DEC notes
Research findings

Valuing the health effects of air pollution

That high levels of air pollution are bad for health and can cause premature death is well known. But policymakers need more specific information, especially about the costs and benefits of reduction measures, to set priorities

Air pollution is a serious and growing problem in many developing countries, particularly in rapidly expanding cities, where pollution levels are often several times the maximum level recommended by the World Health Organization. That high levels of air pollution are bad for health and can cause premature death is well known. But policymakers need more specific information to set priorities. Should available funds go to air pollution reduction—or would they be better spent on sanitation, education, AIDS prevention, or any of a host of other pressing concerns? A cost-benefit analysis of air pollution reduction measures is a necessary input to such a decision. However, answers vary greatly depending on the method used. This note describes some of the pitfalls that commonly arise when attempting to estimate the dollar value of benefits associated with a given reduction in pollution levels in low-income countries. Because cost-benefit estimates are often necessary despite these pitfalls, boxes describe how to prepare a rough estimate of the benefits of pollution reduction, using Delhi, India as an example.

Measuring the effects of air pollution on premature death

Air pollutants affect health in a variety of ways, from itchy eyes to premature death.

Although air pollution affects both death and illness rates, greater social costs are likely to be associated with premature death. Chronic exposure to air pollution can lead to premature death by increasing the rate at which lung tissue ages, by contributing to chronic obstructive lung disease, and by exacerbating cardiovascular disease. Short-term peaks in air pollution (acute exposures) can increase the chance that a person in a weakened state (a person with pneumonia, for example) or a susceptible person (a person with asthma, for example) will die.

The most accurate way to measure the impact of air pollution on death rates in a given area is to conduct epidemiologic studies for that area. To capture both acute and chronic effects, a large cross-section of individuals should be followed prospectively for at least ten years, measuring both the air pollution concentrations to which they are exposed and other factors that affect the risk of death (smoking behavior, body mass index, family history).

Because such studies are expensive, only two have been completed to date, both in the United States (Dockery and others 1993; Pope and others 1995). These studies show how pollution alters the survival function (the probability that a person survives to each age in a community) and allow the number of life-years lost as a result of air pollution to be calculated.

COST-BENEFIT ANALYSIS IS OFTEN AN ESSENTIAL INPUT TO AIR POLLUTION REDUCTION EFFORTS

Because they are less expensive, retrospective studies that use aggregate data are common. Cross-sectional studies correlate aggregate variations in air pollution levels across counties with death rates by county. Cross-sectional studies are generally unreliable, however, for two reasons. First, if there has been recent immigration, historic air pollution levels in a county may not measure the concentrations to which people currently living in the county were exposed. Second, it is usually hard to control for confounding factors (smoking behavior, dietary risk factors) at the county level.

Time series studies, which correlate daily variation in air pollution with variation in daily mortality in a given city, avoid the problems mentioned above, but at best measure the effects of acute exposure to air pollution on death rates. Because they measure primarily the effect of acute exposure to air pollution on people who are in a weakened state and are therefore susceptible to death as a result of a sudden rise in pollution concentrations, such studies measure only some of the effects of air pollution on premature death. To the extent that many of these people would have had short life expectancies even in the absence of pollution, time series studies may overestimate the life-years lost as a result of air pollution. Such studies can provide a lower-bound estimate of the reduction in premature death that would accompany a reduction in air pollution, however.

Prospective studies are generally more accurate—and more expensive—than retrospective cross-sectional or time series studies

Can results obtained for one country be applied to another?

In the absence of epidemiologic studies of the region in question, some researchers advocate the use of dose-response functions from other countries. The only prospective cross-sectional studies of the effects of chronic exposure to pollution on mortality come from the two U.S. studies mentioned earlier. Time series studies have also been conducted, primarily in the United States and Europe (other parts of the world have been studied, such as Santiago, Chile by Ostro and others 1995, China by X. Xu and others 1994 and Z. Xu and others forthcoming, and São Paulo, Brazil by Saldiva and others 1994).

How appropriate is it to transfer results from epidemiologic studies conducted in industrial countries to developing countries? At a minimum, such projections must be made for disease-specific deaths. Extrapolating the effect of air pollution on total death rates from a study in the United States makes no sense if the distribution of deaths by cause differs greatly between the United States and the country of interest.

For instance, the effect of a change in particulate concentrations on total deaths comes mainly from its effect on respiratory and cardiovascular deaths. In the United States half of all deaths are caused by cardiovascular disease or respiratory illness. In Delhi, India, by contrast, fewer than 20 percent of all deaths are attributable to these causes. Even if people in Delhi reacted to a given change in particulate pollution in exactly the same way that people in the United States did, the effect of the change on total mortality would be lower in Delhi (box 1). The figures in the last row of the table in box 1 represent the most accurate estimates of the benefits of reducing air pollution in Delhi based on extrapolations from U.S. studies. These figures may, however, represent lower-bound estimates, for two reasons. First, they represent only the gains from reducing acute exposure to air pollution. Second, people in Delhi may be more susceptible to the effects of air pollution than people in the United States because of lower levels of baseline health and more limited access to medical care.

Estimating the dollar value of lives lost from air pollution

Economists calculate the value of a reduction in risk of death by determining how much an individual is willing to pay for it. One approach to measuring willingness to pay is to infer the value from compensating wage differentials in the labor market. The theory behind this approach is simple: other things being equal, workers in riskier jobs are compensated with higher wages for bearing more risk. A second approach to measuring willingness to pay is to ask people what they would pay to reduce their risk of dying. This is referred to as the contingent valuation approach.

