Volume Title: Distribution of Economic Well-Being

Volume Author/Editor: F. Thomas Juster, ed.

Volume Publisher: NBER

Volume ISBN: 0-884-10478-8

Volume URL: http://www.nber.org/books/just77-1

Publication Date: 1977

Chapter Title: The Distributional Implications of National Air Pollution Damage Estimates

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Chapter URL: http://www.nber.org/chapters/c4373

Chapter pages in book: (p. 201 - 232)

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The Distributional Implications of National Air Pollution Damage Estimates

I. INTRODUCTION

Through the use of data from the 1970 U.S. Population Census, this paper attempts to distribute among the population estimates of national air pollution damages. It is impossible to proceed with such a task unless one is willing to make several assumptions, all of which can be criticized.

As a result, an unsympathetic reader, without too much effort, can discover twenty things wrong with the basic data. With a little imagination, he can convince himself that none of the assumptions is plausible. And, he might conclude that "garbage-in-garbage-out" would be the most fitting descriptor for this paper about pollution.

NOTE: The authors wish to acknowledge the helpful criticisms of Eugene Seskin and the assistance of Richard Ruggles. Financial support was provided by the National Science Foundation, grant SOC74-21391.

However, we feel that such a caustic view overlooks the fact that an estimation technique and not the data is the main focus of this paper. By discussing the distributional implications of a set of data that reflect our current state of knowledge, as poor as it is, we hope to demonstrate the advantages of what appears to be a promising direction for future research: the development and refinement of both aggregate and disaggregate economic measures as complements to one another.

In this analysis of the distributional implications of national estimates of air pollution damage we have, in effect, merged macrodata and microdata sets. We hope that the results are enticing enough to stimulate similar research efforts in this as well as other areas.

II. MAJOR ASSUMPTIONS

Our adjustments to incomes and income distributions require several assumptions. The most important of these will be discussed in this section. Other, less crucial assumptions are mentioned below in the section on methodology.

First, and perhaps most importantly, we are assuming that our basic data on the dollar values of national air pollution damages and on individuals' incomes are valid. Those familiar with the Census data base we are using—the Public Use Samples—are well aware of some of its limitations: the poor sampling of lower-income subpopulations, the failure to count as income in-kind transfers, the failure to include as income the value of a housewife's domestic services, and so on. Those with a knowledge of environmental data are even more aware of the difficulties associated with air pollution damage estimates. In principle, for our purposes, such estimates should measure the amount in dollars that the nation would be willing to pay in order to avoid the damages. However, in this instance, there is a wide gap between principle and practice. The actual data are a mixture of (some would say, wild) extrapolations of results from a handful of studies on health effects and property values, scraps of information on physical damage, and some pure guesses. This is not difficult to understand in view of the fact that the Environmental Protection Agency (EPA) has never made *official* estimates of the monetary damage for all air pollutants. While they did estimate the damage from stationary-source pollutants (especially particulates and sulfur oxides) in 1972,[1] they have not published any similar numbers since (as of this writing).

However, those familiar with the Census data and the environmental data are also aware that the limitations of both these data sets have not prevented their widespread use. In the Executive Office alone, the Council of Economic Advisers freely reports numbers from the Census data, while the Council on Environmental Quality has published damage estimates based on the environmental data.[2] Thus we are in good or, at least, official company when we assume their validity.

A second major assumption is that air quality and the damage associated with air quality at any point in time is highly correlated with the rate of emissions at that point in time. In addition, we assume that current conditions of air quality (as measured by emissions) are good indicators of the cumulative history of past conditions.

Our third major assumption is that over a suitably defined geographical area, the air is of constant quality and is confined to the area. This can be conceptualized if one thinks of each area as being covered by a plastic dome. In effect, this assumption treats air pollution as a pure public "bad" within an area and precludes the possibility of spillovers between adjacent regions.

These two assumptions, which fail to account for both meteorological and biological effects, are made out of necessity. In making them, we are following a frequent practice of blurring the distinction between emissions and ambient air quality. To do otherwise requires the development of comprehensive national air-diffusion models with extremely detailed data on point-source emissions, localized meteorological conditions, and geographical considerations, as well as data on residence times, decay functions, and the effects of cumulative exposures from various pollutants.

A fourth principal assumption is that an industry's emission level in an area is proportional to the industry's employment in the area. This assumption allows us to rely almost exclusively on the Public Use Samples for our basic data on regional effects, despite the fact that there is a considerable amount of data which would permit more precise estimates of local air pollutant emissions based on the size and practices of local establishments. The difficulty with this latter information is that it is not available nationally (and, in certain cases, where the number of establishments is few, the information may never be disclosed).[3]

Both the third and fourth assumptions suggest that the geographical areas chosen for analysis should be small enough to assure approximately uniform air quality, but large enough to assure a minimum of air spillovers and spillovers of people living in one area and working in another. A good compromise is found in the Census County Groups (which are similar to the Office of Business Economics [OBE] Economic Areas). In this analysis, these groups are subdivided into their Standard Metropolitan Statistical Area (SMSA) and non-SMSA components in order to reflect the greater air pollution damage expected in SMSA's as a result of the higher population densities and industrial activity.[4]

A fifth major assumption is that within any area, the value of a unit damage from air pollution is the same for each population unit living in the area. This assumption is probably not valid. As Baumol has noted, even if everyone's preferences for clean air and other goods were identical, under a "public bad" assumption, it is likely that wealthier individuals would place a higher value on a marginal unit of cleaner air than the less wealthy.[5] Thus, the distribution of damages between rich and poor would differ even if each suffered the same physical impacts. Our assumption implies that the distribution of damages is purely a function of the distribution of pollutants.

This assumption is necessary because we are using national damage totals as the starting point of our analysis. Essentially, we prorate the national totals to geographical areas and then we allocate an equal pro rata share of the area damage to each individual in the area. Since to some extent the national totals reflect the differential values placed on clean air by rich and poor,[6] our pro rata individual shares represent a weighted average of these differential values, the weights being the relative proportions of rich and poor in the national population.

There is another difficulty with this assumption. No *single* definition of a population unit is appropriate for calculating the pro rata share of an area's total damage. The national damage estimates that we are using represent a composite of damages to structures, human health, crops, general property, various materials, and so on. Thus, they are in some cases applicable to households alone, in other cases to individuals in households, and in still other cases to families. In this analysis, we assume that the distributional effects are primarily to individuals, and we believe that this assumption does not alter the general conclusions. Below, we shall suggest an approach for obtaining damage estimates that does not rely on national totals as a starting point and that does allow for both differences in the types of damages and in the incomes of people being affected.

Our final assumption is that within any geographical area, the total value of air pollution damage is proportional to the level of emissions. If, as many believe, damage is more than proportional to emissions, we are likely to understate the value of damage in those regions with very high emission levels.[7]

III. METHODOLOGY

The approach we use can be summarized in four major steps.

Pollution Generation

First, we estimated air pollution emissions in 1968 by two-digit Standard Industrial Classification (SIC) and industry Census classifications. This step relied on an extensive amount of data processing, which was undertaken in connection with a National Bureau project designed to expand national accounting systems by including the service flows from environmental assets.[8]

Dispensing with the estimation details, we can summarily describe the technique as an expansion and extension of published EPA estimates. These estimates cover fairly broad classifications by product and process, although neither type of classification is covered comprehensively. Therefore, it was necessary to disaggregate the EPA estimates, regroup them according to SIC classifications, and fill several gaps of missing information. For example, there was a need to fill the gap resulting from EPA's failure to report emissions of air pollutants from natural sources. The importance of this oversight can be seen if one realizes that the vast majority of particulates come from natural sources.[9]

National Damage Estimates

The second step was to estimate the damage value in 1970 dollars of the total 1968 emissions of the five principal types of air pollutants: sulfur oxides, particulates, carbon monoxide, nitrogen oxides, and hydrocarbons. As noted above, we did not estimate these values ourselves. Instead, we utilized two published sources. The first[10] relied heavily on several cross-section studies and estimated a total national damage of approximately $16.1 billion. However, the effects on health and property of carbon monoxide, hydrocarbons, and nitrogen oxides, the so-called mobile-source pollutants, were not estimated due to a lack of data.

