Air Pollution And Medical Care Use By Older Americans: A Cross-Area Analysis

Reducing air pollution not only improves people's health, it also can lead to reduced spending for medical care.

by Victor R. Fuchs and Sarah Rosen Frank

ABSTRACT: The case for reduction of air pollution has been predicated primarily on the frequently observed relationship between pollution and mortality and morbidity. Because pollution control usually involves costs, a rational public policy will weigh the benefits against the costs. This study investigates another potential benefit from pollution reduction: namely, decreased use of medical care. We find a strong relationship between particulate matter and inpatient and outpatient care at ages 65–84 across 183 metropolitan statistical areas (MSAs). The relationship is statistically significant at a very high level of confidence even after the region and population size of the areas, education, real income, racial composition, use of cigarettes, and obesity are controlled for.

The strong relation between air pollution and health that has been reported by many investigators has provided a firm foundation for policy recommendations to reduce pollution. There is little doubt that reduction in pollution emitted primarily from power plants and motor vehicles would confer important benefits for society through decreased rates of death and illness.[1] Because there are frequently large costs associated with efforts to reduce pollutants, a rational public policy should try to strike a balance between the benefits and the costs.[2]

This study investigates another potential benefit from pollution reduction: decreased use of medical care. With medical care spending exceeding $1 trillion per year, even a reduction of only a few percentage points would save society tens of billions of dollars annually.[3] Previous studies of the relation between medical care use and pollution have examined only a limited number of illnesses and have been based on a limited number of areas. A few have focused specifically on children or the elderly, but with relatively small samples.[4]

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This study uses millions of Medicare records of whites ages 65–84 in 183 metropolitan statistical areas (MSAs) of greater than 100,000 population for the period 1989–1991. Measures of inpatient care, outpatient care, medical admissions, surgical admissions, and respiratory admissions are compared with air pollution measures for the same areas during the same period. Control variables include the area's region and population size, as well as education, real income, percentage of the population that is black, cigarette consumption, and obesity.

Study Design

Area differences in medical care use, air pollution, and the other variables are relatively stable over time; thus, we can estimate long-run relationships with a cross-area analysis. We use a three-year average, 1989–1991, to reduce the influence of minor transitory within-area variations.[5] We focus on the elderly because the Medicare database provides a rich source of information on the detailed use of medical care by the elderly. Also, the elderly account for a disproportionate share of health care use and a particularly large share of government spending for health care. We exclude anyone age eighty-five and older because it is more difficult to obtain accurate measures for self-reported variables such as education and income from this population. The decision to exclude blacks was dictated by data limitations and methodological considerations. We did not want our estimates of the relationship between utilization and pollution to be confounded by possible differences between the black and white populations.

We measure utilization as the sum of quantities of medical care services used by the Medicare residents in an MSA weighted by the national Medicare reimbursement rate for that service. Our measure of utilization includes hospital admissions, physician services, and outpatient hospital care and is divided into inpatient and outpatient care. The hospital admissions measures are created using the Medicare Provider Analysis and Review file (MEDPAR) 20 percent sample. Hospital admissions claims are weighted by the national average reimbursement of the diagnosis-related group (DRG). DRG codes are used to classify admissions as medical or surgical and to distinguish respiratory from other admissions. The physician utilization measures are created using the Part B Medicare Annual Data (BMAD) Procedure File 5 percent sample. The physician claims are weighted by the national Medicare reimbursement amount, based on the HCFA Common Procedure Coding System (HCPCS) of more than 12,000 codes.[6] Within the age category we used (65–84), we adjust for age and sex distributions within each area using the indirect method.

The air pollution measure is particulate matter with an aerodynamic diameter of less than 10 micrometers (PM_{10}), measured in micrograms of particulate matter per cubic meter of air as reported by the Environmental Protection Agency's Aerometric Information Retrieval System (AIRS) database. Annual summary arithmetic means were averaged across all monitors in each MSA. For monitors missing a year of data, we used the average percentage change between years from the other monitors in the MSA to estimate the missing data point. If an entire MSA was missing a year of data, we used the average percentage change for areas of the same population size in the same geographic region.

