated, to the extent that the estimation does not take account of possibilities for mitigating them by defensive actions.

Both effects are easily demonstrated graphically. On Figure 1, which describes a reduction in ambient pollution concentration, the implicit price of cleanliness is reduced from p_0 to p_1. If no adjustments, or substitutions, are possible, the demand for cleanliness is inelastic and benefits are estimated as ABCD. If, on the other hand, adjustments are possible, demand is relatively elastic, and benefits are estimated as ABCE. The difference, DCE, is the amount by which benefits are understated if adjustment possibilities are ignored. A similar analysis in the case of an increase in pollution levels shows the damages to be overstated by the amount DCE on Figure 2. For a somewhat different and more detailed exposition, see Zeckhauser and Fisher (1976).

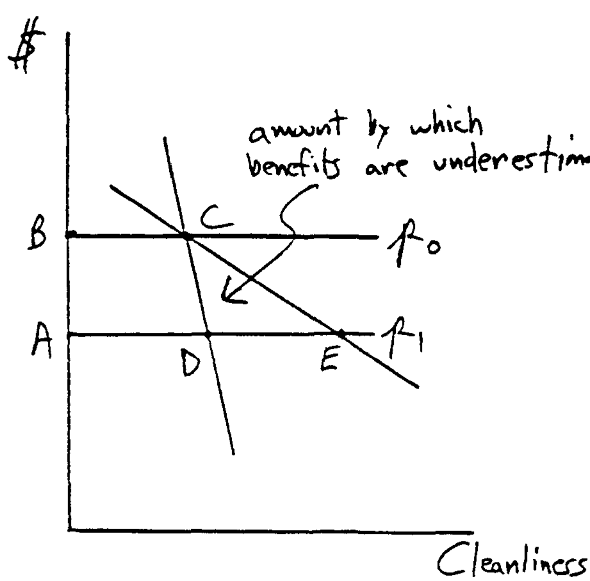

Figure 1. Reduction in Ambient Concentration

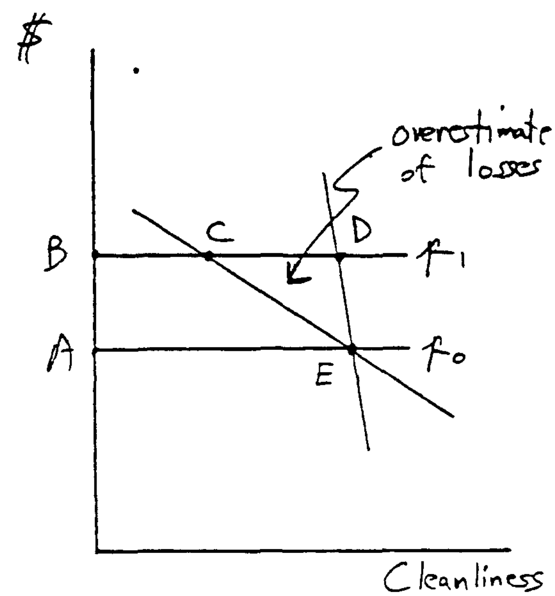

Figure 2. Increase in Ambient Concentration

Still another related point: on p. 4-12 the authors note four ways in which the "null response" may arise. I think there is a fifth, which is likely to be important in practice: the costs of adjustment exceed the perceived damage. This point is implicit in a discussion (p. 4-13) of the household's budget constraint, but even with a perfect capital market, a response would not be expected, or observed, if costs exceeded benefits. This may be a point of some general relevance, to the property value and wage studies as well. If there are costs of movement, or of course other barriers to movement, neither property values nor wages will fully reflect the benefits of an air quality improvement. Or have I missed something?

A second set of questions, or comments, has to do specifically with the relationships among benefit estimates based on (a) the "sector" approach, (b) the property value approach, and (c) the wage rate approach. First, as between the existing approaches, (b) and (c). I understand these are not the authors' main concern, but a number of loose or vague references scattered through the text might be further considered. Freeman (1979, pp. 118-121) suggests that under plausible conditions, such as qualitative differences in natural resource endowments or non-constant returns to scale, factor price (wage) equalization among regions will fail, and benefits of an air quality improvement are then the sum of the absolute values of the changes in wage payments and residential land rents. I get the impression, though, again, the treatment of this question in the text is rather loose, that the authors see property value and wage changes as somehow separate (and unequal?) estimates of the same thing. Perhaps they do not, but at a minimum the discussion ought to be made more precise.

With respect to the relationship between the sector and property value, or property value-plus-wage approaches, the latter is an upper bound to the former only if health effects and benefits are accurately perceived, and then fully reflected in property/wage values. I have suggested they may not be due to cost or other barriers to mobility. Further, it is my impression, shared I believe by many people in the field, that health effects are not in fact accurately perceived, particularly where they result from chronic, low-level exposure to a pollutant. It is for this reason I have argued elsewhere for a separate estimate of the health benefits of pollution control.

Now let me raise a number of questions relating to the empirical procedures or findings of the study. Do the authors find it disturbing, as I do, that the benefits of attaining the secondary standards as they calculate them on the basis of either property value or wage studies are orders of magnitude greater than the same benefits calculated on the basis of the (household) sector approach? (The disparity is of course still greater if, as I have suggested, it is the sum of property value and wage changes that measures the benefits.) Again, as I have suggested, these alternative techniques may fail to capture the health benefits also not captured by the sector approach, and may underestimate such benefits as they do capture. Further, even if health benefits are captured in property value or wage studies, they are presumably exhausted by the move to primary standards. Does the disparity between household sector and property value/wage estimates suggest the existence of very substantial remaining health benefits from the move to secondary standards? Or is it all esthetics? Or could the sector approach be substantially underestimating benefits, perhaps for the reasons I have suggested? My guess is that all three effects are present, and should be noted as explanations of the wide disparity in results.

A quite unrelated question I have is about discounting procedure. It is not clear to me whether the estimates presented represent the present value, in 1980 dollars, of annual benefits of moving from primary to secondary standards, as of (I think) 1987, or rather the present value, in 1980 dollars, of a stream of annual benefits beginning in 1987--and if the latter, how long a stream. Also, if the latter, why? I believe that the other studies, to whose results the authors compare their own, present only annual benefits. It is not clear to me how to interpret, for example, the comparison with Freeman on p. 4-173, until this question is clarified.

A related comment is that a 10% real rate of discount, the one emphasized in the text and (especially) the tables, seems much too high, even in today's fevered financial conditions, and certainly (one hopes) in the longer run. Results based on the 2% and 4% rates used for purposes of sensitivity analysis ought to be at least as prominently displayed.

Finally, a comment suggested by the study concerning directions of future research. Probably one of the most profitable would be more extensive physical monitoring of ambient concentrations. I vaguely recall hearing recently of some promising new low-cost techniques. And in the absence of monitoring, the ability of environmental economists to build on the work represented in this study is greatly impaired. For example, the authors note (p. 2-45) that sulfur dioxide, the more important pollutant in terms of effects on vegetation, is monitored in only 10% of U.S. counties, thereby precluding analysis of the forestry and fishery sectors.

* * *

Concluding Remarks

The study is to be commended for its introduction of new and sophisticated methods for estimating the benefits of air quality, and perhaps equally, for its readable discussion of these methods. The question can be raised as to whether the theoretical development is worthwhile, or appropriate, since data limitations permitted application only to fractions of the several economic sectors distinguished by the authors. My answer is that the development is both worthwhile and appropriate. It leads us to identify gaps in the data and coverage. As these gaps are filled, the benefit estimates that can be generated will be increasingly plausible, and defensible.

A second, related point, is that the conservative assumptions employed at various places in the study, and the other sources of under-estimation of benefits identified in my comments, combine to suggest that the resulting estimates are lower bounds. If, as I learned informally at the close of the public meeting, costs of achieving the secondary standards are still lower, we can be confident that the standards are justified.

References

Freeman, A.M. The Benefits of Environmental Improvement: Theory and Practice. Baltimore: Johns Hopkins University Press, 1979.

Zeckhauser, R.J. and A.C. Fisher. "Averting Behavior and External Diseconomies", Kennedy School Discussion Paper 41D, 1976.

Comments on "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards For Sulfur Dioxide and Total Suspended Particulates"

July 27-28, 1981

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A question of longstanding scientific importance concerns the basis on which to appraise research which purports to add to the stock of knowledge. This question is what this conference is about; these comments will venture an answer as well.

Several bases for appraising research -- especially, applied microeconomic research -- come immediately to mind. They include:

(1) Do the empirical models rest on a solid theoretical base? Does the economic theory used represent that at the frontier of the discipline? Is the theory interpreted correctly and is it employed appropriately in specifying the empirical models?

(2) Are sound econometric methods used in estimating the models? Is the basis for choosing the techniques used rather than alternative approaches fully explained?

(3) Are appropriate data used in the estimation? Was superior data available but not employed, and, if so, why not? Are the data sufficient to the task?

(4) Were the many judgments and decisions necessary in empirical research made judiciously, sensibly, and with good reason?

(5) Were the empirical results interpreted correctly? Was the sensitivity of the results to alternative assumptions tested? Are the limitations of the estimates -- and their dependence on particular assumptions -- spelled out clearly?

(6) Are the results plausible? Is their relationship to other scientific research explored? Are they used appropriately in discussing policy implications?

In my comments, I will appraise the study on each of these criteria. To begin, let me offer a bottom-line: The MATHTECH Report is a very solid piece of work. While the findings are clearly less than optimal for making a policy judgment, they are the most comprehensive and easily the most defensible ones in existence. They rest solidly on economic theory and derive from the application of appropriate modern econometric methods. While they are plausible, I would find it more difficult to say that they are believable. However, if I had to believe something about the economic benefits stemming from reduced soiling and materials and crop damages of attaining secondary standards, I would believe these estimates.

Let us consider the study in terms of each of the criteria noted above: First, the microeconomic theoretical basis for this study is precisely on target. Measuring the welfare gains from policy actions is a tricky business. It requires the careful specification of utility functions and the precise definition of the measures of gains and losses to be employed. These welfare gains are not observed, and must be inferred from underlying behavioral responses to economic stimuli. The authors of this study have done a very careful job with this component -- they lay out clearly the underlying theory, state openly the implied assumptions and constraints required to develop empirical estimates of the theoretical concepts, and specify the limitations of the estimates even if the empirical work were to conform to theoretical requirements. They deserve an A on this criterion.

