The Effects of Pollution on Health: The Economic Toll

Measuring and valuing the health impacts of pollution are very complex, and available methods of economic analysis are often rudimentary. In recent years, however, considerable progress has been made, especially in respect to air pollution. This chapter summarizes the latest findings and outlines some basic approaches that can be applied in the economic analysis of Bank projects and sector studies. It should be noted that some uncertainty remains, and great care must be taken in the application of these methods.

Investments in air pollution control in Mexico City alone are likely to total more than US$4.7 billion over the next five years. Even modest water and sewerage projects cost hundreds of millions of dollars. Health improvements are often cited as the major justification for such investments. Consequently, one of the more troublesome problems, both practical and ethical, facing policymakers is that of valuing the health impacts of pollution. While some argue that it is not possible (or morally ethical) to place monetary values on sickness or death, in many situations governments have to make choices about health interventions or investments. Should available funds go to air pollution reduction, or would they be better spent on water supply and sanitation? Or should priority be given to education and health care, or to some other pressing concerns? Putting a value (even if it is underestimated) on morbidity and mortality due to pollution can be a powerful tool for demonstrating the costs of inaction.

The problems of valuing the health impacts of pollution are twofold. The first difficulty is with the actual identification and measurement of health impacts. The second is that once impacts have been determined, it is often necessary to estimate monetary values for the associated morbidity (illness) and mortality (death).

Measuring the Health Impacts of Pollution

The health impacts of air and water pollution are well recognized. Air pollution affects human health in a variety of ways, from itchy eyes and chest discomfort, to chronic bronchitis and asthma attacks, to premature death. There is ample evidence that inadequate water supply and sanitation can have a significant impact on the incidence of mortality and morbidity associated with diarrhea, intestinal nematodes, and other diseases.

The most accurate way of measuring the health impacts of air pollution or of lack of access to clean water and sanitation in a given area is to conduct epidemiologic studies for that area that establish dose-response relationships (DRRs) linking environmental variables with observable health effects. However, given the time and cost involved in such studies, as well as likely problems with data availability, it may often be the case that DRRs established in other locations will have to be used instead. This chapter summarizes recent progress in quantifying air pollution dose-response functions and addresses major problems in applying these functions to other situations. In the case of water pollution, establishing DRRs is more complicated and far less advanced, since it is not ambient water quality per se that affects health but access to clean drinking water and adequate sanitation, along with the household's level of income and education. Box 1 describes an approach adopted in a recent study of pollution problems in Brazil.

Air Pollution Dose-Response Studies

Dose-response functions correlate mortality and morbidity outcomes for susceptible population groups with the ambient concentrations of a

given air pollutant. Most have focused on the mortality effects of exposure to particulates. Chronic exposure to particulates can lead to premature death by exacerbating respiratory illness, pulmonary disease, and cardiovascular disease. Acute exposure (short-term peaks in the levels of particulates) can increase the chance that a person in a weakened state or an especially susceptible person will die. Detailed studies completed in recent years conclusively indicate that fine particulates (usually measured as $PM_{2.5}$) are responsible for most of the excess mortality and morbidity associated with high levels of exposure to particulate matter. (See Airborne Particulate Matter in Part III of this *Handbook*.)

Although a single study that finds a statistically significant association between a health effect and a specific air pollutant does not prove causality, the inference of causation is strengthened if epidemiologic results are duplicated across several studies, if a range of effects is found for a given pollutant, and if these results are supported by human clinical and animal toxicology literature. An approach for reducing the uncertainty associated with individual studies is to use meta-analytical techniques that, on the basis of the statistical pooling and aggregating of results from several studies, produce a "best estimate" in which more confidence may be placed.

The reported epidemiologic studies involve two principal study designs: time-series and cross-sectional. The more common time-series studies correlate daily variations in air pollution with

Box 1. Health Benefits of Water Supply and Sanitation in Brazil: A New Approach

Few studies have attempted to use epidemiologic data on water-related diseases as the basis for setting priorities in expanding water and sanitation services. A recent World Bank study in Brazil drew on a detailed epidemiologic study of the impact of water and sanitation on infant and under-five mortality to estimate the net benefits of improvements in water and sanitation.