This deficiency was partially corrected in the second source.[11] Babcock and Nagda used estimates of the relative "severities" of air pollutants to account more fully for the probable health and property damages associated with the mobile-source pollutants. As a result, the Babcock-Nagda computation raised the total damage value to $20.2 billion. The amount of damages associated with each pollutant is shown in Table 1.

The Babcock-Nagda procedure is not completely satisfactory, since the relative severities appear to rely almost entirely on EPA's air quality standards, which, in turn, rely heavily on EPA's estimates of the relative contributions of the pollutants to ill health.[12] Hence, the Babcock-Nagda nonhealth damage estimates for hydrocarbons and nitrogen oxides implicitly assume a close correlation between health effects and materials damage. In addition, it should be noted that the health effects which served as a basis for the severity rates were essentially "threshold" effects (i.e., the concentrations of pollutants for which adverse health effects are first observed in a controlled laboratory environment); and whether these "threshold" concentrations reflect actual health effects which can be translated into dollar terms is questionable.[13] There seems to be little consensus among the experts as to the relative severities of pollutants.

TABLE 1 National Air Pollution Damage Estimates: 1968 (1970 dollars)

Pollutant[a]	Tons × 10^6	$ × 10^6
PM	141.3	5,878
SO_x	33.2	8,295
NO_x	20.6	3,062
HC	32.0	2,667
CO	100.1	250
Total		20,152

SOURCE: L. R. Babcock and M. L. Nagda, "Cost Effectiveness of Emission Control," *Journal of the Air Pollution Control Association* 23 (Mar. 1973): 1973–1979. The allocation of damages by pollutant was calculated by the present authors in connection with the National Bureau project mentioned above. U.S. Public Health Service, *Nationwide Inventory of Air Pollutant Emissions—1968* (Washington, D.C.: August 1970), and Midwest Research Institute, *Particulate Pollutant Systems Study*, Vol. I, *Mass Emissions* (Kansas City, Mo.: May 1971).

[a]PM = particulate matter; SO_x = sulfur dioxides; NO_x = nitrogen oxides; HC = hydrocarbons; and CO = carbon monoxide.

Had Babcock and Nagda used the severity ratios claimed by others, the estimated damages to property and health from the mobile-source pollutants would have differed substantially. Fortunately, however, the value associated with these damages accounts for only about 25 percent of the total estimated air pollution damages.

Calculation of Area Damages

Under our second and third major assumptions, the density of air pollutants is proportional to the emissions in an area and inversely related to the size of the area. However, the value of pollution damages depends not only on the density of air pollutants but also on the number of population units (families, households, persons) in the area.

The above considerations led us to the following formula for prorating a national damage estimate for the *j*th pollutant to the *i*th area

(1) $$D_{ij} \equiv \frac{D_j(P_i/A_i)T_{ij}}{\sum_i[(P_i/A_i)T_{ij}]}$$

where D_j is the national damage for pollutant j ($\equiv \sum_i D_{ij}$) in dollars; P_i is the number of population units in area i; A_i is the land area of i (hence, P_i/A_i is equal to the population density of area i); and T_{ij} is the emissions in tons of pollutant j in area i. The total damage in area i, D_i, is thus $\sum_j D_{ij}$.

Equation 1 suggests that for areas of equal size and emissions tonnage, the damage is less, the smaller the population; for areas of equal population and emissions tonnage, the damage is less, the larger the area; and for areas of equal population and size, the damage is less, the smaller the emissions tonnage.

The calculation of T_{ij} relies on our fourth major assumption relating employment to emissions. Generally, national emissions of an industry were prorated in proportion to the industry's employment in the area.[14] In particular, the vector of total national emissions for each industrial sector was divided by the sector's national employment. This yielded a vector of pollution emissions per employee for each sector. Then, by inspecting the Census Public Use records, the number of persons employed in a particular sector within each county group (broken down into its SMSA and non-SMSA components) was estimated. Multiplying the number of persons employed in a sector within an area by the vector of pollution emissions per employee yielded the estimate of the amount of each pollutant generated per area by each sector. Finally, by summing over all sectors having employees within the area, the area's total emissions of each pollutant, T_{ij}, were determined.

There were two exceptions to this procedure. First, the emissions in the household sector were calculated on the basis of automobile registrations and heating fuel consumption. Secondly, emissions from natural sources were allocated on the basis of acres of land by state that were subject to wind erosion[15] and acres of forests by state that were destroyed by wildfire.[16] The particulates from wind erosion were distributed in proportion to the relative size of the county groups, while the pollutants from forest fires were distributed to county groups on the basis of estimates of their relative forested areas.

Calculation of Per Capita Damages

The per capita damage in area i is defined as D_i/P_i. In terms of Equation 1, the formula for per capita damage is

$$(2) \qquad \frac{D_i}{P_i} = \frac{1}{P_i}\sum_j D_{ij} = \frac{1}{P_i}\sum_j \frac{D_j\left(\frac{P_i}{A_i}\right)T_{ij}}{\sum_i\left[\left(\frac{P_i}{A_i}\right)T_{ij}\right]} = \frac{1}{A_i}\sum_j \frac{D_jT_{ij}}{\sum_i\left[\left(\frac{P_i}{A_i}\right)T_{ij}\right]}$$

An examination of the derivatives of equation 2, taken with respect to A_i and P_i, indicates that per capita damages are more sensitive to the land area of i than to the population of i. Thus two regions with roughly the same emissions levels and population densities can have quite different per capita damages. The region with the smaller land area will have the greater per capita damage, reflecting the fact that under our "plastic dome" assumption, the pollutants are emitted to a smaller volume of atmosphere. However, it should be kept in mind that the assumption of no emissions spillovers is less valid the smaller the area. Therefore, a very high per capita damage estimate for a region with small land area is probably an overestimate for that region, while the per capita damage estimates for the neighboring regions are probably underestimates.

Distributing Per Capita Damages

The final step was to distribute the per capita damage estimates to the population in order to investigate the impact on different income and racial groups. The tabulations summarizing these impacts were developed by associating with each Public Use record the per capita damage appropriate to the residence of the responding unit. For these tabulations, per capita incomes were defined as family incomes divided by the number of family members.

IV. RESULTS

The results will be presented in terms of their implications for the distribution of air pollution damages among regions and among individuals in different income and racial groups.

Regional Distributions

Per capita damages, damage levels, and emissions for each county group broken down by source of damage and by pollutant are displayed in the appendixes. Appendix I appears in print following the text of this paper. Appendixes II and III appear on microfiche at the back of the book. Part One of each appendix lists the county groups exclusive of their SMSA's, while Part Two lists the SMSA's. The area covered by both parts taken together includes the continental U.S., Alaska, and Hawaii.[17] An overview of the first appendix is provided by Table 2 which lists the "worst"

TABLE 2 Ranking of Selected SMSA's and Non-SMSA's by Per Capita Damage in Dollars