As with the first criterion, the second -- concerning appropriate econometric methods -- is also well-fulfilled. The methods used are advanced and appropriate to the task. And, by and large, they are used artfully. Especially in the household analysis, the approach is sophisticated and "state of the art". In terms of both theoretical underpinnings and econometric sophistication, this analysis should find its way into the professional literature. Econometric methods again deserve an A.

The third criterion concerns data and its use. As the criterion is phrased, the judgment regarding the absolute quality of the data must be separated from the judgment on its use. In my view, the authors have employed the best -- and in many cases -- the only data relevant to the estimates they require. Indeed, in a few instances, the search for data, the creation of proxies where data did not exist, and their construction of data bases assembled from information from a variety of sources was most creative. The development of input prices and capital inputs and values in the estimates for the manufacturing sector is a case in point.

Judgment on the overall quality of the data, however, is quite a different story. In several instances, the comprehensiveness and the quality of the estimates have been severely compromised by the availability of relevant data. For example, in estimating the corrosion and other materials damage costs in manufacturing industries, the lack of appropriate data has sorely constrained the number of industries which could be analyzed and the significance of the industries included. Some of the sectors most likely to be adversely affected by air pollution -- for example, the steel industry -- were excluded for data reasons. In terms of the collection and creation of appropriate data, the researchers get high grades. However, data constraints which they faced -- in no way their fault -- does impose serious limits on the reliability and comprehensiveness of their estimates.

The constraints imposed by the data raise a quite fundamental question regarding the research strategy chosen for this sort of study. Would one have chosen the empirical approach suggested by frontier economic theory if one knew *ex ante* that the data constraints relevant to that research option would severely limit industry coverage, such that all but about 4 percent of the manufacturing sector (including some of the most pertinent industries) would have to be excluded from the analysis and that extrapolation based on heroic assumptions would be required to build an estimate of benefits for but 25 percent of the manufacturing sector? Is it possible that a less sophisticated, more straightforward empirical approach, but one without the theoretical underpinnings of that chosen, could yield estimates which are at least as plausible as the final, extrapolated estimates of the approach chosen? Clearly, some trade-off exists between theoretical and econometric sophistication requiring poor or unavailable data and a less pure, less sophisticated, less theoretically sound analysis which has fewer data needs. I have some doubts as to whether the study authors chose efficiently along this continuum.

This comment is a natural lead-in to an appraisal of the numerous judgments and decisions made by the researchers in executing the project -- the fourth criterion. By and large, I have little trouble on this score. The numerous operating decisions taken by the researchers appear to me to be based on clear thinking, common sense, and a recognized need to press through to a bottom line estimate.

Having undertaken the research and developed the estimates, the next question concerns their interpretation. Are the uncertainties and potential biases created by the numerous assumptions and data limitations accounted for in the interpretation of results? Or do the researchers come to believe in their final estimates once they have been placed on paper? It is with respect to this issue that the report can be moderately faulted. Perhaps my main objection on this score concerns the tendency to believe in the point estimate on the pollution variables if statistical significance is found. My concern here rests upon several considerations -- the classical omitted variables can serve as an illustration. The bulk of the benefit estimates in the report can be traced back to some regression in which some dependent variable (e.g., industry costs) is related to some air pollution measure. The issue is: Are there phenomena which may affect industry costs which are not included in the regression and which may be correlated with air pollution levels? If such phenomena do exist, the coefficient on the pollution variable will be capturing their effect as well as that of air pollution.

Consider, for example, the measured effect of air pollution (TSP) on total cost in the fabricated structural metal products industry

(Table 1-25). For the primary model estimated, the TSP variable is significant at about the 0.04 level. In this model, TSP enters, with the SO_2 variable omitted. The other explanatory variables are the prices of labor, capital, and materials inputs, and climatological variables. The regression is fit over 57 observations which are counties with available industry output and input prices, and air pollution and climatological data. Most of these counties represent urban areas. The question is: Are there phenomena associated with industry costs which are not captured by the included variables (e.g., input prices or air pollution)? Some reflection suggests that there may well be. Urban problems -- air pollution, crime, high poverty incidence, low property tax base, high urban infrastructure costs -- tend to come in bunches and are often associated with the size and nature of the metropolitan area. All of these phenomena are likely to (1) adversely affect industry costs (if in no other way than through local taxation levels) and (2) be correlated with air pollution levels. All are uniformly excluded from the regression. As a result, the magnitude of the coefficient on the air pollution variable will reflect the cost impact of these phenomena as well. To the extent that it does, the effects of TSP on industry costs will be biased (and probably overstated) -- and the benefits of reducing TSP levels are likewise biased.

In the report, little recognition is given to this very real possibility, and -- after some caveats -- typically the coefficient is accepted at its face value. This, I would suggest does not represent a careful and thoughtful interpretation of results. On this fifth criterion, then, I can award them no better than a B-.

The final criterion is, in some sense, the nub of the issue: Are the results plausible and believable? Answering this question is difficult, as plausibility is an elusive concept. What is it that causes one to believe or not believe research results? Some of these factors are clear, others are not. Common sense, institutional knowledge, comparison of estimates with known related values, comparison of results with those of other studies, an assessment of the limitations and biases imposed by assumptions and constraints adopted in the research, and an ability to trace and verify the various steps in the analysis are all elements in establishing plausibility. At one level, I am inclined to view the overall results of the study as plausible. The magnitudes are not enormous, the researchers have done an admirable job in comparing their findings with those of other studies, the methodological basis is solid, and by and large, most of the separate assumptions and decisions are reasonable. At another level, however, I am troubled. The deeper one probes into some of the estimates, the more one is impressed by the tenuous nature of the terrain.

Consider, as an example, the major component of the benefits of achieving the secondary standards. The benefits from achieving the secondary TSP standard in the fabricated structural metal products sector totaled \$3.7 billion of the total of \$4.5 billion of estimated total manufacturing sector benefits; \$11.4 billion of \$15.9 billion of total extrapolated manufacturing sector benefits for the TSP secondary standard, and $11.4 billion of $22.0 billion of total benefits for the household, agricultural, manufacturing and electric utilities industries for both the SO_2 and TSP standards. That the estimate for this small industry, with $6.7 billion of annual 1972 value added -- 0.6 percent of GNP -- should, when extrapolated, account for over one-half of the total estimated national benefits of the secondary standards seems somewhat remarkable.

The methodology applied in obtaining this estimate involves a regression estimate of the effect of TSP on production costs in this industry, after accounting for input prices and quantities and climatological factors. The following is a partial listing of the constraints imposed and assumptions made in deriving this estimate:

- The production function in the industry is assumed to be weakly separable.
- Prices of inputs and level of output in the industry is assumed to be exogenously determined.*
- Climate and air quality are assumed exogenous to the firms.
- The production function is taken to be a transcendental logarithmic function.
- Firms in the industry are assumed to be cost-minimizers.
- Symmetry (values of cross partial derivatives independent of the ordering) is imposed.
- Input prices for all variable inputs are homogeneous of degree 1.

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* Note that independent evidence cited in the report indicates that wage rates are a negative function of air pollution levels.

- Elasticity of total cost with respect to TSP and SO_2 is assumed to be independent of pollutant concentration.

- Variations in rainfall are assumed to be independent of input cost shares.

- The effects of temperature and rainfall are constrained not to interact with each other.

- The effects of the fixed factors are assumed to be independent of firm size.

- The cost function estimated is taken to represent the fictional "average" establishment in the county.

- All non-production labor inputs have been excluded from the analysis.

- Supplemental labor costs (fringe benefits) have been excluded from the analysis.

- Capital stocks and capital service prices for each industry and county are defined and measured so as to (1) exclude land, (2) exclude rented assets, (3) meet the constraints of a particular perpetual inventory formula, (4) accommodate inter-censal data gaps, (5) accommodate missing capital expenditure data, (6) presume that the benchmark year of capital accumulation is 1953, and (7) fit a particular concept of the price of capital services, which assumes the cost of money equals the average yield on industrial bonds in 1972, average tax life of assets is 20 years, the average effective corporate income tax rate is constant over industries, the depreciation rate is the average of that used in two other studies, and regional asset prices are estimated crudely from partial components of the Producer Price Index.

- Materials inputs and prices across industries and times were constructed from less than ideal data and (1) assume national industry cost shares apply to all regions, (2) price indices for 38 percent of materials inputs are assumed to hold for all inputs, and (3) the index for 1958 to 1972 rests on regional prices only through 1963.

- Equilibrium output prices are estimated as a Cobb-Douglas unit cost function using components of the Producer Price Index which crudely match the specific industry, a variety of functional forms, and input prices and time as independent variables. Regional variation was not introduced into the output price estimates.

- Air pollutant and climatological variables, by county, were used, after correcting for missing data, by inserting mean values. Only the second average high measurement is used for TSP.
- Quadratic and interaction terms involving air pollution and climate variables were excluded in the cost estimations with stable partial derivatives of total cost.
- Benefits are calculated for each county for each year from 1978 to 2050 discounted at a 10 percent discount rate, and aggregated up to obtain a national total. The reduced estimated cost function without the SO_2 variable was employed and output forecasts for the larger SIC industry of which this industry is a part were obtained from the Wharton model.

Given this set of assumptions and imposed procedures, the question of the plausibility of this dominant estimate of pollution control benefits must be answered. While, in some sense, it is not an extraordinary figure, there are substantial reasons for doubting its accuracy -- its magnitude relative to that of other industries, the fact that it applies only to corrosion and soiling damages (in a context in which SO_2 was found to be statistically insignificant), and the fact that the benefits of achieving the secondary standards are 2.6 percent of production costs when total expenditures in this industry on maintenance and repair equal 2.9 percent of total payroll. While this estimate appears to be among the most implausible of those reported in the study, it is also the largest and the dominant contributor to the overall assessment of the benefits of achieving an improvement in air quality. However, having said this, it would not be surprising if many of the same kinds of concerns would surround other components of the estimates were they to be given close scrutiny. As to plausibility, then, I assign a B-, but with a large standard error.

After all this, then, what can be concluded? The report is an ambitious effort to tackle a question which may be empirically intractable given the current state of data. It rests on a firm theoretical underpinning, and data collection and modeling has been vigorously guided by appropriate, state of the art econometric techniques. The data has been gathered carefully and analyzed vigorously. The interpretation of results is somewhat unsettling in that more confidence is placed in estimates than they appear to warrant. More sensitivity analysis should have been done and displayed. And, while the reported results are not unreasonable, it is difficult to say that they are reliable point estimates. A doubling of some of them or a halving of all of them, or the placement of values where none were assigned would not make them more or less plausible. They are, nevertheless, the most comprehensive available -- and their dependence on state-of-the-art theory and empirical techniques makes them uniquely defensible.