The analysis was carried out using a sample of 1,533 municipalities in four states—Minas Gerais, Pernambuco, Rio de Janeiro, and São Paulo—that represent the full range of incomes and living conditions in Brazil today. The main independent variables used in the analysis were average income of head of household, percentage of population living in urban areas, percentage of females age 5 or older who are illiterate, percentage of urban population served by piped drinking water, and percentage of total population served by sewers or septic tanks. The analysis established that the coefficients for the variables characterizing income per person, the level of female education, and access to piped water and sanitation are highly significant and negative. The coefficient on the level of urbanization turned out to be very significant and positive; infant and under-five mortality rates are higher in urban than in rural areas if other factors are held constant. The relative importance of water and sanitation can be illustrated by the impact on mortality rates of 10-percentage-point increases in water and sanitation variables, as shown below.

	Impact of water and sanitation on mortality rates	
	Infant mortality	*Under-five mortality*
Change (reduction) per 10-percentage-point rise in:		
Urban access to piped water	0.8	0.25
Urban access to sewers	0.6	0.15
Average mortality rate	39.4	8.8

The health benefits that would be generated by expanding urban water and sewerage services are large. The analysis shows that in the four states sampled, it should be possible to avoid nearly 3,000 deaths of babies and young children each year and so reduce the burden of disease by nearly 220,000 disability-adjusted life years (DALYs). The largest impact would be achieved by ensuring that the entire urban population has access to piped water, at an average cost of US$1,560 per DALY. The average cost per DALY saved by expanding urban sewers is much higher, US$2,440, but it is still well below a reasonable estimate of willingness to pay to save a DALY in Brazil. Even if the value of statistical life (VOSL) were set at only US$1 million for the United States, this would imply an average willingness to pay per DALY saved for Brazil of about US$5,500 in 1991, well above the annualized costs per DALY saved by expanding water supplies and sewers for all but a small number of municipalities.

Source: World Bank 1997.

variation in daily mortality in a given city and measure, primarily, the effects of acute exposure to air pollution. The advantage of these studies is that they do not have to control for a large number of confounding factors, since the population characteristics (age, smoking, occupational exposure, health habits, and so on) are basically unchanged. On the basis of meta-analysis of acute mortality studies that measure the ambient levels of particulates of less than 10 microns in aerodynamic diameter (PM_{10}), estimates of average percentage change in total mortality per 10 microgram per cubic meter ($\mu g/m^3$) change in PM_{10} range from 0.74 (Maddison 1997) to 1.23 (Ostro 1996).[1]

A cross-sectional analysis compares differences in health outcomes across several locations at a selected point or period of time and, in principle, allows the capture of both acute and chronic effects of air pollution. Two types of cross-sectional long-term exposure studies can be distinguished. The first type is a retrospective (ecological) cross-sectional study design that correlates variations in air pollution levels with mortality rates across various locations at a single point in time. Such studies have consistently found measurably higher mortality rates in cities with higher average levels of particulate matter in the United States. A common concern about these studies is whether potential omitted and confounding variables have been adequately controlled.

A second type involves a prospective cohort design in which a population sample is selected and followed over time in each location. These studies use individual-level data, allowing other health risk factors to be better taken into account. Two such studies conducted to date (Dockery et al. 1993; Pope et al. 1995), both in the United States, reported a statistically significant correlation between exposure to particulate matter, measured as PM_{10} or $PM_{2.5}$, and mortality, which was considerably higher by comparison with acute mortality studies. (Pope et al. 1995 found a 4.2 percent change in all-cause mortality per 10 $\mu g/m^3$ change in PM_{10}.) Prospective cohort studies have potentially greater value for public health and environmental policies and for estimating dose-response functions that can be applied elsewhere. However, these studies are most expensive, so their replication is difficult. Since cohort studies are few and cross-sectional studies are less reliable, the question remains, how can long-term exposure to particulates be factored into results based on acute exposure mortality studies that seem to provide lower-bound estimates for the health effects of air pollution?

In addition to mortality counts, dose-response functions can also be derived for many lesser health impacts, for example, respiratory hospital admissions, emergency room visits, bed disability days, restricted activity days, minor restricted activity days, asthma attacks, acute respiratory symptoms, chronic bronchitis, lower respiratory illness, and so on. The principal results from meta-analyses of available studies for a number of key air pollutants (PM_{10}, sulfur dioxide, nitrogen dioxide, and ozone) are summarized in Table A.1.