We focus on PM_{10} instead of other measures of pollution because reasonably complete data are readily available, this measure has been used in other studies, and the AIRS database does not have measures of $PM_{2.5}$ (smaller, potentially more lethal particulates) for the areas and period covered by this study. Although it is likely that particulate matter is correlated with other pollutants, we do not control for other measures of pollution to avoid substantial problems of multicollinearity. Our measure of the PM_{10} coefficient, therefore, may reflect other pollutants as well; it could be considered an indicator pollutant.[7]

Both air pollution and use of medical care vary considerably across areas grouped by population size and region. In this study, areas are grouped into regions to control for possible differences in climate, occupational mix, availability of medical care, genetic heritage, and other factors. We use a seven-region classification developed by a geographer, Ge Lin, who found it more statistically meaningful than the conventional census regions or divisions in his study of disability among the elderly.[8] We also assign areas to three population-size categories (greater than 500,000; 250,000 to 500,000; and 100,000 to 249,000) to control for possible effects of differences in access to medical care, the physical and psychosocial environments, and other factors.

Exhibit 1 shows that utilization tends to increase as population size increases. Air pollution is also positively correlated with population size. Air pollution is greatest in the West and lowest in Florida and the Big Sky. Inpatient care does not vary much across regions, but outpatient care is twice as high in Florida as in the Big Sky. Hospital admissions are greatest in the Deep South and the West South.

Our regressions control for population size and region. We also control for five other factors that are widely believed to affect use of medical care: education, real income, percent black in the population, use of cigarettes, and obesity. Any finding that utilization was related to pollution would be vulnerable to suspicion if these variables were not included. Education is measured as the proportion of whites ages 65–84, with less than a high school education. Real income per capita of whites ages 65–84 is nominal income adjusted for area differences in cost of living.[9] Both education and income measures were obtained from the 1990 U.S. census. We include the proportion of an area's population that is black because this variable has been shown to be a significant predictor of white mortality, although the reasons for the relationship have not been determined.[10] There may be differences among the areas in locally provided public services or in the physical and psychosocial environments. Alternatively, there may be differences among the white populations resulting from differential migration patterns.[11] Mortality is a significant predictor of utilization, especially at ages 65–84: 25–30 percent of

EXHIBIT 1
Mean Values Of Pollution And Utilization Variables, By Population Size And Region

		Quantity of care per person, expressed in dollars (whites ages 65–84)				
	Pollution[a]	Inpatient care	Outpatient care	Medical admissions	Surgical admissions	Respiratory admissions
Population size						
>500,000	32.6	$2,162	$1,223	$919	$863	$211
250,000–500,000	29.8	2,068	1,098	886	850	205
100,000–249,999	29.0	2,050	1,019	894	835	209
Region						
North	30.0	2,098	1,115	915	842	198
Upper South	31.8	2,123	1,237	891	839	191
Deep South	32.1	2,184	1,164	968	880	243
Florida	26.2	2,138	1,884	811	857	188
West South	26.8	2,260	1,167	972	909	232
Big Sky	30.4	2,169	943	952	872	213
West	40.0	2,187	1,232	899	875	225

SOURCE: Authors' calculations based on data from the Centers for Medicare and Medicaid Services and Environmental Protection Agency.

NOTES: Mean values are weighted by the number of whites, ages 65–84, in each area. The North region is New England, Middle Atlantic, and East North Central; Upper South: Delaware, Maryland, the District of Columbia, Virginia, and West Virginia; Deep South: North Carolina, South Carolina, Georgia, and East South Central; West South: West South Central; Big Sky: West North Central, Montana, Idaho, Wyoming, and Colorado; West: Pacific, Nevada, Utah, Arizona, and New Mexico.

[a] Micrograms of particulate matter with an aerodynamic diameter of less than 10 micrometers (PM_{10}) per cubic meter of air.

Medicare expenditures are incurred in the last year of life.

Cigarette consumption is measured by state sales per capita (number of packs) as reported by the Tobacco Institute for the years 1984–1989, adjusted for cross-state sales and tax-exempt purchases.[12] Obesity, defined as the proportion of each state's population with a body mass index (BMI) greater than 30 kg/m^2, is taken from a study by Ali Mokdad and colleagues (from self-reported height and weight), adjusted for the racial mix of the state because of the much greater prevalence of obesity among blacks.[13] Because the cigarette and obesity measures are statewide, each MSA within a state is assigned the same value.