Comments by Allen V. Kneese on
Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates

EPA, July 1981

My general impression is that this document reports on a very competent piece of research. In general, its important strong points are:

(a) The analyses take account of the fact that man can adapt to pollution situations. Most other studies do not do this.

(b) The analysis is based on appropriate, carefully developed, economic models.

(c) The empirical work is technically sophisticated and sound.

(d) The report is very well written.

I do, however, have a number of questions and doubts (these are not in order of priority).

(a) The study accepts the legalistic fiction that primary standards completely protect against health effects. This is most likely not true and starting from this premise could seriously bias the interpretation of the study's results.

(b) It counts no benefit for maintenance of high quality air in areas which already have air as good as, or better than, the secondary standards. This could be a substantial source of downward bias, especially in rapidly developing areas of the west.

(c) This is not a fault of the research under review but, it should be noted, it excludes categories of benefits that may be much larger than the ones included -- these may include health, aesthetic, and nonuser benefits.

(d) Despite the claim that it does not include acid effects, the study did implicitly do so. The statement is frequently made in the report that SO_2 does this or does that, where in fact, it is not SO_2, but the actual damage often results from SO_3 and H_3SO_4.

(e) This leads to an instance of what may be a rather general deficiency in the report -- inadequate attention to the use of prior knowledge in the specification of estimation equations. For example, SO_2 and NO_2 may be highly correlated precursors of H_3SO_4 and HNO_3. In some areas HNO_3 may be a large source of acid damage. If HNO_3 is not included, some of its actual effects might be picked up by the sulfur variable. I understand that there are data problems, but specification issues are potentially so serious that I think they need greater attention in the report.

(f) Another general matter is aggregation of variables to the county level. I think more systematic treatment of what this means both conceptually and empirically is needed. For example, in the industry studies, can the county level data take adequate account of such potentially important factors as technological design of equipment, plant layout, degree of vertical integration, etc.? Given the aggregation and crudity of data, can much credence be given to the small effects found, even though in the formal statistical sense they are "significant"?

A few more specific comments:

(a) On the household studies -- others have concluded from surveys that people do not alter their cleaning behavior when there is more pollution, but simply live in dirtier surroundings. Since the disutility experienced because of this cannot be captured by the method used in the study, a large benefit may be missed.

Second, since the available measures of atmospheric pollution are often poor reflections of actual ambient conditions, and since the exposure of home furnishings and equipment occurs indoors, it is hard to see how there could be any real connection between those measures and damage to household items.

(b) On the manufacturing study, I have already mentioned problems that might be associated with county-level aggregation. But cost differentials may be more complex than the study appears to recognize. Hoch has found systematic wage differentials between large and small cities for what he took to be all sorts of environmental reasons (e.g., traffic congestion, long commuting times, crime, high levels of pollution). If SO_2 correlates highly with city size, might not these analyses be attributing cost differentials to SO_2 than actually related to other things also? I realize that pollution and wages were controlled for, but it may be that other "urban phenomena" also affect costs. This might be tested by including some sort of an urbanization variable.

(c) Utilities -- one might think they would be more affected by their own pollution than by air ambient condition possibly measured some distance away.

APPENDIX C

Comments from the American Iron and Steel Institute

STATEMENT

OF

EARLE F. YOUNG, JR.

VICE PRESIDENT

ENERGY AND ENVIRONMENT

AMERICAN IRON AND STEEL INSTITUTE

AT

EPA PUBLIC MEETING

ON

"BENEFITS ANALYSIS OF ALTERNATIVE SECONDARY NATIONAL AMBIENT AIR QUALITY STANDARDS FOR SULFUR DIOXIDE AND TOTAL SUSPENDED PARTICULATES"

BY

MATHTECH INC.

JULY 28, 1981

My name is Earle Young. I am Vice President, Energy and Environment for the American Iron and Steel Institute. AISI is a trade association whose 65 domestic member companies account for 91% of the nation's steel producing capability. I am extremely gratified to have this opportunity to present some comments relative to a technical report containing benefit analysis methodology related to the National Ambient Air Quality Standards.

AISI has long been an advocate of the use of cost benefit analysis in the area of environmental regulations. In our major policy statement, "Steel at the Crossroads: The American Steel Industry in the 1980s," published in January 1980, AISI said in discussing the Clean Air Act: "All welfare related requirements should, at a minimum, be subject to rigorous cost benefit analyses and local options." Therefore, the report being discussed today, "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates," is of great interest to us.

The steel industry is very familiar with the cost side of the cost benefit considerations in the steel industry. Just today, we have released a report by Arthur D. Little, Inc., entitled "Environmental Policy for the 1980's: Impact on the American Steel Industry" which shows that the steel industry has already in place $5 billion dollars worth of equipment (in 1980 dollars) to control air pollution and will in the next few years be spending another $1.3 billion essentially to achieve the present primary standards. That report also shows that if the industry is forced to make additional expenditures directed at attainment of the secondary standards it will have to spend by the end of this decade another $3.8 billion. Thus, we do have what we consider is a good estimate of the costs of achieving the secondary standard for particulate.

The other half of the cost benefit consideration is evaluation of the benefits. The steel industry has long recognized that it is much more difficult to evaluate the benefits of achieving air quality standards than to estimate the costs. Therefore, we welcome efforts to develop a quantitative methodology which will put those benefits on some sort of a sound, realistic basis.

Since the primary pollutant emitted by the steel industry and the one we have spent and will spend the greatest amount of money to control is total suspended particulates, we were particularly interested in that portion of this report dealing with the particulate standard.

A quick analysis of the report showed that it indicates a total benefit value of about $18 billion dollars for achieving the secondary standard for total suspended particulate, of which $16 billion can be attributed to benefits in reduced costs to the manufacturing sector. By a complex mathematical analysis, the contractor has developed a relationship which indicates that manufacturing costs, particularly in the metal fabricating and machining industries, are higher where suspended particulates in the air are higher.

The mathematics involved are quite sophisticated. AISI does not have the expertise internally to comment on them. Therefore, we have requested an outside expert to review and comment on the methodology and mathematics. Following my presentation, Dr. Dale Denny of ERT, Inc., will present a more detailed analysis of the methodology.

A major point that I would like to make, however, is that the contractor's report makes no attempt to distinguish between correlation and causation. It is not particularly surprising to me that manufacturing costs are somewhat higher in areas where the total suspended particulate content in the air is somewhat higher. Generally speaking, you can expect higher particulate levels in the air in concentrated urban areas, where there are greater concentrations of people and traffic, where there are older manufacturing facilities, where there tends to be an older, more unionized labor force, and where there tends to be a higher cost of living and higher tax rates. These are exactly the same factors which one would expect to result in higher costs of production. The older plants located in these more polluted areas are precisely the plants which do tend to have higher production costs. Therefore, I repeat, I don't find it surprising that some relationship may be indicated or calculated between production costs and the average level of air pollution in the areas. On the other hand, I see nothing in that sort of correlation which implies causation, nothing that indicates it is the air pollution which leads to these higher production costs. The authors point out deep in Chapter 7 of their text that their findings, "do not prove the existence of a cause and effect relationship."

A well known statistical correlation exists between the stork population and the human birth rate in Rothenstead, England; yet, I haven't believed for a long time that there is a cause and effect relation between stork population and human birth rate. In his classic paper, "Use and Abuse of Regression," George E. P. Box discusses the phenomenon of "nonsense correlation" and discusses "regression variables and latent variables" and points out that regression coefficients can be "utterly misleading."

Yet, the entire statement of benefits, the attribution of a value of $16 billion as a benefit attributable to the attainment of secondary standards, depends on the existence of such a cause and effect relationship.

Thus, we are seriously concerned that the methodology used in this study has resulted merely in an apparent correlation and that, in the interpretation of the study, that correlation will be construed as causation. Benefits could be attributed to the secondary standards which, in truth, do not in any factual sense relate to the attainment of those standards.

We ask that you give very serious consideration to this question of correlation versus causation before any use is made of the potentially misleading results generated in this study.

I would now like to introduce Dr. Dale Denny of ERT who will present a critique of the study and its methodology.

TESTIMONY: A CRITIQUE OF EPA COST BENEFIT ANALYSIS ON SECONDARY AIR QUALITY STANDARDS

ERT Document No. P-B129

Prepared for
American Iron and Steel Institute
1000 16th Street, N.W.
Washington, D.C. 20036

Environmental Research & Technology, Inc.
601 Grant Street, Pittsburgh, PA 15219

July 28, 1981

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INTRODUCTION

My name is Dr. Dale A. Denny. I am Senior Program Manager with the Environmental Engineering Group of Environmental Research and Technology, Inc. (ERT). I was formerly a technical manager in the U.S. Environmental Protection Agency, Office of Research and Development. I and my colleagues at ERT have reviewed the subject contractor report, "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulates" and wish to offer comment on the study and its conclusions. The focus of our comments are on the parts of the report that address information from the Manufacturing Sector, Volume 3, Section 7 and Volume 5, Section 10. Six 3-digit SIC categories are evaluated in the Manufacturing Sector, but our emphasis addresses SIC 344 (Fabricated structural metal parts).

We appreciate the difficult task that faced MATHTECH, Inc. in its assignment; we recognize that they have tried to make use of state-of-the-art econometric models, but we seriously question whether or not this modeling approach properly fits into this benefits analysis. The contractor has used a multiple regression technique with the premise that there is a correlation between air quality and costs of production in the manufacturing sector. There is no evidence to display this relationship on a cause-and-effect basis, and we believe the contractor is aware of this lack. However, the report concludes that, in spite of a lack of knowledge of cause-and-effect, there is a positive correlation between production costs and air quality and then assigns dollar benefits to the air standard on the basis of this correlation. We do not believe that the contractor has shown the confidence that one can assign to this correlation, nor has he shown the uncertainty that accompanies the use of his production cost model in calculating marginal costs due to incremental changes in air quality. Until these state-of-the-art, unproven econometric models have been otherwise verified, we do not think that the models can be used and extrapolated to calculate benefits on a national scale. Fundamentally we also have serious problems with (1) the contractor's choice and manipulation of data bases for the study and

(2) the contractor's efforts to achieve a solvable regression and to demonstrate the mathematical significance of his results. Unless and until the EPA and its contractor can resolve adequately these reservations, we question the technical significance of MATHTECH's report as a basis for assigning any quantitative measure of benefits to attainment of the secondary air quality standards. We believe that when the EPA and its contractor take into account fully the variability in the data as employed in the subject study and express accurately the standard errors in final study results, no statistical significance will be evident.