Valuation of Health Impacts

Several methods have been used in various studies to value the health costs associated with environmental pollution. These methods can be grouped in two broad categories. The first includes methods that measure only the loss of direct income (lost wages and additional expenditures). These measures do not include inconvenience, suffering, losses in leisure, and other less-tangible impacts to individual and family well-being and may seriously underestimate or completely ignore the health costs of people who are not members of the labor force. Therefore, they indicate only the lower bound of the social costs and understate the total costs to individuals. The second category includes approaches that attempt to capture individuals' willingness to pay to avoid or reduce the risk of death or ill health. The principal techniques are summarized in Table 1 and discussed below.

Lower Bound of the Social Costs Estimates

The human capital approach, which places a value on a premature death, is the easiest but perhaps the least accurate and most ethically troubling method of valuing health impacts. It considers individuals as units of human capital that produce goods and services for society. Just as the

Table 1. Valuation Methods for the Health Effects of Pollution

Valuation method	*Example*
Human capital	Earnings forgone due to premature death as a result of exposure to air or water pollution
Cost of illness	Lost workdays, plus out-of-pocket costs (medical and other), due to health effects of pollution
Preventive or mitigative expenditure	Purchase of bottled water to avert health effects of polluted water Installation of air conditioners to avert air pollution in the residence
Wage differential	Value of reduction of risk to health implicit in the difference in otherwise similar occupations
Contingent valuation	Direct questioning to provide a value for a potential change in air quality or health

useful life of man-made capital can be calculated on the basis of the discounted stream of future production, the human capital theory assumes that the value of each unit of human capital is equivalent to the present value of the future output, in the form of earnings, that might have been generated had the individual not died prematurely.

The values calculated are very dependent on the age of death and on income, skill level, and country of residence. (Both the very young and the old would have low values when the human capital approach is used; see Table 2.) For example, in Mexico each life lost due to exposure to TSP pollution was valued at US$75,000, using the human capital approach, whereas in Brazil, the cost of premature death was estimated at US$7,700 for São Paulo in 1989 and at US$25,000 for Cubatao in 1988. The big difference between São Paulo and Cubatao was accounted for by the difference in average age at which exposed people died.

Table 2. Human Capital and Mortality Cost by Age, United States

Age group (years)	*Life years lost*	*Mortality cost (1992 U.S. dollars)*
Under 5	75	502,421
5–14	68	671,889
15–24	57	873,096
25–44	42	785,580
45–64	25	278,350
65 and older	10	22,977

Note: The cost estimates are based on life expectancy at the time of death and include labor-force participation rates, average earnings, the value of homemaking services, and a 6% discount rate.
Source: Institute for Health and Aging.

Even taking only this minimal estimation of the cost of deaths, the economic benefits of investments that prevent the health effects of pollution are often apparent. For example, the minimal estimate of the "worth" of the life of a child outweighs the costs of a major immunization program.

The cost of illness approach applies to morbidity and is consistent with the human capital approach. The direct cost of morbidity can be divided into two categories: medical expenditure for treating illness (a large portion of the costs of hospital admissions and emergency room visits) and lost wages during days spent in bed, days missed from work, and other days when activities are significantly restricted due to illness.

For example, in Mexico in 1990, cases of nonlethal diarrhea were estimated to number 3,360,000. The costs of treatment and laboratory analysis alone came to US$30 million, or about US$9.00 per person. (This figure represents less than 1% of the estimated costs for deaths from similar causes.)

Under the *preventive expenditures approach,* tentative inferences about the minimum amount people are willing to pay to reduce health risks are made on the basis of the amounts people living in polluted areas spend on averting measures. For example, expenditures on bottled water can be used to infer the minimum value people are willing to pay to avoid waterborne diseases.

Willingness-to-Pay Approaches

If people's preferences are a valid basis on which to make judgments concerning changes in human well-being, it follows that changes in human mortality and morbidity should be valued accord-

ing to what individuals are willing to pay for (or are willing to accept as compensation for) the changes in health status or the risks that they face. This is not the same as valuing an actual life and should not be interpreted as such. Instead, it involves valuing ex-ante changes in the level of risk people face and then aggregating those changes. Since the exact identity of those at risk is unknown, valuing ex-ante changes in the level of risk is the appropriate policy context.