	20 "Worst" SMSA's			20 "Best" SMSA's			20 "Best" Non-SMSA's	
1.	Jersey City, N.J.	888.41	1.	Binghamton, N.Y.-Pa.	9.90	1.	Montana	.84
2.	New York City, N.Y.	415.47	2.	Santa Barbara, Calif.	12.99	2.	W N.Dak.	1.56
3.	Erie, Pa.	348.28	3.	Bakersfield, Calif.	13.20	3.	NW Minn.-E N.Dak.	2.47
4.	Newark, N.J.	292.45	4.	Salinas-Monterey, Calif.	14.44	4.	N Kansas	2.65
5.	Paterson-Clifton, N.J.	253.88	5.	San Bernadino, Calif.	15.56	5.	NW Texas	2.71
6.	Detroit, Mich.	242.61	6.	Duluth, Minn.-Wis.	16.13	6.	EC Calif.	3.22
7.	Chicago, Ill.	221.40	7.	Flint, Mich.	17.55	7.	SE S.Dak.-SE Minn.	3.30
8.	Cleveland, Ohio	214.69	8.	W. Palm Beach, Fla.	18.03	8.	SW Texas	3.31
9.	Providence, R.I.	205.21	9.	Utica-Rome, N.Y.	19.96	9.	SE Nebr.	3.59
10.	Philadelphia, Pa.	199.42	10.	Fresno, Calif.	21.71	10.	SE Colo.	3.70
11.	Gary-Hammond, Ind.	189.50	11.	Tucson, Ariz.	22.12	11.	C. Texas	3.86
12.	Los Angeles, Calif.	188.14	12.	Greenville, S.C.	22.15	12.	S. Dak.	3.88
13.	New Haven, Conn.	182.42	13.	Sacramento, Calif.	22.34	13.	S. Texas	4.30
14.	Pittsburgh, Pa.	179.01	14.	South Bend, Ind.	22.49	14.	SC Texas	5.10
15.	Salt Lake City, Utah	176.04	15.	Stockton, Calif.	23.65	15.	NW Fla.	5.31
16.	Milwaukee, Wis.	169.18	16.	Austin, Texas	24.57	16.	SW Okla.-NC Texas	6.27
17.	Boston, Mass.	154.77	17.	Las Vegas, Nev.	24.74	17.	W Ga.-E Ala.	6.28
18.	Bridgeport, Conn.	147.21	18.	Oklahoma City, Okla.	25.20	18.	NE Colo.	6.37
19.	Hartford, Conn.	135.44	19.	Honolulu, Hawaii	25.79	19.	NW Ohio	6.96
20.	Trenton, N.J.	134.65	20.	Rochester, N.Y.	25.81	20.	E Iowa-SW Wis.	6.97

SOURCE: See text.

(highest per capita damage) and "best" (lowest per capita damage) regions.

Perhaps the most significant feature of this appendix is the unevenness in the distribution of per capita air pollution damage across regions. While the national average is about $99 per person, it is at least twice as high in 10 SMSA's, and over four times as high in the two "worst" SMSA's. Clearly, the "worst" SMSA's are not typical of the nation as a whole. Of the 272 regions designated in the first appendix, 237 have damages less than $99 per person and 45 are under $10. In fact, of the national damage total of $20 billion, the 20 "worst" SMSA's account for 67 percent and the five "worst" for 31 percent.[18]

There are a few surprises in the results displayed in the appendixes and in Table 2. For example, Los Angeles's relative ranking is "in spite of," not "because of," the automobile. The contribution to per capita damage from the household sector in Los Angeles is a modest $30 or 16 percent of its total. This is largely due to the relatively low dollar damages that are assigned to the automobile's major pollutant, carbon monoxide.

Other peculiarities in the results can be better understood by studying the individual characteristics of the regions. Table 3 displays some of these characteristics for a few selected SMSA's. Note, for example, that Birmingham exceeds Erie in emissions tonnages for all pollutants and has only a slightly lower population density, yet it has only one-fifth of Erie's per capita damage. This result is a consequence of Erie's much smaller land area.

The effect of small land area is especially apparent with respect to Jersey City's $888 per capita damage estimate. Certainly this is an overestimate since much of the area's pollution probably spills over into Newark on the West, Paterson on the north, and the ocean on the east.[19] However, even when the Jersey City, Paterson, New York City, and Newark SMSA's were combined as one area in order to analyze this spillover effect, the combined per capita damage equaled $405, still exceeding all other SMSA's.

A comparison of Cleveland and San Francisco points out the importance of the composition of pollutants. The two SMSA's are roughly similar in population density, although Cleveland has a smaller land area. While this smaller land area partially explains Cleveland's higher per capita damage figure, another important factor is Cleveland's emissions of SO_x (even though its emissions of other pollutants are less than San Francisco's). The national damage estimates indicate that, per ton, SO_x is by far the most damaging pollutant.

An inspection of those areas with low damages reveals another feature of our results: the importance of the source of pollutants, especially

TABLE 3 Characteristics of Selected SMSA's

SMSA's	Land Area (square miles) (1)	Population (2)	Population Density (2)/(1)	Per Capita Damages (dollars)	Emissions (million tons/year) PM	SO_x	CO	HC	NO_x
Birmingham	2,721	739,274	272	75.99	0.305	0.226	0.472	0.104	0.107
Los Angeles	4,069	7,036,463	1,730	188.14	0.926	0.734	2.732	1.002	0.514
Jersey City	47	609,266	12,851	888.41	0.024	0.055	0.160	0.056	0.036
San Francisco	2,478	3,109,519	1,254	126.00	0.373	0.245	1.426	0.580	0.219
Pittsburgh	3,049	2,401,245	788	179.01	0.542	0.748	1.668	0.350	0.338
Cleveland	1,519	2,064,194	1,359	214.69	0.216	0.489	0.855	0.347	0.203
New York	2,136	11,571,883	5,419	415.47	0.621	1.061	3.730	1.248	0.780
Erie	813	263,654	324	348.28	0.039	0.065	0.107	0.027	0.026
Bakersfield	8,152	329,162	40	13.20	0.279	0.028	0.203	0.074	0.037

SOURCE: See text.

TABLE 4 Total Pollution Damage to Regions by Source (Millions of dollars)

Region	Total (1)	Industry (2)	Household (3)	Nature (4)
New England	1,108.9	858.6	240.8	9.5
Middle Atlantic	8,696.4	6,305.0	2,362.7	28.6
South Atlantic	1,478.7	1,084.2	240.8	153.7
East South Central	605.0	439.4	49.1	116.5
West South Central	558.0	403.7	47.0	107.3
East North Central	4,493.7	3,740.4	590.1	163.2
West North Central	591.7	368.8	55.3	167.7
Mountain States	304.6	167.5	19.4	117.7
Pacific States	2,315.1	1,784.3	377.0	153.8
Total	20,152.1	15,151.9	3,982.1	1,018.0

SOURCE: See text.
NOTE: See the reference in footnote 17 for a map defining these regions.

natural sources. In many of the rural areas, nature is the dominating polluter.[20] The relative importance of pollution souces is summarized for broad regional classifications in Table 4. The proportionally stronger role for nature is apparent in the less industrialized regions.

Effect on Individuals

We now turn to the implications of our results as they relate to the distribution of air pollution damages among individuals classified by income and race.

Both Freeman, using data from the Kansas City, St. Louis, and Washington, D.C., SMSA's,[21] and Zupan, using data from the New York region,[22] have found evidence that poorer income groups are exposed to higher pollution levels. In contrast, our results, summarized in Table 5, do not support the hypothesis that air quality is distributed in a "prorich" manner. Of course, as a group the poor suffer more; but that is only because there are more of them. In per capita terms, we found that the greatest damage, as Baumol hypothesized, was suffered by high-income groups.

However, before concluding that the Freeman-Zupan results are inconsistent with ours, three differences in the studies should be emphasized. First, both Freeman and Zupan analyze air pollution differences *within* a smaller number of SMSA's. By design, such intra-SMSA differences are ruled out of our analysis. Had we used smaller geographical units, our results might have conformed more closely to

TABLE 5 Mean Per Capita Pollution Damage Incurred by Income Class

Income Class	Mean Pollution Damage	Percent of Persons in Income Class
$ 1,000 or less	$ 72.96	19.0
1,001–3,000	94.57	47.7
3,001–5,000	112.82	20.0
5,001–7,000	124.57	7.2
7,001–10,000	130.43	4.0
10,001–15,000	133.89	0.8
15,000 and above	142.76	1.2
Overall	99.29	100.00

SOURCE: See text.

theirs. Secondly, it is important to point out that our analysis, in contrast to Freeman and Zupan's, is geographically comprehensive, covering all SMSA's and non-SMSA's. Thus, account is taken of the fact that a significant number of poor live in rural regions that are relatively clean. Thirdly, it should be noted that Freeman's data are for 1960, while ours are for 1970. If air pollution has become more evenly distributed across and within SMSA's over the decade (perhaps as a result of air-cleanup programs), then the value of air pollution damages would have also become more evenly distributed between richer and poorer areas. In this connection, it is interesting to note that Zupan's analysis, using pollution data for 1970, evidenced a far weaker maldistribution to the poor than Freeman's analysis.

On one result, Freeman and ourselves agree. Nonwhites clearly suffer more damage than whites.[23] The relevant comparisons are shown in Table 6.