What follows is a discussion of specific problems we believe cast serious question on the usefulness of the study results. Remarks focus first on the contractor's premise and choice of data bases. Comments are then directed to the contractor's regression modeling. Finally, comments are made regarding the statistical significance of the contractor's findings.

CONTRACTOR'S PREMISE AND CHOICE OF DATA BASE

The contractor's basic premise is that (1) a statistically significant portion of the variability in national statistics on SIC 344 manufacturing costs can be explained by variations in ambient SO_2 and TSP air quality (2) such a relationship can be shown to exist at a county-level of aggregation of air quality and manufacturing cost data. There is a large set of factors which is known to contribute to wide variability in measured local air quality levels, e.g., rural vs. urban station readings, proximity of station to industrial vs. other sources (power plants, road dust, cars). There is also a large set of factors which the industry knows contributes to observed variability in member company SIC 344 manufacturing costs, e.g., cost of labor, cost of materials, cost of capital, age of facility and its various process units, geographical location. It was the contractor's challenge either to address these factors and their interpendencies directly, or to demonstrate a procedure for filtering out these dependencies to permit a direct observation of the degree of impact of variable air quality levels on manufacturing costs. We believe that the contractor has inadequately tried the second approach, and has not displayed in his report the data that would demonstrate the many simplifications, and assumptions, that were necessary to make the problem mathematically tractable. In most cases it appears to us that the contractor's efforts addressed questions regarding how to make the mathematics fit the problem rather than the question of the appropriateness of the model and the assumptions for the problem.

Air Quality Data Base

Serious analysts of air pollution and its sources appreciate the local nature of emission impacts on air qualiaty. They also appreciate the difficulty of allocating cause for both the levels and the variability in levels of local air quality to specific sources. Without specific evidence of justification, the contractor has dismissed all of these interactions. He has chosen to aggregate available local air quality data to a countywide level. In so doing, he has largely decoupled the local relationships between emission sources and air quality. The result is an estimate of the average air quality in each county having a SIC 344 facility. The contractor's report does not contain information to evaluate either the representativeness of these averages, or the size of the standard deviations in estimated values.

Manufacturing Cost Data Base

Having chosen the county level for the display of data, the contractor found it necessary to aggregate large amounts of site-specific manufacturing statistics to produce estimates of the manufacturing costs for an average SIC facility. The contractor's view of the difficulties inherent in such a exercise speak for themselves:

> ".....the total cost function is based on the assumption of cost-minimizing behavior on the part of individual firms. It is therefore more appropriately estimated using data on individual firms. However, the data available from the Census of Manufacturing are county totals for all of the firms in each county. To reduce the potential problems introduced by the aggregation of data across firms, we divided total cost, C, and total quantity of output, Q, in each county by the number of establishments, N, in the county. This does not completely solve the problem of aggregation but may reduce its importance.....the cost function is hypothesized to represent the production structure for the "average" establishment in a county." (p7-113, Text)

Again, the contractor provides neither specific indication of the representativeness of his averages for each SIC 344-containing county nor the size of the standard error in his estimates.

CONTRACTOR'S REGRESSION ANALYSIS OF THE DATA

Contractor selection of the county-level as the level of data aggregation yielded a maximum candidate sample size of 124 sets of data (economic and environmental) for regression analysis (Text Table 7-12). When corrected for missing economic data, the sample was reduced to only 57 sets of data. To achieve even this sample size, missing SO_2 and TSP data had to be estimated for 21 and three data sets, respectively.

In its most general form, the contractor's regression model contains 54 coefficients all of which must be estimated on the basis of only 57 sets of data. Even the contractor admits to the impossibility of meaningful analysis with such a mismatch in model complexity and data availability. Through a series of largely unsubstantiated assumptions regarding the actual behaviour of the SIC 344 air quality/cost relationship, the contractor attempts to reduce the complexity of his regression model to one compatible with his meager data base. The result is a regression model with 17 coefficients (Model 4; SIC 344). While most analysts would expect to use many more data sets to reliably estimate such a large number of coefficients, the contractor estimated his coefficients using his meager sample size of 57 data sets.

When fitted with its estimated coefficients, the contractor regression model perports to correlate manufacturing costs with a series of variables including air quality. The cost model, by itself, is not central to the benefit analysis. The partial derivitive, a quantity derived by mathematical manipulation of the cost model, with respect to air quality is the critical term upon which further benefit estimates and extrapolations are made. Thus, the contractor must take the mathematical partial derivative of his regression model to arrive at his final model for estimating benefits from air quality improvements. In the case of TSP, the result is an equation for marginal total cost of productioin due to changing TSP level (MTCTSP) with only three coefficients. Although we appreciate the mathematical accuracy of the step, the AISI seriously questions whether the available data base justifies such a mathematical manipulation. At a minimum, we note somewhat skeptically that the widely accepted complex problem of air quality benefits analysis has in the end been reduced by the contractor to numerical analysis of a three parameter model! These particular parameters are identified by the contractor as parameters which describe interactions between TSP and labor costs, TSP and material costs, and TSP alone on the MTCTSP.

STATISTICAL SIGNIFICANCE OF THE CONTRACTOR'S FINAL RESULTS

The contractor argues the significance of his results in two ways, (1) by displaying range in his SIC 344 results, e.g., $240 to $410 improvement per microgram of TSP per cubic meter per establishment and (2) by conducting tests on the statistical significance of individual coefficient estimates and on the collection of coefficients in his model. Neither of these procedures represents a full test of the statistical significance of the partial differential or marginal cost portion of his regression model results which are the basis of his calculation on which is based the study conclusions. The range of data for MTCTSP merely represent the results of two modeling calculations made with different assumptions. The statistical testing applies only to individual coefficient data in the cost model rather than the more important marginal cost model. No test, statistical or otherwise, is proposed to give a quantitative measure of the uncertainty in the individual estimates of marginal costs (MTCTSP) for each of the models. A quantitative measure of uncertainty in individual estimates of marginal costs is more relevant for a decision maker forced to make a value judgment on benefits than a display of a range of results from different models.

While the above problems are troublesome, our greatest concern centers on the contractor's procedures, or, more accurately, his lack of procedures for identifying and dealing with uncertainty in his data bases. We are dubious of the merits of any air quality-related analysis which is predicated on county-wide averages of data. However, if the EPA and its contractor wish to postulate such a basis for their data, it is incumbent upon them (1) to provide reasonable estimates of the standard errors inherent in their county-based average values and (2) to propagate these errors to their logical impact on the statistical significance of final study results. We believe that, when properly corrected for the full impact of data base variability, contractor results will show no statistical significance. While the contractor performs no such analysis of significance, his own words seem to suggest his bias toward the possible outcome:

> ".....total cost of production in certain industries are positively associated with local ambient TSP/SO_2 concentrations, after accounting for other sources of cost variation (e.g., input prices, in-place capital, and climate). These findings are, of course, contingent upon the assumptions made in the analysis and do not prove the existence of a cause-and-effect relationship."
> (p. 7-202 Text).

APPENDIX

In critiquing the contractors report we found it helpful to write out the multiple regression models in expanded form and to show explicity the reduced form of the equations for Model 4, SIC 344.

The general regression model in (Equation 7.9 Text)

$$\log C = a_0 + a_i \log P_i + 1/2 \; a_{ij} \log P_i \log P_j$$
$$+ b_0 \log Q + 1/2 \; b_{00}(\log Q)^2 + b_{01} \log Q \log P_i$$
$$+ c_{ij} \log P_i \log Z_j + d_i \log Z_i$$
$$+ 1/2 \; d_{ij} \log a_i \log Z_j + e_{0i} \log Q \log Z_i$$

The 54 Coefficients to be evaluated may be grouped as:

(a) Economic coefficients (18 numbers)

a_0, a_1, a_2, a_3, a_4 and
a_{11}, a_{12}, a_{13}
a_{21}, a_{22}, a_{23}
a_{31}, a_{32}, a_{33} and

$b_0, b_{00}, b_{01}, b_{02}, b_{03}$ where
1 = (labor), 2 = (capital, 3 = (materials)

(b) Economic-environmental coefficients (12 numbers)

$c_{11}, c_{12}, c_{13}, c_{14}$
$c_{21}, c_{22}, c_{23}, c_{24}$
$c_{31}, c_{32}, c_{33}, c_{34}$ where c_{ij}

i = (1, 2, 3) = (labor, capital, materials) and
j = (1, 2, 3, 4) = (SO_2, TSP, TEMP, RAIN)

(c) Environmental coefficients (20 numbers)

d_1, d_2, d_3, d_4 and
d_{11}, d_{12}, d_{13}, d_{14}
d_{21}, d_{22}, d_{23}, d_{24}
d_{31}, d_{32}, d_{33}, d_{34} where d_{ij}

$i,j = (1,2,3,4) = (SO_2, TSP, TEMP, RAIN)$

(d) Size of Firm - Environment coefficients (4 numbers)

e_{01}, e_{02}, e_{03}, e_{04} where

$(1 = SO_2, 2 = TSO, 3 = TEMP, 4 = RAIN)$

The important equation for marginal total cost due to incremental charge in TSP is of the form

$$MTCTSP = (C/TSP)\,({}_i \; c_{i2} \log P_i + d_2 + {}_j \; d_{2j} \log Z_j + e_{02} \log Q)$$

which has 9 coefficients to be evaluated, namely:

c_{12} = (labor, TSP) coefficient
c_{22} = (capital, TSP) coefficient
c_{32} = (materials, TSP) coefficient
d_2 = (TSP) coefficient
d_{21} = (TSP, labor) coefficient
d_{22} = (TSP, TSP) coefficient
d_{23} = (TSP, TEMP) coefficient
d_{24} = (TSP, RAIN) coefficient
e_{02} = (size of firm, TSP) coefficient

For SIC 344, Model 4, the marginal cost equation reduces to a three term expression using data reported in the text (p. 7-214).

$$MTCTSP = \frac{(C)}{(TSP)} \cdot [0.020111 \log P_{labor} - 0.026114 \log P_{mat'ls} + 0.069585]$$

Using as a definition of uncertainty the ratio of the coefficient standard error divided by its value (data from table, p. 7-214 Text), we may estimate that in the above equation, the first coefficient (number) has an uncertainty of about 102 percent, the second coefficient - 90 percent uncertainty, and the third coefficient - 80 percent uncertainty. The contractor does not demonstrate the influence of these uncertainties on the estimation of MTCTSP.