We estimate the relation between pollution and utilization with ordinary least squares (OLS) regressions weighted by the number of whites ages 65–84 in the area. In the first specification the variables are in original (untransformed) units. In the second specification the utilization measures (that is, the dependent variables) are transformed to logarithms. In the third specification all variables except the region and population-size dummy variables are transformed to logarithms. All three regression specifications are run with no controls and with controls.

Results

The regression results reported in Exhibit 2 show a statistically significant relation between air pollution and inpatient care, outpatient care, medical admissions, and respiratory admissions, with or without controlling for the other variables. Surgical admissions are significantly related to air pollution when there are

EXHIBIT 2
Relation Between Air Pollution And Use Of Medical Care Among Whites Ages 65–84, Regression Results Across 183 Metropolitan Statistical Areas (MSAs)

	Absolute change in use (expressed in dollars) per 10 μg/m³ change in PM_{10} (A)		Percent change in use per 10 μg/m³ change in PM_{10} (B)		Percent change in use per 1 percent change in PM_{10} (C)	
	No controls	With controls[a]	No controls	With controls[a]	No controls	With controls[a]
Inpatient care, $2,145[b]	$93.4 (20.0) [<.0001]	$76.7 (26.6) [.0044]	0.043 (0.010) [<.0001]	0.035 (0.013) [.0056]	0.159 (0.032) [<.0001]	0.129 (0.043) [.0031]
Outpatient care, $1,196[b]	$59.8 (25.8) [.0216]	$100.3 (20.4) [<.0001]	0.060 (0.020) [.0025]	0.091 (0.017) [<.0001]	0.184 (0.068) [.0072]	0.291 (0.059) [<.0001]
Medical admissions, $914[b]	$40.9 (11.8) [.0006]	$43.2 (15.1) [.0047]	0.046 (0.013) [.0005]	0.048 (0.017) [.0044]	0.177 (0.044) [<.0001]	0.164 (0.056) [.0040]
Surgical admissions, $860[b]	$20.7 (7.0) [.0036]	$6.4 (8.8) [.4677]	0.025 (0.008) [.0030]	0.008 (0.010) [.4310]	0.095 (0.028) [.0008]	0.044 (0.036) [.2254]
Respiratory admissions, $210[b]	$21.7 (3.1) [<.0001]	$18.6 (3.7) [<.0001]	0.100 (0.015) [<.0001]	0.084 (0.018) [<.0001]	0.344 (0.051) [<.0001]	0.246 (0.060) [<.0001]

SOURCE: Authors' calculations based on data from the Centers for Medicare and Medicaid Services, Environmental Protection Agency, U.S. Department of Commerce, and other sources. See text and Notes 12 and 13.

NOTE: Standard errors of regression coefficients are in parentheses; *p* values are in brackets. PM_{10} is particulate matter with an aerodynamic diameter of less than 10 micrometers.

[a] Controls were low education, real income, cigarette use, obesity, percent black in MSA, region, and population size.

[b] Weighted mean utilization per white person ages 65–84.

no controls, but this relation becomes insignificant when controls are introduced. Introduction of controls greatly increases the relationship between air pollution and outpatient care. The conclusions are not sensitive to the form of the regression; the results for the three specifications are very similar.[14]

With controls, outpatient care shows the largest relation to air pollution in all three specifications. In specification (A) we find that a change of 10 μg/m³ of PM_{10} is associated with a change of $100.30 in per capita outpatient utilization. The regression coefficient is five times as large as its standard error (20.4), a highly statistically significant result. Specification (B) shows a 9.1 percent change in outpatient utilization for every change of 10 μg/m³ of PM_{10}, and specification (C) shows a change of 29.1 percent for every 1 percent change in PM_{10}. Respiratory admissions also show a very strong relation to pollution; the absolute change, specification (A), is small because the mean level of respiratory admissions is small.

To illustrate the relation between air pollution and the five measures of utilization, we divide the areas into quintiles based on their level of PM_{10}. We then use the regression results from specification (A) with controls to predict the utilization levels in the most and the least polluted quintiles, under the assumption that the areas in each quintile had the same values for all variables except pollution.