Recent compensating wage studies in the United States have produced estimates of the value of a statistical life in the range of $1.9–$10.7 million (1990 dollars). Contingent valuation studies have produced slightly lower estimates of $1.2–$9.7 million (1990 dollars). Compensating wage studies measure compensation for risk of instantaneous death for people who are about 40 years old and thus measure the approximate value of 35 years of life (Viscusi 1993). Because death from air pollution reduces life-years by less than 35 years on average, labor market estimates should be adjusted accordingly.

Compensating wage and contingent valuation studies have not yet been conducted in developing countries. Premature death in these countries is typically valued by using estimates of the value of a statistical life from the United States and adjusting for income differences between the two countries, or by calculating forgone earnings. Which method is preferable?

Economic theory tells us that the willingness-to-pay approach yields a value of a statistical life that exceeds the value of forgone earnings as long as people are risk averse (Rosen 1988). In the United States, for example, estimates of the value of a statistical life are typically five to ten times higher than the value of forgone earnings. If people in other countries were equally risk averse, then it would be appropriate to multiply the value of forgone earnings in the country of inter-

Properly controlled for, results from industrial countries can be extrapolated to developing countries

Box 1. Estimating the effects of air pollution on premature death

Delhi, the capital of India, suffers from extremely high levels of particulate air pollution, with levels of total suspended particulates (TSP) sometimes reaching five times the maximum level suggested by the World Health Organization (WHO).

How can the effects of air pollution on total mortality in Delhi be calculated? Applying results from dose-response relationships calculated for U.S. cities can seriously misrepresent the effect of pollution on health in Delhi. On average a 10 microgram (µg) change in PM_{10} (particulate matter measuring 10 microns or less in diameter) results in a 1 percent change in total mortality in the United States (Ostro 1994). Applying this relationship to Delhi would imply that reducing average annual TSP from its 1991 level of 374.95 micrograms per cubic meter (µg/m^3) to the WHO's upper guideline level (90 µg/m^3) would result in a 15.05 percent decline in nontraumatic deaths, or 8,244 fewer deaths (see table). This finding suggests that nearly all deaths in Delhi resulting from pneumonia, chronic obstructive pulmonary disease, and cardiovascular disease (8,244 of 8,402) would be eliminated simply by reducing the level of TSP to 90 µg/m^3. One explanation for this implausible result is that the leading causes of death in the United States and India differ.

To minimize this type of error and to obtain more reliable estimates, we can apply dose-response functions estimated for specific causes of death to the Delhi figures. According to Schwartz and Dockery (1992), a 100 µg/m^3 change in TSP results in a 19 percent change in the number of deaths from chronic obstructive pulmonary disease, an 11 percent change in the number of deaths from pneumonia, and a 10 percent change in the number of deaths from cardiovascular disease. Applying these figures to Delhi, lowering the average annual TSP to meet the WHO guideline would result in 2,712 fewer deaths, a 5 percent reduction in nontrauma mortality.

Estimated number of deaths avoided in Delhi by reducing average annual total suspended particulate levels

Study/ cause of death	Number of deaths, 1991	Percentage reduction in mortality	Number of deaths avoided
Ostro 1994			
Total nontrauma	54,783	15.05	8,244
Schwartz and Dockery 1992			
Cardiovascular disease	5,701	28.50	1,625
Pneumonia	1,644	31.34	515
Bronchitis and asthma	1,057	54.14	572
Total	8,402	5.00	2,712

est by the same factor found in U.S. studies. It is, however, likely that risk aversion varies with living standards and that the value of a statistical life in developing countries is a smaller multiple of forgone earnings than it is in the United States.

Until further research provides estimates of the value of a statistical life in developing countries, one approach to valuation is to use forgone earnings as a lower bound to the value of changes in life expectancy and projections of the value of life from U.S. studies as an upper bound, as shown in box 2.

—by Maureen L. Cropper and Nathalie B. Simon

Compensating wage studies and contingent valuation studies calculate the value of reduced life expectancy

Further reading

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Box 2. Valuing life in Delhi, India

A rough approximation of the value of life-years saved by reducing particulate levels in Delhi to meet the World Health Organization (WHO) guideline can be obtained by calculating forgone earnings (for a lower-bound estimate) and projecting the value of life from U.S. studies (for an upper-bound estimate).

First we need to determine the number of life-years lost because of air pollution. In box 1 we estimated that about 2,712 lives would be saved if total suspended particulates (TSP) were reduced to meet WHO guidelines. If the age distribution of these deaths is about the same as that for total mortality, the air quality improvement would result in 727 fewer deaths among people over 65 (26.8 percent), 1,348 fewer deaths among people between 15 and 64 (49.7 percent), and 637 fewer deaths among people under age 15 (23.5 percent). Using estimates of life expectancy at each age in India, these figures imply a total of 79,516 life-years saved.

Given an average annual income in manufacturing in Delhi of $500.58 and an annual interest rate of 5 percent, and assuming that individuals are not productive in the workplace until age 14, the present value of life-years lost as a result of pollution exposure based on forgone earnings comes to roughly $14,893,422 (1991 dollars), our lower-bound estimate.

Rosen (1988) has shown that value of life estimates based on willingness to pay are about five times as high as estimates obtained using forgone earnings. Applying this figure to our example, we estimate the upper-bound value of life-years lost at $74,467,111.

This *DECnote* was prepared by Maureen L. Cropper and Nathalie B. Simon in the Policy Research Department of the World Bank. *DECnotes* transmit key research findings to Bank Group managers and staff. They are drawn from the work of individual Bank researchers and do not necessarily represent the views of the World Bank and its member countries—and therefore should not be attributed to the World Bank or its affiliates. *DECnotes* are produced by the Research Advisory Staff. We welcome your questions and comments; please e-mail them to the authors or to Evelyn Alfaro, RAD.