TABLE 6 Mean Per Capita Pollution Damage Incurred by Whites and Nonwhites

Race	Mean Pollution Damage	Mean Income	Percent of Persons
Whites	$ 97.55	$ 3,080.97	88.6
Nonwhites	115.67	1,823.22	11.4
Total	99.29	2,937.62	100.00

SOURCE: See text.

If air pollution damage is considered negative income, it is natural to investigate its effect on the income distribution. Given our previous findings that the rich seem to be suffering more damage than the poor, one would expect only a minor effect on the income distribution. In fact, the Gini coefficient for the distribution of personal incomes in 1970 was 0.421. After subtracting the per capita negative income attributed to air pollution damage, the Gini coefficient for the distribution rises to 0.434, indicating a slight tendency towards less equality of incomes.

Finally, we investigated the hypothesis—implicitly underlying Nordhaus and Tobin's use of income differentials to measure urban disamenities[24]—that higher income offsets air pollution damage. We looked at both the correlation between per capita income and per capita damage and the rank correlation between an area's mean income and its per capita damage. The first correlation was 0.34, indicating small but significant support for the hypothesis. However, the rank correlation, also small but significant, was −0.15, which, by itself, does not support the hypothesis. Both results taken together suggest that while there is a general tendency for higher incomes to parallel higher damages, there are probably many exceptions to the rule.

V. CONCLUSION

In at least two respects, the results of this study warrant further investigation because of their implications for policy. In the first place, if the rich suffer more than the poor from air pollution, then they have more to gain from cleanup programs. Thus, even without the equity consideration of how much different income groups *should* pay for a cleanup program, policymakers and politicians can take advantage of the fact that the rich should be *willing* to bear a proportionately larger tax burden, because it is in their own interest.

In the second place, if the geographical distribution of damages is as unequal as our results suggest, policymakers may wish to concentrate their antipollution activities in a similarly uneven manner. However, before EPA decides to "crack down" on Jersey City while neglecting Bakersfield, it should be recognized that our analysis looked only at the damages from air pollution and not at the opportunity costs of reducing those damages. Furthermore, it is possible that cleaning up only the very dirty areas engenders other distributional impacts that might be considered socially undesirable.

Given that a more thorough examination of the issues is needed, we can suggest three research efforts in increasing order of difficulty. First, the entire study should be replicated using newly available EPA data on pollution emissions. These data are not necessarily better than our emissions data, but their use would provide a measure of the sensitivity of our results to emissions levels.

Secondly, the implications of using smaller geographical areas should be investigated. At a minimum, the damage levels in Central Business Districts should be contrasted with the damage levels in non-Central Business Districts.

Thirdly, instead of national damage totals, a detailed microdata base should be used as the starting point of the analysis. Since microdata give important family and individual characteristics, it should be possible to assign a probable damage value to each microunit. For example, by using air pollution-health studies, an expected value of lost income due to increased morbidity and mortality from air pollution can be assigned to individual wage earners. This method of assigning air pollution damage will automatically account for the earner's position in the income distribution, and if he is at the higher end, he should be willing to pay more for cleaner air.

One by-product of this third effort would be the development of new and, hopefully, more accurate national damage totals. This line of research would further demonstrate that the development of aggregate and disaggregate economic measures are complementary activities.

NOTE: Appendix II, "Total Damage (in millions of dollars) from Pollutants, by County Group," and Appendix III, "Total Emission (in millions of tons), by County Group," appear on microfiche at the back of the book. Duplicate microfiche cards can be obtained from Microfiche Systems Corporation, 440 Park Avenue South, New York, N.Y. 10016.

APPENDIX I

TABLE A-1 Per Capita Damage (in Dollars) from Industrial, Household, and Natural Causes by County Group Part One: County Groups, Exclusive of Selected SMSA Components

County Group Code	County Groups	Total	Industry	Household	Nature
1	N Maine	7.41	1.08	0.58	5.75
2	S Maine	8.83	6.04	1.89	0.89
3	N Vermont, New Hampshire	11.09	9.78	1.31	0.0
4	S Vermont, Massachusetts, Rhode Island	51.45	39.75	10.59	1.11
5	S New Hampshire, Vermont, C Massachusetts, Connecticut	34.46	28.81	5.65	0.0
6	W Vermont, Massachusetts, E New York	12.55	8.14	1.62	2.79
7	N New York	12.35	8.09	1.53	2.72
8	W New York, NC Pennsylvania	16.98	9.98	1.22	5.78
9	W Pennsylvania, NE Ohio	26.39	24.37	2.03	0.0
10	C Pennsylvania	16.00	12.77	1.58	1.64
11	SC New York, NE Pennsylvania	10.05	8.62	1.43	0.0
12	E Pennsylvania	17.67	13.99	3.68	0.0
13	SE New York, N New Jersey, Connecticut	96.20	84.10	12.09	0.0
14	E Pennsylvania, C New Jersey	50.13	44.03	5.12	0.99
15	Mid Pennsylvania	18.48	15.60	2.88	0.0
16	Delaware, Maryland	16.30	13.18	1.88	1.24
17	W Virginia, N West Virginia	8.67	6.10	1.21	1.36
18	S Virginia	11.41	9.54	1.87	0.0
19	C Virginia	11.85	9.19	1.13	1.52
20	E North Carolina, S Virginia	7.16	5.97	1.19	0.0

TABLE A-1 Part One (continued)

County Group Code	County Groups	Total	Industry	Household	Nature
21	C North Carolina	10.88	7.53	2.29	1.06
22	SE North Carolina	11.56	7.11	1.80	2.64
23	NW North Carolina	11.73	9.87	1.85	0.0
24	S North Carolina	30.50	18.10	2.81	9.59
25	W North Carolina	25.88	7.62	1.65	16.60
26	W South Carolina	23.00	19.50	2.08	1.41
27	C South Carolina	24.73	9.48	1.07	14.18
28	N South Carolina	10.55	8.01	1.10	1.44
29	S South Carolina	12.05	4.85	0.61	6.58
30	E Georgia	9.95	5.57	0.83	3.55
31	N Florida	26.80	7.58	0.73	18.49
32	EC Florida	62.60	16.45	1.83	44.32
33	SW Florida	12.25	10.57	1.05	0.63
34	NW Florida	5.31	3.04	0.70	1.56
35	W Florida	10.43	5.83	1.44	3.15
36	SE Alabama	12.36	5.89	0.80	5.67
37	SW Georgia	11.65	8.21	0.66	2.78
38	C Georgia	10.37	6.39	0.88	3.10
39	W Georgia, E Alabama	6.28	4.96	1.32	0.0
40	N Georgia	29.20	17.24	1.10	10.86
41	C Alabama, E Mississippi	11.73	7.37	0.83	3.52
42	N Mississippi, W Tennessee, E Arkansas	9.23	6.05	0.66	2.51
43	N Alabama	20.03	18.79	1.24	0.0
44	SE Tennessee, NE Georgia	9.02	8.13	0.89	0.0
45	C Tennessee	16.86	12.09	1.16	3.61
46	E Tennessee	28.22	18.21	0.84	9.17
47	W Virginia	34.47	27.49	1.74	5.24
48	S West Virginia	21.31	15.88	0.96	4.47
49	C Kentucky	23.44	9.15	1.15	13.13
50	N Kentucky	24.88	10.83	1.12	12.94
51	W Kentucky, SW Indiana	14.16	11.03	1.16	1.97
52	WC Indiana	15.36	7.16	1.60	6.61
53	C Illinois	32.20	5.37	1.42	25.41
54	EC Illinois	41.34	5.60	1.86	33.88
55	NC Indiana	18.92	10.65	1.69	6.58

TABLE A-1 Part One (continued)