The results are shown in Exhibit 3. The percentage differential (given by the ratio in column 3) between the highest and the lowest pollution quintiles is 7 percent for inpatient care and 18 percent for outpatient care. The comparable differentials for medical and surgical differentials are 10 percent and 2 percent, respectively; for respiratory admissions, the differential is 19 percent.

Between 1989–91 and 1999–2001 the mean level of PM_{10} in the 183 areas fell by 6.4 μg/m^3 (from 32.0 to 25.6). The results of this study imply that this decline (holding all else constant) would have lowered inpatient utilization by 2 percent and outpatient utilization by 5 percent. In fact, of course, utilization increased over the decade: The introduction and diffusion of new medical technologies more than offset the effects of less pollution.

Discussion

The study results are strong and statistically highly significant except for surgical admissions. However, several qualifications and limitations should be noted. First, as with all pollution studies, we have no data that link the health care use of particular individuals directly to their personal exposure to pollution. The regressions establish a presumption of a causal relationship but do not constitute absolute proof. Second, while utilization is well measured, pollution is probably subject to considerable measurement error. It relies on a limited number of monitors in each area—in some cases, only one. For any given level of monitor reading, the actual exposure of the inhabitants of an area could vary depending on where they live, where they work, how much time they spend outdoors, and other factors. Some of the control variables are also probably measured with error. Unless offset by correlations with other variables, random measurement error in pollution probably results in an underestimate of its relation to utilization.[15]

Omitted variables are a source of concern if they are correlated with the risk factors and with utilization in ways that bias the regression coefficients. Such variables might include the quantity and quality of medical care, differences in the

EXHIBIT 3
Predicted Utilization In Areas With The Most And The Least Pollution Holding All Other Variables Constant, Among Whites Ages 65–84, Annual Average 1989–1991

	37 areas with most pollution (A)	37 areas with least pollution (B)	Ratio of A to B
Inpatient care	$2,225	$2,074	1.07
Outpatient care	1,300	1,103	1.18
Medical admissions	960	874	1.10
Surgical admissions	867	854	1.02
Respiratory admissions	229	193	1.19

SOURCE: Authors' calculations; see Exhibit 2.

NOTES: Predicted utilization was calculated by the authors from multiple regression specification (A) with controls. Most and least pollution represents the highest and lowest 20 percent of areas.

physical or psychosocial environment, or possibly even genetic differences. Measures of pollution other than PM_{10} represent a special case of the omitted variable problem. PM_{10} is positively correlated with many other pollutants, but high multicollinearity makes it unlikely that their separate relationships with utilization can be estimated with satisfactory precision.

Two other limitations of this study are inherent in its focus on whites ages 65–84. We do not know if the observed relationships between pollution and medical care use would be same for blacks ages 65–84, nor is it certain that the relation at ages 65–84 is a good indicator of the relation at other ages. Also, changes in the incidence of disease or in modes of treatment (for example, a shift to outpatient care in the 1990s) could possibly alter the relationships reported for 1989–1991.

Conclusion

Despite the qualifications and limitations, we conclude that air pollution, as reflected in PM_{10}, greatly increases the use of medical care among whites ages 65–84. The problem of omitted variables, while potentially significant in theory, may not be of great practical importance. It is noteworthy that the relationship between air pollution and utilization is much stronger for outpatient than for inpatient care and for medical than for surgical admissions, and is particularly strong for admissions for respiratory diseases. For the problem of omitted variables to be a significant source of bias, the variable(s) would have to have the peculiar quality of affecting respiratory disease a great deal, outpatient utilization much more than inpatient care, and medical admissions but not surgical admissions. To posit the existence of such a variable stretches the limit of plausibility. Moreover, inevitable errors in measurement of pollution probably result in an underestimate of its relation to utilization.

Other studies have shown that air pollution increases mortality and morbidity. This study shows that use of medical care is significantly higher in areas with more pollution and that decreased use of care is an important potential benefit from pollution control.[16] Pollution levels were reduced somewhat in the 1990s, but even in 1999–2001, PM_{10} in the areas in the highest quintile was still 8.0 $\mu g/m^3$ higher than in the median quintile. Thus, pollution control offers an important opportunity for further gains in health and reductions in medical care spending.