SECTION 13

ANALYSIS OF POLLUTANT CORRELATIONS

SECTION 13

ANALYSIS OF POLLUTANT CORRELATIONS

INTRODUCTION

The sector models estimated in Volumes II through IV of this report include only two measures of ambient air pollution -- total suspended particulates (TSP) and sulfur dioxide (SO_2). Other pollutants, however, may also contribute to the physical effects or behavioral responses analyzed in the models. For example, ozone concentrations are believed to be an important factor in explaining reductions in yield for various agricultural crops [Criteria Document (1)]. Unfortunately, because of data limitations, it was not possible to test whether estimated coefficients for other pollutant measures were significantly different from zero in the model specifications. In many cases, the number of observations would have been reduced to less than ten if data on additional, plausibly significant, environmental variables were employed.

If other pollutants are indeed relevant explanatory variables for the postulated models, then omission of these variables results in a specification error. This has implications for the statistical integrity of the estimated models. In fact, in the case where there is a non-zero correlation between an omitted variable and an included variable, the estimator of the included variable will be biased and inconsistent. The direction of bias in such circumstances depends on: 1) the sign of the correlation between the omitted and included explanatory variables; and 2) the sign of the coefficient of the excluded variable when the "true" regression model is estimated. If these two factors work in the same direction, the bias imparted to the coefficient of the included variable will be positive; otherwise, it will be negative.

Another way to view the problem of multiple pollutants affecting behavioral responses is in terms of proxy variables. That is, inclusion of a single pollutant measure in a specification serves as a proxy for the many pollutants that may affect behavioral decisions. In this case, the statistical issues are better analyzed as an errors-in-variables problem rather than as an omitted variables problem. The implication of adopting such a perspective (i.e., proxy variable) is that the relevant explanatory variable becomes "air quality" and not a specific pollutant. Given that the objective of this study is to determine the benefits associated with particular pollutant standards, individual pollutants and not the generic "air quality" are the desired variables for the various specifications. In fact, the results of physical damage function studies provide support for including specific pollutants in the developed models. As a consequence, empirical estimation of the specifications best proceeds in terms of the pollutants. Thus, we feel it is more appropriate to examine the issue of multiple pollutants as an omitted variables problem.

This section of the report addresses the omitted variables problem by analyzing pairwise correlations between various pollutants. Under the presumption that pollutants other than TSP and SO_2 are relevant explanatory variables in the sector models, the analysis of correlations provides a partial indication of the direction and severity of bias that may be present due to specification error.

ESTIMATION OF CORRELATION COEFFICIENTS

Correlations among the two pollutants included in the sector models of this report (TSP, SO_2), and five pollutants not included in the sector analysis -- nitrogen dioxide (NO_2); carbon monoxide (CO); ozone (O_3); total oxidants (TO_x); and total hydrocarbons (THC) -- are examined in this subsection. The discussion of bias due to an omitted, relevant explanatory variable is based on results derived explicitly for single equation, linear multiple regression models. Although such models are more restrictive than the nonlinear systems methods employed in some sections of this report, similar conclusions with respect to bias can be made. In fact, the problem may be made worse, since as Theil (2) notes, a disadvantage of full information systems estimation is that any biasedness and inconsistency problems may be propagated to all equations in the system. Thus, even if only one equation in the system is misspecified, statistical problems need not be limited to the single equation.

Our analysis begins with a general overview of the statistical problems that arise with the omission of a relevant explanatory variable from a regression specification. This is followed by a brief discussion of the source of the air quality data. Finally, results are reported for pairwise correlations between air pollution variables when the variables are defined in three distinct ways. Specifically, correlations are reported for alternative assumptions with respect to the spatial, temporal, and pollutant measurement characteristics of the data. A major conclusion of the analysis is that the degree and direction of bias introduced because of the omission of a relevant air quality variable is sensitive to the forms of the variables used in the analysis. This result highlights the importance of selecting the "correct" measure of air quality for use in benefits analyses.

Statistical Background*

The problem examined here involves the omission of a relevant explanatory variable from a linear, multiple regression model. Assume that the correct specification of an equation is:

$$Y_i = \beta_1 + \beta_2 X_{i2} + \beta_3 X_{i3} + \varepsilon_i \qquad (13.1)$$

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* The discussion in this subsection is taken from Kmenta (3).

but because of lack of data, it is not possible to develop a data series for X_{i3}. Thus, the equation that is estimated is of the form

$$Y_i = \beta_1 + \beta_2 X_{i2} + \varepsilon_i' \tag{13.2}$$

In this case, it can be shown that the expected value of the coefficient β_2 in Equation (13.2) is equal to

$$E(\hat{\beta}_2) = \beta_2 + \beta_3 d_{32} \tag{13.3}$$

where

$$d_{32} = \frac{\Sigma(X_{i2} - \bar{X}_2)(X_{i3} - \bar{X}_3)}{\Sigma(X_{i2} - \bar{X}_2)^2} \tag{13.4}$$

In the case where Equation (13.1) is estimated, the expected value of β_2 is equal to β_2. This is the statistical property of unbiasedness. As can be seen from Equation (13.3), estimation of the misspecified equation (13.2) will lead to a biased estimate of β_2 with the bias equal to $\beta_3 d_{32}$. The purpose of the present analysis is to attempt to define at least the sign of $\beta_3 d_{32}$ so that it is possible to identify the direction of bias.

There are two components to the term $\beta_3 d_{32}$. The first, β_3, represents the marginal effect on Y_i of a small change in X_{i3}. If we think of X_{i3} as some measure of air pollution and Y_i as a variable describing an output that may be affected by air quality improvements (e.g., agricultural yield), then we might generally take β_3 as positive. However, because Equation (13.1) has not been estimated, it is not possible, without outside information, to determine the magnitude of β_3.

The second component of interest is d_{32}. As shown in Kmenta (3), this term represents the coefficient in the linear specification relating the excluded and included explanatory variables. In particular,

$$X_{i3} = d_{31} + d_{32}X_{i2} + \text{residual} \tag{13.5}$$

Note that the coefficient d_{32} in a regression specification like (13.5) can also be stated in terms of the correlation between X_{i2} and X_{i3}:

$$d_{32} = r \frac{SX_{i3}}{SX_{i2}} \tag{13.6}$$

Here, r is the simple correlation between X_{i2} and X_{i3}, SX_{i3} and SX_{i2} are the standard errors of X_{i3} and X_{i2}, respectively.

In view of Equation (13.6), if β_3 is different from zero, then estimation of the misspecified (13.2) will lead to an estimator of β_2 that is biased unless d_{32} is zero. That is, unless X_{i2} and X_{i3} are uncorrelated. If β_3 and d_{32} have the same sign, then the bias will be positive; otherwise it will be negative. Note that additional information on SX_{i3} and SX_{i2} would be required before one could assess the magnitude of d_{32}. However, knowledge of the simple correlation may help provide a partial indication of the severity of the bias. All else equal, a small correlation will lead to less bias than a relatively high correlation.*

Source of Data

The data used in the calculation of correlations are taken from the SAROAD data base maintained by EPA. The measures of TSP and SO_2 included in our sector analyses also came from SAROAD. Although measures of concentration can be obtained on a daily basis, the data used here represent annual measures. This is consistent with the frequency assumed in the estimation of the sector models. In addition, only those sites meeting EPA's summary criteria for reporting annual averages are included in the correlation analysis of this section. Finally, because of a possible bias in SO_2 data collected by the gas bubbler method, only continuous monitor SO_2 data are included in the correlations reported below. Similarly, no NO_2 data collected via the biased Jacobs-Hochheiser method are included in this analysis.

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* Statistical problems can also arise with a zero correlation between an included and an excluded variable. With zero correlation, the estimator of β_2 is no longer biased. However, the estimator of the variance of β_2 in the misspecified equation will contain an upward bias, so that tests of statistical significance will be overly conservative.

Data were available for the seven pollutants mentioned earlier for each of seven years, 1972 through 1978. The total number of valid site observations by pollutant and year are shown in Table 13-1. Although it would be possible to analyze pairwise correlations as a time series across the seven years, all correlations reported here are based on cross-sectional data.

Spatial Variation

For this analysis, we focus on three factors that help define the air quality variable. These included the attributes of time,

Table 13-1

COUNT OF AVAILABLE SITE OBSERVATIONS FOR CORRELATION ANALYSIS

Year	Pollutant						
	TSP	SO_2	NO_2	CO	O_3	TO_x	THC
1972	2,172	1,356	53	323	1	62	40
1973	2,294	1,874	95	429	19	67	50
1974	2,634	2,824	685	606	81	68	21
1975	2,702	3,138	964	676	138	57	59
1976	3,105	3,644	1,162	733	207	23	67
1977	3,133	3,482	1,000	734	232	26	59
1978	3,003	2,498	783	715	247	18	50

location, and measurement type. In this section, we assume that the time and pollutant measurement factors are fixed, and analyze the impact of changes in spatial definition on the pairwise correlations. The locational identifiers examined include sites, counties, and Standard Metropolitan Statistical Areas (SMSAs). For this analysis, the time period is fixed at 1978 and all correlations are reported for annual arithmetic means.

The data reported in Table 13-1 are site data. This represents the most disaggregate data in terms of location currently available. Each site is identified by a 12-digit identification code. Observations are included in the analysis of pairwise correlations only if data are available for both pollutants at a given site.

The second level of spatial aggregation is the county. Air pollution statistics at the county level were evaluated in three ways. First, the arithmetic average of readings from all sites in the county were calculated. Second, the maximum across all sites in the county was recorded as the indicator of county air quality. Finally, the minimum across all site readings in the county was taken as the air quality index. Although correlations were calculated for each of these ways of forming an index of county air pollution, only the correlations involving the arithmetic means are reported here. Note that the number of observations at the county level can exceed the number of observations in the analysis of site data since different sites in a county may monitor different pollutants.

The final level of aggregation was to the SMSA level. Since SMSAs are groups of contiguous counties, the SMSA air quality index was formed in a manner equivalent to that described for the site-to-county aggregation. In particular, indices reflecting average, maximum, and minimum of county readings were developed. As with the county data, the SMSA data reported here represents the arithmetic average of county parts.

Note that correlations at the SMSA level are reported only for the 24 SMSAs used in the household sector analysis of Volume II. This limitation was imposed only in the interest of reducing the scope of the analysis.