County Group Code	County Groups	Total	Industry	Household	Nature
56	C Indiana	25.48	20.80	2.01	2.66
57	EC Indiana	28.28	17.22	3.69	7.37
58	SW Ohio	15.07	8.30	1.60	5.16
59	WC Ohio	24.58	11.56	2.48	10.54
60	C Ohio	22.90	16.71	1.54	4.64
61	N West Virginia	19.05	17.84	1.21	0.0
62	SW Pennsylvania	37.91	35.50	2.41	0.0
63	NE Ohio	28.76	26.64	2.12	0.0
64	NW Ohio	6.96	5.03	1.93	0.0
65	N Ohio	20.09	17.98	2.11	0.0
66	E Michigan	23.29	20.13	3.16	0.0
67	NE Michigan	8.94	6.83	1.07	1.04
68	NW Michigan	7.97	5.58	1.08	1.32
69	SC Michigan	13.95	10.45	3.50	0.0
70	NE Indiana	13.52	11.99	1.53	0.0
71	SW Michigan, N Indiana	27.43	24.53	2.90	0.0
72	NE Illinois	19.97	18.38	1.59	0.0
73	NC Illinois	32.95	6.39	1.49	25.07
74	N Illinois, SE Iowa	37.48	7.91	1.27	28.30
75	E Iowa, SW Wisconsin	6.97	5.97	1.00	0.0
76	NC Illinois, SC Wisconsin	9.91	8.20	1.70	0.0
77	SE Wisconsin	12.98	9.48	1.93	1.57
78	NE Wisconsin	7.26	4.97	0.81	1.48
79	NC Wisconsin	14.59	10.99	0.77	2.83
80	NW Wisconsin	13.28	5.54	0.45	7.29
81	WC Wisconsin	9.84	6.08	1.00	2.76
82	Minnesota	9.81	4.76	0.67	4.37
83	NW Minnesota, E North Dakota	2.47	2.10	0.37	0.0
84	W North Dakota	1.56	1.42	0.13	0.0
85	Montana	0.84	0.77	0.07	0.0
86	South Dakota	3.88	1.37	0.12	2.39
87	SE South Dakota, SE Minnesota	3.30	1.92	0.51	0.87
88	Wyoming, W Nebraska	31.84	0.97	0.09	30.78
89	C Nebraska	22.84	1.46	0.17	21.22

TABLE A-1 Part One (continued)

County Group Code	County Groups	Total	Industry	Household	Nature
90	NE Nebraska, NW Iowa	20.02	2.15	0.41	17.47
91	NC Iowa	40.95	5.12	0.67	35.17
92	NW Iowa	37.62	4.24	0.93	32.44
93	S Iowa	25.89	4.36	0.78	20.75
94	SW Iowa	33.51	5.31	0.54	27.66
95	SE Nebraska	3.59	2.80	0.79	0.0
96	N Kansas	2.65	1.63	0.19	0.83
97	S Kansas	12.24	1.86	0.22	10.16
98	NW Missouri, NE Kansas	14.26	4.15	0.74	9.37
99	NC Missouri	26.80	4.83	0.62	21.35
100	WC Illinois	9.01	8.14	0.87	0.0
101	W Illinois, E Missouri	28.66	7.93	0.85	19.88
102	SE Missouri, SW Kentucky	8.17	7.47	0.70	0.0
103	S Missouri, SE Kansas	21.87	5.87	0.56	15.45
104	C Arkansas	13.61	7.22	0.45	5.94
105	WC Arkansas, EC Oklahoma	43.72	7.04	0.40	36.28
106	NE Oklahoma	39.60	12.56	0.87	26.17
107	Oklahoma	7.67	3.01	0.33	4.33
108	SW Oklahoma, NC Texas	6.27	2.06	0.49	3.72
109	NW Texas	2.71	1.13	0.15	1.43
110	WC Texas	8.26	2.69	0.42	5.14
111	SW Texas	3.31	1.10	0.16	2.06
112	C Texas	3.86	1.41	0.23	2.22
113	NE Texas	7.92	3.81	0.54	3.56
114	EC Texas	10.52	1.99	1.00	7.53
115	Mideast Texas	9.72	3.94	0.43	5.34
116	E Texas, NW Louisiana	10.40	6.60	0.58	3.22
117	NE Texas, SW Arkansas	14.59	6.35	0.43	7.82
118	E Louisiana	25.03	5.83	0.69	18.51
119	S Arkansas, WC Mississippi	12.22	6.75	0.46	5.02

TABLE A-1 Part One (concluded)

County Group Code	County Groups	Total	Industry	Household	Nature
120	Midwest Mississippi	31.21	6.45	0.43	24.33
121	EC Mississippi	28.47	7.74	0.53	20.20
122	SW Alabama, SE Mississippi	51.49	6.08	0.69	44.71
123	SE Louisiana, SW Mississippi	13.31	9.05	0.63	3.64
124	S Louisiana	9.38	7.63	0.99	0.75
125	SE Texas	11.55	4.86	0.59	6.11
126	SC Texas	5.10	2.49	0.20	2.41
127	S Texas	4.30	1.07	0.33	2.90
128	S New Mexico, W Texas	18.42	.80	0.07	17.55
129	N New Mexico	33.45	.98	0.09	32.38
130	SE Colorado	3.70	1.61	0.29	1.80
131	NE Colorado	6.37	1.78	0.18	4.42
132	W Colorado, SE Utah, SW Wyoming	15.90	1.56	0.10	14.23
133	W Idaho	12.55	1.77	0.15	10.63
134	W Montana, N Idaho	8.91	5.58	0.17	3.15
135	W Washington	16.11	15.29	0.82	0.0
136	SC Washington, NW Oregon	12.12	5.20	0.27	6.65
137	NW Oregon, SW Washington	20.06	10.70	0.58	8.78
138	SW Oregon	14.23	5.71	0.35	8.17
139	SE Oregon, SW Idaho	9.29	1.44	0.14	7.71
140	Nevada, SW Utah	18.36	0.43	0.04	17.89
141	Arizona	19.94	1.06	0.08	18.80
142	SW California[a]	0.0	0.0	0.0	0.0
143	C California	17.19	9.33	0.31	7.55
144	EC California	3.22	2.60	0.62	0.0
145	Mideast California	10.07	9.45	0.62	0.0
146	N California	8.62	4.76	0.16	3.70
147	WC California	20.84	12.37	1.31	7.16
148	Alaska	7.06	0.07	0.02	6.97
149	Hawaii[a]	0.0	0.0	0.0	0.0

TABLE A-1 Per Capita Damage (in Dollars) from Industrial, Household, and Natural Causes by County Group Part Two: SMSA's

County Group Code	SMSA's	Total	Industry	Household	Nature
4	Boston, Massachusetts	154.77	116.56	37.10	1.11
4	Worcester, Massachusetts	64.88	50.98	12.78	1.11
4	Providence, Rhode Island	205.21	166.87	37.24	1.11
5	Hartford, Connecticut	135.44	103.04	32.40	0.0
5	New Haven, Connecticut	182.42	145.99	36.43	0.0
5	Springfield, Massachusetts–Connecticut	103.86	82.63	21.23	0.0
6	Albany, Troy, New York	35.50	23.47	9.23	2.79
7	Rochester, New York	25.81	14.18	8.91	2.72
7	Syracuse, New York	38.01	29.16	6.13	2.72
7	Utica–Rome, New York	19.96	14.21	3.03	2.72
8	Buffalo, New York	128.37	108.20	14.39	5.78
9	Erie, Pennsylvania	348.28	311.69	36.59	0.0
9	Youngstown–Warren, Ohio	89.73	80.85	8.88	0.0
11	Binghamton, New York–Pennsylvania	9.90	6.57	3.33	0.0
12	Wilkes-Barre–Hazleton, Pennsylvania	63.56	53.21	10.35	0.0
13	New York, New York	415.47	279.73	135.74	0.0
13	Bridgeport, Connecticut	147.21	109.15	38.06	0.0
13	Jersey City, New Jersey	888.41	569.67	318.74	0.0
13	Paterson–Clifton, New Jersey	253.88	162.30	91.58	0.0
13	Newark, New Jersey	292.45	218.06	74.40	0.0
14	Trenton, New Jersey	134.85	98.64	35.23	0.99
14	Philadelphia, Pennsylvania–New Jersey	199.42	166.74	31.69	0.99

TABLE A-1 Part Two (continued)