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NOTES

1. On mortality, see, for example, J.M. Samet et al., *The National Morbidity, Mortality and Air Pollution Study Part II: Morbidity, Mortality, and Air Pollution in the United States,* Report no. 94 (Cambridge, Mass.: Health Effects Institute, May 2000); C.A. Pope and D.W. Dockery, "Epidemiology of Particle Effects," in *Air Pollution and Health*, ed. S.T. Holgate et al. (San Diego: Academic Press, 1999), 673–705; and C.A. Pope et al., "Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution," *Journal of the American Medical Association* 287, no. 9 (2002): 1132–1141. On morbidity, see, for example, Samet et al., *The National Morbidity, Mortality, and Air Pollution Study Part II*; B.D. Ostro and S. Rothschild, "Air Pollution and Acute Respiratory Morbidity—An Observational Study of Multiple Pollutants," *Environmental Research* 50, no. 2 (1989): 238–247; and J. Schwartz et al., "Particulate Air Pollution and Hospital Emergency Room Visits for Asthma in Seattle," *American Review of Respiratory Disease* 147, no. 4 (1993): 826–831.
2. See, for example, P.R. Portney, "Policy Watch: Economics and the Clean Air Act," *Journal of Economic Perspectives* (Autumn 1990): 73–81; and J. Kaiser, "Showdown over Clear Air Science," *Science* (25 July 1997): 466–469.
3. K. Levit et al., "Inflation Spurs Health Spending in 2000," *Health Affairs* (Jan/Feb 2002): 172–181.
4. See, for example, J. Schwartz et al., "Acute Effects of Summer Air Pollution on Respiratory Symptom Reporting in Children," *American Journal of Respiratory and Critical Care Medicine* 150, no. 5 (1994): 1234–1242; and J. Schwartz, "Air Pollution and Hospital Admissions for the Elderly in Detroit, Michigan," *American Journal of Respiratory and Critical Care Medicine* 150, no. 3 (1994): 648–655.
5. Although the data are more than a decade old, the key issue in this analysis is not the absolute quantities, which would vary over time, but rather the correlations between variables, which we expect are stable over relatively short time periods.
6. The national dollar weights permit us to aggregate the number of different types of surgery or the number of different types of physician services. These aggregates are expressed in dollars, but it should be clear that they represent quantities of medical care. HCFA is the former name of the Centers for Medicare and Medicaid Services (CMS).
7. Abt Associates, "Particulate-Related Health Impacts of Eight Electric Utility Systems," Report prepared for Rockefeller Family Foundation (New York: Rockefeller, 20 April 2002).
8. G. Lin, "A Regional Assessment of Elderly Disability in the U.S.," *Social Science and Medicine* 50, no. 7–8 (2000): 1015–1024.
9. An area cost-of-living index was calculated by the authors using an age- and sex-adjusted wage index and median house prices.
10. A. Deaton and D. Lubotsky, "Mortality, Inequality, and Race in American Cities and States," NBER Working Paper no. 8370 (Cambridge, Mass.: National Bureau of Economic Research, July 2001).
11. V.R. Fuchs, M.B. McClellan, and J. Skinner, "Area Differences in Utilization of Medical Care and Mortality among U.S. Elderly," NBER Working Paper no. 8628 (Cambridge, Mass.: NBER, December 2001).
12. Tobacco Institute, *The Tax Burden on Tobacco, Historical Compilation*, vol. 33 (Washington: Tobacco Institute, 1998); and Advisory Commission on Intergovernmental Relations, *Cigarette Tax Evasion: A Second Look* (Washington: Advisory Commission, 1985).
13. A.H. Mokdad et al., "The Spread of the Obesity Epidemic in the United States, 1991–1998," *Journal of the American Medical Association* 282, no. 16 (1999): 1519–1522.
14. Results for all variables are available in an appendix upon request; write to Victor Fuchs at fuchs@newage3.stanford.edu.
15. R.S. Pindyck and D.L. Rubinfeld, *Econometric Models and Economic Forecasts,* 3d ed. (New York: McGraw-Hill, 1991).
16. Because pollution control leads to an increase in life expectancy, some increase in utilization could be expected, but this offset would be relatively small. The percentage effect of pollution on utilization is much greater than its effect on life expectancy. Also, a great deal of utilization is in the last year of life, whenever it occurs.