Results of the correlation analysis for the three levels of spatial aggregation are shown in Tables 13-2 and 13-3. The tables show the correlations between TSP and the other pollutants, and SO_2 and the other pollutants, respectively.

It is difficult to draw specific conclusions from the correlations reported in these tables. First, the correlation coefficient by itself does not provide sufficient information to determine the possible magnitude of bias due to an omitted variable. Second, no information is provided in the tables as to the statistical significance of the reported correlations.

Table 13-2

CORRELATION COEFFICIENTS FOR 1978 ANNUAL ARITHMETIC MEANS OF TSP AND OTHER POLLUTANTS FOR DIFFERENT LEVELS OF SPATIAL AGGREGATION

Area	Pollutant					
	SO_2	NO_2	O_3	CO	TO_x	THC
Site	0.521	0.450	-0.037	--	0.486+	0.648
County	0.117	0.373	-0.075	0.082	0.657+	0.611*
SMSA	0.020*	0.432*	0.141*	0.586*	--	0.291+

Table 13-3

CORRELATION COEFFICIENTS FOR 1978 ANNUAL ARITHMETIC MEANS OF SO_2 AND OTHER POLLUTANTS FOR DIFFERENT LEVELS OF SPATIAL AGGREGATION

Area	Pollutant					
	TSP	NO_2	O_3	CO	TO_x	THC
Site	0.521	0.554	--	--	--	--
County	0.117	0.285	-0.084	-0.058	0.991+	0.046*
SMSA	0.020*	-0.266*	0.048*	-0.108*	--	-0.693+

* 15 to 30 observations.

\+ 3 to 14 observations.

-- Less than 3 observations.

With respect to the latter observation, note that if the pollution measures are normally distributed random variables, a test statistic of the form

$$t^* = \frac{r_{12}\sqrt{n-2}}{\sqrt{1-r_{12}^2}} \qquad (13\text{-}7)$$

follows a student-t distribution with (n-2) degrees of freedom.* In Equation (13-7), r_{12} represents the pairwise correlation and n is the number of observations. For t^* greater than the critical value (given a significance level), the null hypothesis of no correlation would be rejected.

A plot of the frequency of concentration intervals indicates that the pollution data tend to follow a log-normal distribution. Consequently, the test statistic in Equation (13-7) is more properly applied to a logarithmic (base e) transformation of the original data. This transformation was made for the 1978 county annual arithmetic mean data and correlations computed. The results are recorded in Table 13-4. Except for the logarithmic transformation, the definition of the variables in Table 13-4 is equivalent to the middle rows of Tables 13-2 and 13-3. Table 13-4 shows that at the 5 percent level of significance (two-tail test), we fail to reject the null hypothesis of

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* See Neter and Wasserman (4), p. 4Ø5.

Table 13-4

SIGNIFICANCE OF CORRELATION COEFFICIENTS FOR
1978 COUNTY ANNUAL ARITHMETIC MEANS

	SO_2	NO_2	O_3	CO	TO_x	THC
TSP With:						
r_{ij}	0.168	0.423	-0.074	0.130	0.490	0.587
n	221	335	156	144	7	29
$t^*_{(n-2)}$	2.52*	8.52*	-0.92	1.56	1.26	3.77*
SO_2 With:						
r_{ij}	0.168	0.425	0.025	-0.127	0.997	0.214
n	221	124	89	99	3	20
$t^*_{(n-2)}$	2.52*	5.19*	0.233	-1.26	12.88*	0.929

* Significantly different from zero at the 95 percent level of two-tailed t-test.

no difference for 1) TSP with CO, TO_x, and O_3; and 2) for SO_2 with CO, THC, and O_3.

A comparison of the middle-row correlations in Tables 13-2 and 13-3 versus the correlations in Table 13-4 illustrates that the mathematical form of the data represents another way in which the variables may be characterized. Additional application of the significance test of the correlation coefficient will be presented in the discussion of the specific Mathtech sector models.

A qualitative observation can also be made with respect to the variation in the reported correlations. From the tables, it is clear that both the magnitude and sign of the correlation coefficient are sensitive to the level of spatial aggregation. For example, in one case, the correlation is positive at the site and county level, but negative at the SMSA level. Thus, for any given study, the definition of geographical unit may be an important element that influences the magnitude and direction of bias introduced because of a misspecified equation.

Temporal Variation

Tables 13-5 and 13-6 show the pairwise correlations found at the county level for three distinct years. The statistical measure for each pollutant is the annual arithmetic mean. Table 13-5 reports the correlations between TSP and the other six pollutants, while Table 13-6 records the correlations between SO_2 and the other pollutants. The calculation of correlations for different years was done to check the stability of the measure across time. This can be important information for time series, cross-section models or in those cases where there is some flexibility in the choice of data from a specific year.

Table 13-5

CORRELATION COEFFICIENTS FOR ANNUAL ARITHMETIC MEANS OF COUNTY LEVELS OF TSP AND OTHER POLLUTANTS FOR THREE YEARS

Year	Pollutant					
	SO_2	NO_2	O_3	CO	TO_x	THC
1972	0.023	0.206	--	0.058	0.341	0.175
1975	0.388	0.351	0.134	0.175	0.728*	0.609
1978	0.117	0.373	-0.075	0.082	0.657*	0.611*

Table 13-6

CORRELATION COEFFICIENTS FOR ANNUAL ARITHMETIC MEANS OF COUNTY LEVELS OF SO_2 AND OTHER POLLUTANTS FOR THREE YEARS

Year	Pollutant					
	TSP	NO_2	O_3	CO	TO_x	THC
1972	0.023	0.339+	--	0.201	0.219+	-0.396+
1975	0.388	0.289	0.037	0.161	0.143+	0.115*
1978	0.117	0.285	-0.084	-0.058	0.991+	0.046*

* 15 to 30 observations.

+ 3 to 14 observations.

-- Less than 3 observations.

As in the tables reporting correlations for different location aggregates, Tables 13-5 and 13-6 show that the correlation coefficients vary across the different years. In general, the correlations are not large in magnitude. However, as noted earlier, this is not sufficient information to determine the magnitude of bias. From the information reported in the tables, it is only possible to address the issue of direction of bias. If the correlation coefficient and the (unestimated) coefficient of the relevant excluded variable have the same sign, the bias is positive; otherwise it is negative.

It is important to reiterate that this discussion of bias depends on the assumption that an excluded variable is a relevant explanatory factor. In the economic models estimated in this report, there are typically no sound economic reasons for believing that one or more pollutants belong in a particular specification. As a consequence, there must be reliance on literature such as that summarized in the Criteria Document (1) to guide the selection of environmental variables. For the soiling, materials damage, and yield reduction effects analyzed in this report, there is evidence that both NO_2 and O_3 may be relevant explanatory factors. For example, NO_2 has been implicated in the fading and yellowing of textiles, while O_3 has been shown to have a deleterious impact on a variety of agricultural crops. Note that if other likely impacts of air pollution, such as health effects and aesthetic impairments, are considered, then each of the seven pollutants looked at here may be expected to be relevant variables in a benefits analysis.

Variations in Pollution Measurement

A third way in which the correlation of air pollution data can be reported is by the statistical measure used to summarize the data. Three such measures are analyzed in Tables 13-7 and 13-8. These are the arithmetic mean, the geometric mean, and the second highest readings. These statistical measures were chosen because they are consistent with the forms typically used in the definition of the ambient air quality standards.

The correlations reported in Tables 13-7 and 13-8 were calculated for combinations of pollutants defined for the same statistical measure. That is, the correlations shown for "arithmetic means" represent the case where both pollutants were measured in this way. Correlations that mixed the statistical measures were calculated but they are not reported here.

As a point of clarification, the arithmetic mean used earlier in defining a county index from site data is a different measure than the arithmetic mean reported in Tables 13-7 and 13-8. In these tables, since the data are defined at the county level, the row labelled arithmetic mean should be interpreted as an arithmetic mean of site data in a county, where the site data are recorded in terms of the

Table 13-7

CORRELATION COEFFICIENTS FOR 1978 COUNTY-LEVEL DATA OF TSP AND OTHER POLLUTANTS FOR DIFFERENT STATISTICAL MEASURES

Statistical Measure	Pollutant					
	SO_2	NO_2	O_3	CO	TO_x	THC
Arithmetic mean	0.117	0.373	-0.075	0.082	0.657+	0.611*
Geometric mean	0.117	0.383	-0.233	0.097	0.324+	0.553*
Second high	0.000	0.214	0.043	0.109	0.576+	0.348*

Table 13-8

CORRELATION COEFFICIENTS FOR 1978 COUNTY LEVEL DATA OF SO_2 AND OTHER POLLUTANTS FOR DIFFERENT STATISTICAL MEASURES

Statistical Measure	Pollutant					
	TSP	NO_2	O_3	CO	TO_x	THC
Arithmetic mean	0.117	0.285	-0.084	-0.058	0.991+	0.046*
Geometric mean	0.117	0.309	-0.278	-0.071	0.955+	-0.120*
Second high	0.000	-0.085	-0.085	0.166	0.751+	0.288*

* 15 to 30 observations.

\+ 3 to 14 observations.

annual arithmetic mean. Similarly, for the row labelled geometric mean, the interpretation is that the data represents the arithmetic mean of site data in a county, where the site data are recorded in terms of the annual geometric mean.

As might be expected, the magnitude and signs of the correlations for the arithmetic and geometric means are similar. Also of interest is the fact that the correlations for the extreme measure, the second high, appear to be generally lower in absolute magnitude. As before, since there is no knowledge of the magnitude of the (unestimated) coefficient for the relevant omitted variable, it is not possible to assess whether this lower correlation translates into a lower bias relative to annual mean measures.

POTENTIAL FOR BIAS IN MATHTECH STUDY

Tables 13-2 through 13-8 report correlations for general assumptions related to time, location, and pollutant measurement alternatives. This was done to facilitate comparisons of correlations when any one of these factors is varied. Clearly, there are many other ways in which each of these factors could be defined and combined to analyze selected pairwise correlations.

In this subsection, the three factors are defined in ways that best represent the underlying structure of the three major economic sector models estimated in this study -- the household, manufacturing, and agricultural models. Correlations are then computed for pairs of pollutants. One of the pollutants selected will be a variable included in the economic model under discussion, while the other pollutant represents an excluded variable for which there is an *a priori* belief that it may be a relevant explanatory variable. As before, the correlations help to identify the likely direction of bias, but more information is required if the magnitude of the bias is to be ascertained. Finally, the statistical significance of the computed correlation coefficients is determined for the manufacturing sector results. This sector was chosen because the air quality data used in the original study (Section 7) are defined in logarithmic terms. Consequently, the transformed data more closely follow a normal distribution and the test statistic in Equation (13-7) can be applied.