County Group Code	SMSA's	Total	Industry	Household	Nature
14	Wilmington, Delaware–New Jersey–Maryland	78.60	66.83	10.79	0.99
14	Reading, Pennsylvania	71.99	62.31	8.70	0.99
14	Allentown, Pennsylvania–New Jersey	84.73	75.61	8.14	0.99
15	Harrisburg, Pennsylvania	33.91	27.27	6.65	0.0
15	Lancaster, Pennsylvania	67.40	58.66	8.74	0.0
15	York, Pennsylvania	46.93	41.13	5.79	0.0
16	Baltimore, Maryland	78.61	61.48	15.89	1.24
16	Washington, D.C.–Maryland–Virginia	105.81	77.92	26.66	1.24
19	Richmond, Virginia	82.84	72.14	9.17	1.52
20	Newport News–Hampton, Virginia	63.26	35.09	28.17	0.0
20	Norfolk–Portsmouth, Virginia	122.35	95.78	26.57	0.0
23	Greensboro–Salem, North Carolina	30.90	24.28	6.62	0.0
24	Charlotte, North Carolina	73.17	55.59	7.99	9.59
26	Greenville, South Carolina	22.15	15.38	5.36	1.41
27	Columbia, South Carolina	53.96	33.66	6.11	14.18
29	Augusta, Georgia–South Carolina	31.76	21.02	4.16	6.58
29	Charleston, South Carolina	26.35	16.77	3.01	6.58
31	Jacksonville, Florida	102.09	69.43	14.17	18.49
32	Orlando, Florida	84.74	33.23	7.18	44.32
33	Fort Lauderdale, Florida	56.31	46.82	8.86	0.63
33	Miami, Florida	59.20	48.24	10.32	0.63

TABLE A-1 Part Two (continued)

County Group Code	SMSA's	Total	Industry	Household	Nature
33	Tampa, St. Petersburg, Florida	97.05	82.57	13.85	0.63
33	West Palm Beach, Florida	18.03	14.32	3.08	0.63
40	Atlanta, Georgia	114.86	90.44	13.56	10.86
41	Birmingham, Alabama	75.99	68.22	4.24	3.52
42	Memphis, Tennessee–Arkansas	53.88	42.70	8.67	2.51
44	Chattanooga, Tennessee–Georgia	122.41	117.22	5.19	0.0
45	Nashville–Davidson, Tennessee	46.96	37.02	6.33	3.61
46	Knoxville, Tennessee	104.35	89.52	5.66	9.17
48	Huntington, West Virgina–Kentucky–Ohio	82.00	74.63	2.91	4.47
50	Louisville, Kentucky–Indiana	113.15	84.77	15.44	12.94
56	Indianapolis, Indiana	48.66	38.94	7.06	2.66
58	Cincinnati, Ohio–Kentucky Indiana	70.52	53.39	11.97	5.16
59	Dayton, Ohio	87.81	67.67	9.60	10.54
60	Columbus, Ohio	87.05	70.20	12.20	4.64
62	Johnstown, Pennsylvania	48.59	46.14	2.45	0.0
62	Pittsburgh, Pennsylvania	179.01	166.55	12.46	0.0
63	Akron, Ohio	90.71	77.02	13.69	0.0
63	Canton, Ohio	116.72	105.31	11.41	0.0
63	Cleveland, Ohio	214.69	192.27	22.42	0.0
63	Lorain–Elyria, Ohio	85.19	76.29	8.91	0.0
65	Toledo, Ohio–Michigan	90.04	81.02	9.02	0.0
66	Detroit, Michigan	242.61	206.14	36.47	0.0
66	Flint, Michigan	17.55	10.95	6.60	0.0
68	Grand Rapids, Michigan	55.53	46.46	7.75	1.32

TABLE A-1 Part Two (continued)

County Group Code	SMSA's	Total	Industry	Household	Nature
69	Lansing, Michigan	37.23	31.89	5.33	0.0
70	Fort Wayne, Indiana	75.39	66.69	8.70	0.0
71	South Bend, Indiana	22.49	15.62	6.87	0.0
72	Chicago, Illinois	221.40	189.17	32.24	0.0
72	Gary–Hammond, Indiana	189.55	177.91	11.64	0.0
73	Peoria, Illinois	56.34	27.75	3.52	25.07
74	Davenport, Iowa–Illinois	69.73	37.60	3.83	28.30
76	Rockford, Illinois	33.65	27.13	6.52	0.0
77	Madison, Wisconsin	35.92	28.63	5.73	1.57
77	Milwaukee, Wisconsin	169.18	148.69	18.91	1.57
78	Appleton–Oshkosh, Wisconsin	38.94	32.90	4.57	1.48
80	Duluth, Minnesota–Wisconsin	16.13	7.94	0.90	7.29
82	Minneapolis, Minnesota	127.74	105.78	17.59	4.37
93	Des Moines, Iowa	81.39	51.16	9.48	20.75
94	Omaha, Nebraska–Iowa	67.46	33.74	6.17	27.66
97	Wichita, Kansas	30.57	17.70	2.72	10.16
98	Kansas City, Missouri–Kansas	83.76	67.04	7.34	9.37
101	St. Louis, Missouri–Illinois	98.44	69.08	9.48	19.88
104	Little Rock, Arkansas	63.78	54.08	3.76	5.94
106	Tulsa, Oklahoma	44.54	16.27	2.10	26.17
107	Oklahoma City, Oklahoma	25.20	15.30	5.56	4.33
113	Dallas, Texas	48.26	38.79	5.91	3.56
113	Forth Worth, Texas	48.75	36.96	8.22	3.56
115	Austin, Texas	24.57	12.82	6.41	5.34
116	Shreveport, Louisiana	32.62	26.90	2.51	3.22
120	Jackson, Mississippi	50.19	23.05	2.81	24.33
122	Mobile, Alabama	70.21	23.48	2.01	44.71
123	Baton Rouge, Louisiana	111.03	96:33	11.06	3.64

TABLE A-1 Part Two (continued)

County Group Code	SMSA's	Total	Industry	Household	Nature
123	New Orleans, Louisiana	77.62	66.98	7.00	3.64
125	Beaumont–Orange, Texas	122.96	113.13	3.72	6.11
125	Houston, Texas	87.96	76.88	4.97	6.11
126	San Antonio, Texas	37.44	27.29	7.74	2.41
127	Corpus Christi, Texas	60.25	54.52	2.84	2.90
128	El Paso, Texas	55.75	33.11	5.09	17.55
129	Albuquerque, New Mexico	53.99	17.03	4.57	32.38
131	Denver, Colorado	39.33	28.85	6.05	4.42
132	Salt Lake City, Utah	176.04	153.15	8.66	14.23
134	Spokane, Washington	27.68	20.63	3.89	3.15
135	Seattle–Everett, Washington	44.10	36.49	7.62	0.0
135	Tacoma, Washington	56.43	49.47	6.96	0.0
137	Portland, Oregon–Washington	95.59	80.71	6.10	8.78
140	Las Vegas, Nevada	24.74	6.18	0.68	17.89
141	Phoenix, Arizona	33.91	13.34	1.77	18.80
141	Tucson, Arisona	22.12	2.66	0.66	18.80
142	San Diego, California	26.03	18.75	7.28	0.0
143	Los Angeles, California	188.14	150.72	29.87	7.55
143	Anaheim, California	118.80	80.13	31.12	7.55
143	Bakersfield, California	13.20	5.00	0.65	7.55
143	Fresno, California	21.71	13.04	1.12	7.55
143	Oxnard–Ventura, California	40.04	28.96	3.53	7.55
143	San Bernardino, California	15.56	7.26	0.75	7.55
143	Santa Barbara, California	12.99	3.51	1.92	7.55
144	Stockton, California	23.65	20.02	3.63	0.0
145	Sacramento, California	22.34	18.41	3.93	0.0
147	Salinas–Monterey, California	14.44	5.43	1.85	7.16
147	San Francisco, California	126.00	97.63	21.21	7.16

TABLE A-1 Part Two (concluded)

County Group Code	SMSA's	Total	Industry	Household	Nature
147	San Jose, California	50.24	28.83	14.25	7.16
149	Honolulu, Hawaii	25.79	15.61	2.26	7.91
	National Total	99.29	74.65	19.62	5.02

[a]There are no non-SMSA components.

NOTES

1. *The Economics of Clean Air*, Annual Report of the Administrator of the Environmental Protection Agency, Senate Document No. 92-67; 92nd Congress, 2nd Session, March 1972. The damage estimates therein are based on Larry B. Barrett and Thomas E. Waddell, "The Cost of Air Pollution Damages: A Status Report," Appendix I–J in the Final Report of the Ad Hoc Committee on the Cumulative Regulatory Effects on the Cost of Automotive Transportation, Office of Science and Technology, February 28, 1972. A revision of the Barrett and Waddell estimates will be published shortly.
2. For example, see *Environmental Quality*, The Second Annual Report of the Council on Environmental Quality (Washington, D.C.: August 1971), p. 107.
3. Recently, a completely new source of regional data on emissions has become available, EPA's National Emissions Data System. These data are derived by applying EPA's pollution emission factors to state estimates of industrial activity and automobile usage. Unfortunately, this information is so new that we have not been able to exploit it for the present analysis.
4. The specific rules for allocating employment (and thus emissions) between the SMSA and non-SMSA components of a County Group are as follows: If a person both works and lives in an SMSA or works and lives outside an SMSA, employment is allocated by place of residence. If he lives in an SMSA but works outside an SMSA, employment is allocated to the non-SMSA component of the County Group. If he lives outside an SMSA but works in an SMSA, employment is allocated proportionally to total employment among all the SMSA components in the County Group. (If a person lives in a County Group with no SMSA's but works in an SMSA, he is excluded from the sample. Approximately 0.8 percent of all cases fell into this category.)
5. William J. Baumol, "Environmental Protection and Income Distribution," in Harold M. Hochman and George Peterson, eds., *Redistribution Through Public Choice* (New York: Columbia University Press, 1975).
6. This is true if health damages are measured by forgone earnings.
7. Depending on the shape of the true emissions-damage relationship, we also may be overstating the damage in regions with very low emissions levels. Since it turns out that our damage estimates for these regions are already very low, we do not feel that this latter problem is very serious.
8. A large amount of detailed documentation supporting the emissions estimates is available through direct communication with the authors.

9. Efforts of reworking and expanding the EPA estimates required a detailed review of more than one hundred technical studies on the generation of air pollutants.
10. Barrett and Waddell, *Cost of Air Pollution Damages*.
11. L. R. Babcock and M. L. Nagda, "Cost Effectiveness of Emission Control," *Journal of the Air Pollution Control Association* 23 (Mar. 1973): 1973–1979.
12. L. R. Babcock and M. L. Nagda, Letter to the Editor, *Journal of the Air Pollution Control Association* 22 (Sept. 1972): 727–728.
13. For a discussion of the merits of using laboratory experiments to infer the human health effects of air pollutants, see L. Lave and E. Seskin, *Air Pollution and Human Health* (Baltimore: Johns Hopkins University Press, forthcoming).
14. See footnote 4 for the employment allocation rules.
15. U.S. Department of Agriculture, *Basic Statistics—National Inventory of Soil and Water Conservation Needs, 1967* (Washington, D.C.: Jan. 1971).
16. U.S. Department of Agriculture, *Wildfire Statistics* (Washington, D.C.: Aug. 1973).
17. For a map showing county group and SMSA boundaries, see U.S. Department of Commerce, *Areas Defined on County Group Public Use Samples*, Form BC-81.
18. It is interesting to note that the 20 "worst" SMSA's account for 26 percent of the U.S. population, while the five "worst" account for 8 percent of the population.
19. The amount of the overestimate is somewhat offset since, as noted above, our assumption of a proportional emissions-damage relationship tends to *underestimate* the damages in heavily polluted areas such as Jersey City.
20. Indeed, we may be greatly underestimating the total impact of natural sources. Lack of data has precluded estimates of natural emissions of biologically produced NO_x, which on a worldwide basis ten times exceeds man-made emissions. See Environmental Protection Agency, *Air Quality Criteria for Nitrogen Oxides* (Washington, D.C.: January 1971), p. 3-1.
21. A. Myrick Freeman, III, "Distribution of Environmental Quality," in Allen V. Kneese and Blair T. Bower, eds., *Environmental Quality Analysis* (Baltimore: Johns Hopkins University Press, 1972).
22. Jeffrey M. Zupan, *The Distribution of Air Quality in the New York Region* (Baltimore: Johns Hopkins University Press, 1973). Zupan defines the New York region as "a 31-county tri-state area centered on Manhattan."
23. Zupan, relying on IRS data for his incomes, did not report any racial distributions.
24. William Nordhaus and James Tobin, "Is Growth Obsolete?" *Economic Growth*, Fiftieth Anniversary Colloquium V (New York: National Bureau of Economic Research, 1972).

6 | COMMENTS

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The purpose of the paper under discussion is to advance our understanding of the way in which damages from air pollution, and in turn the benefits from cleaning it up, are likely to be distributed nationwide with respect to per capita income, race, and geographical location. Before summarizing the paper, let me emphasize why I feel that the issue is one of particular importance from the point of view of federal policy. The environmental program which has been legislated by Congress differs from the great majority of federal programs in two fundamental respects. First, the benefits, unlike those that can be presumed to flow from national defense, medical research, and similar efforts, cannot be construed as serving members of the community at large in more or less equal proportions, nor are they aimed at specific, identifiable target groups such as the poor, the elderly, or farmers. The beneficiaries are as yet not well defined. Second, the burden of support for the program does not follow the conventional pattern of federal financing, since virtually none of it flows from the federal treasury. While the distribution of the costs of programs which are financed through the federal tax system can be assumed, in general, to reflect some sort of public consensus regarding what constitutes a desirable degree of equity, the distribution of the burden of meeting federal air pollution standards is only beginning to be understood. It appears at the moment that it will look more like a consumption tax than the progressive federal tax structure. In launching what is to become a continuing and expensive under-national taking of this sort, it is not sufficient to evaluate it from the point of view national costs and benefits without some attention to its distributional consequences.

Efforts to appraise the distribution of the costs of the program have already yielded some promising insights. Further investigation is called for, but both the conceptual framework and the empirical basis for such studies are already well advanced. Although estimates of total costs leave much to be desired at the present time, we have, at least, a pretty good idea of what it is that we are trying to measure. Analyzing the benefits of the program presents a challenge of a different order. To date, most economists have hesitated to wrestle with such delicate issues as how to place values on human life and health or on the amenities of clean air. Their reluctance has demonstrated an uncharacteristic humility, but it has left the field to policymakers who, though they cannot afford such modesty, may be even less well equipped to deal with the issues. Decisions are, in fact, being, and will continue to be, made regarding permissible standards of environmental quality and, unless economists come to grips with the problem of measuring benefits and their distribution, such decisions are likely to be made on grounds that are not only inadequate but possibly totally irrelevant. The present study helps to underscore some of the hurdles that will have to be overcome before economists can offer policymakers much good advice in this area.

The specific task which the authors set themselves was to prorate some rather widely used estimates of the annual dollar cost of nationwide damages from five major air pollutants among all SMSA's and county groups exclusive of SMSA's in the United States, to convert the prorated damages within each area to a per capita basis and then to evaluate them with respect to income and race of area residents. The final product purports to be a nationwide distribution of the cost of pollution damages by income, race, and geographical area.

Estimates of nationwide dollar damages were prorated to individual areas on the basis of indexes which the authors developed of the proportion of total national damages due to each pollutant that occurred in each area in 1970. Their indexes were arrived at in the following ways.

First, for industrial pollution, the total volume of emissions of each pollutant was estimated by two-digit Standard Industrial Classification (SIC) categories, using what the authors describe as an "expansion and extension" of published Environmental Protection Agency (EPA) industry estimates. The resulting vectors of emissions for each industry were divided by industry employment to yield a set of vectors of emissions per employee by industry. The latter were in turn multiplied by industry employment in each area to derive total emissions by area. Emissions due to households in each area were estimated separately on the basis of automobile registrations and home fuel consumption. Natural source emissions were calculated on the basis of total acreage and forested areas within each location.