Household Sector

The estimation of demand systems in the household sector model is based on SMSA-level data from 1972 and 1973. The measures of TSP and SO_2 included in the reported specifications are maximum second high values.

One of the demand equations for which SO_2 is a relevant variable is the demand for household textiles. Evidence in the Criteria Document (1) indicates that this is to be expected since acids derived from SO_2 can lead to the discoloration and deterioration of fabrics.

In addition, the revised draft staff paper for NO_2 (5) notes that NO_2 has been demonstrated as having deleterious effects on textile dyes, natural and synthetic fibers, metals, and various rubber products. As a consequence, there is reason to consider NO_2 as a plausible explanatory variable in the demand equation for textiles.

Correlations for both 1972 and 1973 are calculated. Because both SO_2 and NO_2 observations are limited to data collected by current pollutant reference methods, less than ten observations are available in each case. Note that the correlation analysis described here is appropriate for single equation, multiple regression models only. Since the household sector analysis estimates systems of nonlinear demand relations, more complex methods are required to determine the actual impact of omitting a relevant variable from the demand specifications.

Table 13-9 lists the correlations between SO_2 and NO_2 in 1972 and 1973. The geographic unit is the SMSA. Since the household sector model used the maximum of the second highs for all sites in an SMSA, this is the measurement unit of SO_2 in the correlation analysis. This measure is then correlated with the maximums of the arithmetic mean, the geometric mean, and the second highs for NO_2.

In the context of the omitted variables problem, the correlations reported in Table 13-9 indicate that if NO_2 is a relevant explanatory variable, then omission of the variable would likely impart a positive

Table 13-9

CORRELATION OF SO_2/NO_2 FOR HOUSEHOLD SECTOR STUDY, 1972 AND 1973

	SO_2 - Maximum Second High	
	1972*	1973**
NO_2 Arithmetic Mean	0.320	0.530
NO_2 Geometric Mean	0.350	0.480
NO_2 Second High	-0.087	0.375

* Correlations calculated from five observations.

** Correlations calculated from seven observations.

bias to the estimator of the coefficient for SO_2 in the textile demand equation. This occurs because the correlation coefficient is positive in all but one case. In turn, this implies that the benefits associated with specified changes in SO_2 would be overstated. This result is independent of the three measurement types shown in Table 13-9 for 1973. However, if the appropriate NO_2 measure is the maximum of second high readings, then the data indicate that in 1973 there would be an underestimate of benefits. Thus, the direction of bias is sensitive to the measurement method and year of data assumed.

Although it is possible to deduce the direction of bias, it is not possible to assess the magnitude of bias without additional information. It should be stressed that the discussion of bias rests on the assumption that NO_2 is a relevant explanatory variable.

Manufacturing Sector

The various cost equations estimated in the manufacturing sector were based on county-level data for 1972. The basis for including measures of air pollution in the cost specifications was to test the hypothesis that ambient levels of air pollution increase costs of production for specific industries. On the basis of the analysis conducted in Section 7, measures of TSP or SO_2 were relevant explanatory variables in several of the 3-digit SICs that were analyzed.

As noted above, NO_2 can have a damaging effect on a variety of materials that may be instrumental in production processes. In particular, NO_2-related damage to metal products may be an important element in increased production costs. Thus, there is reason to believe that NO_2 may be a relevant variable in the cost equations.

Table 13-10 reports county-level correlations for 1973 between SO_2 and NO_2 as well as between TSP and NO_2. Observations were drawn from the valid SAROAD data and not limited to those counties covered by the manufacturing sector analysis. In the manufacturing sector analysis, the TSP and SO_2 measures were defined as a logarithmic transform of the arithmetic averages of the second high readings across sites in a county. This is the pollutant measurement index

Table 13-10

CORRELATIONS FOR SO_2/NO_2 AND TSP/NO_2 FOR

MANUFACTURING SECTOR STUDY, 1973

	NO_2 Arithmetic Mean	NO_2 Geometric Mean	NO_2 Second High
SO_2 - Second High			
Correlation	-0.249	-0.179	-0.082
Observations	22	22	22
t^*	-1.15	-0.81	-0.37
TSP - Second High			
Correlation	0.408	0.375	0.438
Observations	54	54	54
t^*	3.22*	2.92*	3.51*

* Significantly different from zero at the 5 percent level of the two-tailed t-test.

used in the correlation calculations shown in Table 13-10. Because the logarithmic transformation is approximately normally distributed, the test statistic of Equation (13-7) is used to ascertain the statistical significance of the correlations in Table 13-10. The results of this test are also shown in the table.

Each of the correlations between SO_2 and NO_2 are negative. However, the significance test indicates that we cannot reject the null hypothesis that these correlations are zero. Thus, one can infer that omission of NO_2 as an explanatory variable in the manufacturing sector analysis may not lead to bias in the estimated coefficient for SO_2. There are three caveats to this conclusion. First, the correlations are computed from a sample that differs from the one used in the manufacturing sector analysis. Second, prior information and empirical testing must be undertaken before a specific form for NO_2 can be considered as the appropriate variable in the "true" regression. Third, the correlation test is really only appropriate for single equation multiple regression models.

With respect to TSP, the positive correlations observed in Table 13-10 for all averaging times indicate that the estimator of the coefficient for TSP may be biased upward if NO_2 concentrations contribute to an increase in production costs. Thus, benefits for a specific reduction in TSP could be overestimated. In this case, the statistical tests of significance indicate that the correlations are significantly different from zero. However, the caveats mentioned above apply here as well.

Agricultural Sector

The estimation of yield equations for soybeans and cotton in Section 9 was based on county-level agricultural, economic, and air quality data from 1974 to 1976. The air quality data used in the analysis were data from the second quarter, rather than annual data.

This was done to better match the air quality readings to the time period when the crops were likely to be most susceptible to air pollution-related damage. Because of data limitations, only measures of SO_2 were included in the yield specifications reported in Section 9.*

There exists a good deal of evidence from laboratory and field studies that elevated levels of ozone may be a significant contributing factor to damage for a variety of crops -- including soybeans and cotton. Thus, exclusion of ozone from the yield equations may lead to a specification error.

An analysis of the correlation between ozone and the SO_2 data used in the agricultural study required the collection of air quality data different from that used earlier. In particular, quarterly data were required for ozone to be consistent with the measure of SO_2 used in the agricultural study. These data were obtained from the SAROAD data base for the second quarters of 1974-76 for a variety of averaging times. The sample was limited in that data were collected only for 47 counties included in the agricultural analysis of cotton. Time and resource constraints precluded the acquisition of a more general data base for this correlation analysis. Even with the restricted sample, not all counties had data available for both pollutants in each of the years. However, because three years (one

* TSP was not considered to be an appropriate explanatory variable for the yield equations. However, other pollutants may effect yield.

quarter per year) of data were available, the sample size for the correlations is greater than 30.

Table 3-11 reports the correlations between ozone and SO_2. The diversity of signs and magnitudes for the various pollutant measurements shows the sensitivity of results to the choice of pollutant measurement. This reinforces the conclusion that caution must be exercised in an analysis of the omitted variables problem. The sensitivity of the correlation coefficients to specific assumptions about the form of the excluded variable cannot be ignored.

Table 3-11

CORRELATIONS OF SO_2/O_3 FOR AGRICULTURAL SECTOR STUDY -- QUARTERLY DATA 1974-76

SO_2	Ozone			
	Average Second High	Maximum Second High	Average Arithmetic Mean	Maximum Arithmetic Mean
Average Second High	-0.201	-0.176	-0.085	-0.160
Maximum Second High	-0.380	-0.315	-0.328	-0.375
Avg. Arithmetic Mean	0.250	0.312	0.291	0.295
Max. Arithmetic Mean	0.188	0.233	0.204	0.194

SUMMARY AND CONCLUSIONS

A possible source of bias in the benefits estimates reported in this study relates to statistical problems associated with misspecification of the economic models. The particular issue addressed in this section involves the extent to which omission of potentially relevant environmental variables in the models may lead to such a bias. Under the assumption that pollutants other than TSP and SO_2 are relevant explanatory variables in the economic models, the relevance of the bias issue is evaluated through an analysis of pairwise correlations.

Such an analysis is limited in its usefulness. Although a non-zero correlation implies that some bias is introduced by omitting a relevant variable, it is not possible to identify either the magnitude or the direction of bias without additional information. In particular, knowledge is required of the expected sign and magnitude of the coefficient of the excluded variable in the (unestimated) "true" regression. In most cases, it is possible to specify the sign of the coefficient with some confidence so that the direction of bias can be identified for specific assumptions about the definition of the included and excluded variables. As the analysis in this section shows, the definition of the variables is a crucial element that cannot be overlooked.

The key question considered in this section is: Are the benefit estimates developed in Volumes II through IV of the study biased because only measures of TSP and SO_2 are considered in the estimation process? With currently available information, it is not possible to say with any confidence whether the bias will be positive or negative, large or small. Any combination of these outcomes is a possibility. However, we have shown that in several instances it is not possible to reject the null hypothesis that the correlations are zero. In such cases, the possibility of bias introduced through the omission of a relevant explanatory variable is reduced.

Despite this negative conclusion, there are several positive aspects to the analysis in this section. First, the analysis makes apparent the sensitivity of the correlations to assumptions about the implied temporal, spatial, and pollution measurement definitions for a given variable. With respect to studies involving environmental variables, this result has not always been explicity recognized.

The second area where valuable information has been generated relates to the size of the correlation coefficients reported in this section. The conventional wisdom is that very high correlations exist between pollutant types so that inclusion of more than one pollution variable in a regression specification will likely result in a high degree of multicollinearity.* If multicollinearity is present, this

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* Note that a high level of correlation between two explanatory variables is a sufficient but not necessary condition for the presence of a high degree of multicollinearity when the number of explanatory variables in the regression model exceeds two. See Kmenta (3), p. 384.

can lead to inflated standard errors, and hence, overly conservative tests of statistical significance.

In general, the correlations reported in this section tend to be lower than expected, with most being less than Ø.5Ø. This can be contrasted with correlation estimates in the benefits literature of Ø.7 to Ø.8 between TSP and SO_2 [see, for example, Crocker (6)]. However, extreme caution must be exercised in making comparisons across studies. Again, the magnitude and sign of the correlations is very sensitive to the definition of the variables. For example, Table 13-2 shows that the correlation between TSP and SO_2 is Ø.521 (annual arithmetic mean) when computed across sites in 1978. This is close to the values reported elsewhere in the literature. On the other hand, if the geographical unit is the county or the SMSA, the correlation between TSP and SO_2 falls to Ø.117 and Ø.Ø2, respectively. Thus, much like the case of omitted variables, multicollinearity may or may not be a serious statistical problem, depending on the units of the variables included in the specification. This implies that emphasis should be given to the identification of the most appropriate form of the explanatory variables, with the choice based on a combination of theoretical and empirical criteria.

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SECTION 14

SUMMARY OF MANUFACTURING SECTOR REVIEW

SECTION 14

SUMMARY OF MANUFACTURING SECTOR REVIEW

INTRODUCTION

In July 1981, a public meeting was held to review a draft version of Volumes I through V of this report. Participants in the meeting included a panel of experts in environmental benefits analysis, assembled to critically review the report. In the review of the manufacturing sector analysis in Volume III, the general conclusion at the meeting was that the analysis was a careful and sophisticated piece of research. Specific positive and negative features of the study were identified. Section 12 contains a summary of the comments from the panel and audience.

One suggestion of the review panel was that additional investigation of one of the manufacturing industries be undertaken. The industry of interest was SIC 344, the Fabricated Structural Metal Products industry. The draft analysis had suggested that production costs in that industry were adversely affected by high levels of ambient particulate matter (PM) concentrations. The analysis also suggested that reducing PM concentrations could lead to significant economic benefits for this industry ($3.7 billion discounted present value for attainment of the TSP secondary standard). The panel recommended that further effort be made to evaluate the plausibility of this result. Two specific tasks were undertaken in response to this suggestion. These included interviews with some plant managers in the industry and re-evaluation of the draft analysis. The results are summarized in this section.

INFORMAL PLANT INTERVIEWS

During the course of the study reported in Section 7, telephone contact was made with a small number of companies to see if additional evidence could be obtained concerning the plausibility of the results for SIC 344. As summarized in Section 7 (see pp. 7-190 through 7-192), two metal fabricating companies and one air filtration system manufacturer were contacted. They suggested several ways in which dust or particles might affect metal fabricating operations. These included contamination of welding operations, power sources, and electronic equipment; and contamination or corrosion of metal inventories. These were suggested as possibilities, but no specific documentation or quantitative evidence was obtained.

Following the public meeting, a small number of additional companies in SIC 344 were contacted. As with the previous contacts, the interviews were informal and unstructured. However, some of the interviews were conducted in person, as well as by telephone, and three geographic areas were included to provide some variation in ambient TSP concentrations. The three geographic areas included Denver, Seattle, and Philadelphia. The ambient TSP concentrations in these three areas and the other areas included in the draft analysis are identified in Table 14-1.

There were originally three objectives to the additional interviews. These included: 1) obtaining qualitative evidence of damage and/or behavioral adjustments due to PM deposition; 2) determining whether plant managers perceived ambient PM deposition as affecting either their production processes or their production costs; and 3) estimating the potential impact of PM deposition on production costs. The third objective proved very difficult to accomplish from interviews and thus effort was focused primarily on the first two.

Questions asked during the interviews sought to identify how plants in SIC 344 might be affected by particulate matter. A list of possible effects compiled prior to the interviews is provided in Table 14-2. The first column in the table identifies some of the possible physical effects which PM may have on SIC 344 plants. The second column suggests some of the ways in which plant managers may respond to the physical effects (in addition to the option of not responding in any way). The third column identifies the economic consequences of the different responses. Questions asked during the interviews attempted to determine whether any of the listed physical effects had

Table 14-1

COUNTIES USED IN THE DRAFT ANALYSIS FOR SIC 344

State	County	TSP*
Alabama	Jefferson	336.8
California	San Francisco	109.0
Colorado	Denver	325.2
Connecticut	Fairfield	132.2
Connecticut	New Haven	176.1
District of Columbia		325.0
Georgia	Fulton	134.0
Illinois	Cook	213.3
Louisiana	E. Baton Rouge	130.0
Louisiana	Orleans	122.5
Maryland	Baltimore (City)	210.3
Maryland	Baltimore (County)	154.5
Massachusetts	Bristol	102.5
Massachusetts	Hampden	142.3
Massachusetts	Middlesex	160.0
Massachusetts	Worcester	257.3
Michigan	Wayne	231.1
Minnesota	Hennepin	168.0
New Jersey	Bergen	181.8
New Jersey	Union	161.3
New York	Bronx	188.1
New York	Erie	166.0
New York	Queens	174.5
New York	Suffolk	117.5
New York	Westchester	124.5
Ohio	Hamilton	168.3
Ohio	Stark	144.8
Pennsylvania	Allegheny	235.0
Pennsylvania	Berks	178.6
Pennsylvania	Lackawanna	251.5
Pennsylvania	Philadelphia	206.0
Rhode Island	Providence	138.3
Texas	Dallas	196.3
Texas	Harris	159.3
Washington	King	129.7
Wisconsin	Milwaukee	195.0

* Second highest 24-hour concentration in 1972, average across all monitors in county.

Source: See Section 2.

Table 14-2

POSSIBLE EFFECTS AND RESPONSES TO PARTICULATE MATTER IN SIC 344

Physical Effect	Plant Response(s)	Economic Effect ($)
Contamination of welding joints	Install dust control systems	Cost of installing & maintaining dust control equipment
	Clean metal before welding	Cost of installing & operating metal cleaning equipment
Contamination of metal inventories	Store inventories in covered or indoor areas	Cost of storage facilities
	Maintain smaller inventories	Loss of quantity discounts on purchased metal due to smaller quantities purchased
		Production bottlenecks
	Purchase coated metals	Higher metal cost
	Clean metal before use	Cost of metal cleaning
Contamination of finished or semifinished products	Store produce inventories in covered or indoor areas	Cost of storage facilities
	Maintain smaller inventories	Production bottlenecks
		Loss of sales due to "out of stock"
	Apply paints or coatings to products	Cost of painting & coating
Contamination of other equipment (e.g., optical or magnetic tape readers, transformers, etc.)	Increased maintenance frequency	Higher maintenance cost
	Use of closed or sealed equipment	Higher equipment cost
Contamination of freshly painted surfaces	Install dust control systems	Cost of installing & maintaining dust control equipment
	Utilize clean rooms	Cost of constructing & maintaining clean rooms

occurred and what the plant responses had been. As noted earlier, data on economic factors proved more elusive.

Few of the plant managers perceived PM as producing the physical effects listed in the first column of Table 14-2. This included no reported PM effects on welding operations or painting operations, and little or no physical effect on metal inventories. One plant indicated its product underwent a final cleaning and finishing operation to remove PM and other contaminants acquired during processing or while in inventory. However, it was not clear how much of the PM came from ambient air as opposed to internal plant sources. One other plant indicated a prior problem with dust and soiling caused by ambient PM generated from a nearby highway. This problem was eventually solved by installing double-glazed, non-opening windows and additional air filters.

The minimal perception of PM physical effects by plant managers raised the question of whether PM effects could be perceived even if present. That is, the draft analysis predicted PM would cause small changes in cost and thus PM effects may be present but not observed. For example, the effects of temperature and moisture may be larger than those of PM. Yet, it was found that managers did not respond differently in cities with quite different levels of humidity and temperature (i.e., Denver and Seattle). One advantage of the econometric methods used in the draft analysis is that they can capture both perceived and unperceived effects of PM in the industry (see pp.

7-16 to 7-17). The interviews are likely to reflect only perceived effects.

In addition to the problem of perception, there is also the possibility that prior adjustments made to prevent contamination or corrosion may already have occurred. These adjustments would reduce the extent to which PM effects might currently be observed. For example, several of the plants indicated that they practiced one or more of the activities listed in the second column of Table 14-2. These included the use of coatings on exposed metal surfaces, indoor storage of metal inventories, and surface cleaning before painting or welding. However, it was also indicated that these activities were undertaken for a variety of reasons (e.g., indoor inventory storage for prevention of rust or vandalism). The activities were not attributed exclusively, or even primarily, to ambient PM.

On balance, the overall results of the interviews were inconclusive. There was little evidence found suggesting that PM is perceived as affecting plants in this industry. There was little evidence of actual effects. At the same time, however, there was an indication that perception might be difficult even if effects are present. And some plants undertake various activities that may have been an earlier response to PM or that would at least reduce the extent to which PM may currently have an effect.

STATISTICAL REANALYSIS

After the plant interviews proved inconclusive, it was decided to undertake further analysis of the econometric model for SIC 344. The analysis included additional testing, sensitivity analysis and data evaluation. The process identified two problems with the data for the District of Columbia (DC). First, the data used for DC were found to be an unintended mixture of data for DC and for the DC SMSA. When the data were corrected, the model was re-estimated and the results were as reported in Section 7 of this report (pp. 7-149 through 7-158). A comparison of these results with those appearing in the July 1981 draft analysis report shows a decrease in the magnitude of the implied effect of TSP. However, the estimated coefficients for TSP became even more statistically significant.

A second feature observed with the DC data is that the calculated wage rate for DC was found to be 4.4 standard deviations from the mean wage rate among all counties in the sample listed in Table 14-1. As discussed in Section 7 of this report, some of the problem may be due to the limited number of significant digits used by the Census Bureau in reporting the data. In any case, a test was made to see how this particular observation may have influenced the results. The model was therefore re-estimated after excluding the DC data. In this version, the implied effect of TSP was found to increase but the TSP coefficients were not as statistically significant.

The various results from the statistical reanalysis are compared in Table 14-3. As can be seen, the implied effect of TSP varies from $247 to $410 per microgram. Both versions with the DC data are statistically significant at the 5 percent level. The version without the DC data is not as significant. The implication of these differences is that the model for SIC 344 is somewhat sensitive to sample composition. Thus, some caution is warranted in interpreting benefit estimates developed using the econometric model for this industry. For reasons discussed in Section 7, benefit calculations for this industry in the final analysis are based on the model estimated with the DC data excluded.

Table 14-3

COMPARISON OF RESULTS FOR SIC 344

	Dataset		
	Original DC Data*	Corrected DC Data**	Without DC Data**
MTCTSP+ ($)	410	247	339
Level of Significance (%)	3.8	0.8	10.6

* As reported in July 1981 Draft Analysis Report.

** As reported in Section 7 of this report.

\+ Dollar increase in total production cost per unit increase in ambient TSP.