The authors recognized that damages from pollution depend not only on the volume of emissions but on population within an area as well, so that, in arriving at their indexes of area damages, they multiplied total area emissions by local population density. This product was in turn divided by the sum of such products for all areas in the United States to derive an index of the relative share of total national damages from each pollutant by area. Pollution indexes were then divided by local population estimates to arrive at the final set of area indexes of per capita damages from each pollutant. These were, in turn, multiplied by the national dollar damage totals per pollutant, to achieve measures of per capita dollar damages by area. Lastly, damage estimates were summed across pollutants to arrive at the final measures of total per capita damages by area.

The authors were now in a position to evaluate their estimates of per capita pollution damages in relation to income and race of residents of each area. From a conversation with two of the authors, I understand that income and race of a sample of residents from each area were established from the Census of Use file, permitting them to build up a nationwide distribution of per capita damages by income, race, and location.

With respect to race, they found blacks, on the average, to suffer about 25 percent greater pollution damages than whites. Geographically, the distribution showed a high degree of variance, as might have been expected. By income, damages appear to fall more heavily on the rich than on the poor, but the correlation between per capita income and per capita damages was only .35, while the rank correlation was −.15. Let us now examine more closely the method by which these distributions were arrived at.

The authors were careful to spell out the succession of assumptions which underlie their estimates. The list bears repeating: (1) Air quality within an area is highly correlated with the rate of emissions. (2) Damages are highly correlated with the level of air quality. (3) Emissions from an industry within an area are proportional to local employment in that industry. (4) Damages from emissions which emanate from an area are confined to that area. (5) Air quality is constant throughout an area. (6) Within any area, the value of a unit of damage is the same for each population unit. (7) Estimates of national damages from pollutants are valid.

The authors are more comfortable with most of these assumptions than I am, but, in view of the need for some basis for conjecture in this area and the obstacles that line the path to it, I am prepared to live with the first four for the time being. Acceptance of the last three, however, calls for a suspension of critical judgment which I am not yet ready to grant.

Ignoring, for the moment, the values that different members of the population are likely to place on damages from pollution, the assumption that all individuals within an area suffer equal exposure to pollution is contrary to the limited information which we have. The authors themselves cite two independent studies of pollution exposure within metropolitan areas which indicate its distribution by income to be just the reverse of what they found nationwide. Specifically, both Freeman and Zupan found the poor to be subject to significantly higher concentrations than the rich within four major urban areas. Although the number of areas studied was limited, given what is known about the tendency for the poor to congregate in central cities, there is reason to believe that replications would confirm these results in other urban areas. Had the present authors limited themselves to establishing between-area differentials in concentration of various pollutants, their results might have presented an interesting counterpoise to those of the earlier studies. But, unfortunately, any insights along these lines have been thoroughly beclouded by their procedure in assigning values to damages from each pollutant which they then summed across pollutants.

If the damages from separate pollutants are to be totaled, rather than examined separately, then, in order to assess even the relative distribution of damages by income class, it is essential, at the very least, that relative values assigned to units of damages from different pollutants be correctly measured. In other words, their "weights" in the total must approximately conform to the relative costs they impose. The authors assigned values to damages from individual pollutants on the basis of a set of rather widely publicized estimates of total national damages attributable to each pollutant in 1968, which they updated to 1970. Let us consider how these national damage estimates were arrived at in the first place. They come from two separate sources. The estimates of total national damages from sulfates and particulates are based on a much-cited survey by Barrett and Waddell of a number of independent cross-sectional studies of losses of property, life, and health due to air pollution. For each pollutant, Barrett and Waddell added the damages caused to health and mortality, materials, residential property values, and vegetation. It would appear, to begin with, that they became involved in a certain amount of double counting when they added to their estimates of damages to residential property values the damages to health and mortality. If homeowners place any value at all on the health aspects of clean air, it ought to be reflected in property values.

But what of the valuation of damages to life and health themselves? These are based on Lave and Seskin's estimates of the savings that a 50 percent reduction in nationwide air pollution would effect in terms of reductions in days of work lost due to ill health and early mortality, and in the cost of treatment and prevention of illness. Days of work lost are valued in terms of average earnings of those actually in the labor force, thereby excluding housewives, the retired, and children.

Lave and Seskin have made pathbreaking contributions to our knowledge of the association between morbidity and air pollution rates, but it is difficult to regard their valuation of losses as other than an act of desperation. It is all too easy to find fault with specific details of the method: the numerous omissions, as well as the insensitivity to the specific incidence of morbidity from air pollution among individual groups, for example the elderly and the poor, whose earnings differ from the average, not to mention the absence of any attention at all to the cost of pain and anguish. However, my major quarrel is with the basic premise that the collective willingness to pay for an increase in health and longevity has much of anything to do with its effect on gross national product. The question at issue is how much, altogether, would individuals be willing to pay for marginal increments in the community's average expectation of life and health? I doubt that most persons, if asked, would weigh very heavily the anticipated effect on either their own or the nation's gross value of product. Judging from the apparent unwillingness of most persons to insure themselves or their families fully against loss of earnings due to death or ill health, I infer that most of us prefer to assume some risk in this respect. On the other hand, few of us would happily go to our graves or succumb to chronic bronchitis merely by virtue of having our lifetime earnings insured.

So much for the valuation of damages from sulfates and particulates. For estimates of damages from mobile-source emissions, the authors relied on a second study by Babcock and Nagda with which I am not familiar. According to the present authors, the bases of these estimates are even more questionable than those of stationary sources and, furthermore, only damages to health and materials are allowed for. Mobile-source emissions, as it happens, are not known to cause severe damage to health or materials, although their effect on the amenities can sometimes be devastating. The lack of attention to these effects shows up in an anomaly, which the present authors allude to, in the damage estimates for the city of Los Angeles. Per capita estimates of damages in that community due to mobile-source emissions turn out to be only 7 dollars per year, while damages from other sources amount to 201 dollars per year. It is difficult to know what to make of area damage totals whose components are so capriciously weighted.

Even were we to accept the national damage estimates as a basis for valuing total costs of emissions, the question of differential willingness to pay would remain when it comes to distributing such costs by income class. The authors have assumed an equal willingness to pay among all individuals in the country per unit of pollution exposure. This implies that an individual's willingness to pay is not influenced by his ability to pay and that damages sustained by an individual are independent of his earnings or of the value of his property. The latter postulate violates, of course, the premise on which the national damage estimates are based. The authors take cognizance of this shortcoming as far as the within-area distribution of damages is concerned but make no effort to adjust for differential damages due to income variances either within or between areas.

The authors of the paper are not, of course, responsible for the unsatisfactory state of the art of measuring pollution damages. In adopting the existing estimates, even if only as a common denominator to permit them to cumulate damages from a variety of sources, they have, however, left themselves open to criticism, not the least of which is that they have lent credence to the estimates. However, more to the point, in assigning the implied dollar weights to damages from various pollutants, they have camouflaged what might otherwise have been a useful set of estimates of the distribution, by income and other variables, of average per capita exposure to specific pollutants among a comprehensive list of geographical sectors of the country. Such estimates could not, in themselves, have provided an adequate basis for determining the income distribution of pollution exposure nationwide because of the neglect of within-area differentials, but they would have provided some information about the between-area distribution to contrast with what is already known about the distribution within certain areas. In the attempt to push their results beyond what the present state of knowledge justifies, ground has been lost rather than gained.

I should like to recommend that the authors report their distributions in terms of the volume of emissions of specific pollutants rather than in terms of cumulative dollar damages. For purposes of policy making, the cumulation of damages across pollutants is, in any event, a mixed blessing. The abatement effort is, after all, not one, but a collection of programs. All sources of pollution need not be attacked in the same degree, nor is the distribution of the burden of abatement costs the same for all sources. Mobile sources of emissions, for example, present a rather different regulatory problem than do stationary sources. The burden, as well as the benefits, in abating the former tends to be concentrated within the geographical area from which they emanate, unlike the situation which prevails regarding industrial pollution. From the point of view of examining tradeoffs, aggregation destroys valuable evidence in this case.

Finally, some thought ought to be given to whether the passage of a federal pollution control act does not, in itself, suggest that the benefits from abatement are regarded by the public as accruing not solely to the local residents who breathe the air. Some, at least, ought perhaps to be treated as external to the specific locality.