The *wage differential approach* uses differences in wage rates to measure the compensation people require for (perceived) differences in the chance of dying or falling ill from occupational hazards. Recent wage differential studies in the United States have produced estimates of the value of statistical life (VOSL) in the range of US$1.9 million–$10.7 million (1990 dollars).

The *contingent valuation approach* uses survey information to determine what people are prepared to pay to reduce the likelihood of premature death or of certain diseases. Contingent valuation studies have produced slightly lower estimates of US$1.2 million–$9.7 million (1990 dollars) per statistical life.

A question often asked is how a difference in the age distribution of those involved in willingness-to-pay studies and those primarily affected by pollution would affect the VOSL estimates. Wage differential studies measure compensation for risk of instantaneous death for people of about 40 years old and thus value approximately 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. For instance, the relative numbers of people over 65 and people under 65 who will die prematurely from air pollution in the United States (estimated at 85% of the over-65 group), coupled with some evidence of a lower willingness to pay for that group (about 75% of mean willingness to pay), implies that the respective VOSL should be adjusted downward by 20%.

The concept of disability-adjusted life years (DALYs) provides a standard measure of the burden of disease (World Bank 1993; Murray and Lopez 1996). DALYs combine life years lost due to premature death and fractions of years of healthy life lost as a result of illness or disability. A weighting function that incorporates discounting is used for years of life lost at each age to reflect the different social weights that are usually given to illness and premature mortality at different ages. Thus, it is possible to link the VOSL obtained from wage differential and contingent valuation studies with the corresponding number of DALYs lost and so estimate the implicit value per DALY, as well as adjust the respective VOSL according to an average number of DALYs lost in a specific study. DALYs can also serve as an independent aggregate measure of health benefits (losses) in cost-effectiveness analysis of pollution control policies and options.

Although the valuation of morbidity is very important to cost-benefit analysis of air pollution control programs and to many other areas of economic activity, relevant studies are much more limited in scope and are based entirely within the United States. The main findings are shown in Table A.2.[2]

How Can These Methods Be Used in Developing Countries?

How appropriate is it to transfer the results from dose-response studies of air pollution in industrial countries into the context of developing countries? Three issues warrant careful attention:

- *Measures of particulate matter.* To obtain reliable results when applying dose-response functions derived in other countries, it is essential to use epidemiologic studies based on PM_{10} or $PM_{2.5}$ in combination with PM_{10} or $PM_{2.5}$ measurements for the country in question.
- *Disease-specific mortality profile.* If the distribution of deaths by cause differs significantly between the country of interest and the countries where dose-response studies were done, it may be necessary to use dose-response functions for disease-specific mortality or to adjust for the difference to improve the accuracy of the projections. For instance, exposure to particulates affects primarily respiratory and cardiovascular deaths, which account for half of all deaths in the United States. In Delhi, fewer than 20% of all deaths are attributable to these causes. Therefore, even identical reactions by susceptible groups of population in Delhi and the United States to the change in the levels of particulates would result in a lower total mortality in Delhi (Cropper and Simon 1996).

- The *age pattern of deaths from air pollution causes.* The age profile of those affected by air pollution may be very different in developing and industrial countries. Whereas peak effects were observed among people age 65 and older in the United States (Schwartz and Dockery 1992), in Delhi, peak effects occur in the 15–44 age group, implying that more life years are lost there as a result of a death associated with air pollution (Cropper et al. 1997).

The need to adjust the social costs of mortality and morbidity for income levels in different countries is obvious. In the United States, for example, VOSL estimates are typically 5 to 10 times higher than the value of forgone earnings. If people in other countries were equally risk averse, it would be appropriate to multiply the value of forgone earnings by the same factor. It is plausible to assume, however, 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 in the United States. Unfortunately, the literature on the income elasticity of willingness to pay for reducing the risk of insults to health is extremely limited, and empirical analyses in industrial countries do not lend sufficient support to this assumption (Maddison, et al. 1997). Until further research is conducted, one possible approach is simply to adjust an average U.S. value for the income difference between countries. For a conservative estimate of the VOSL in a developing country, a lower-bound U.S. value, adjusted for the income difference, can be used.

Application of this approach to valuing a variety of health effects of exposure to particulate matter in China produced estimates of the total health costs of urban air pollution countrywide of about US$27 billion–$32 billion. Estimates of the costs attributable to mortality were US$11billion–$15 billion. It is important to stress that, under a number of assumptions on dose-response levels and base costs for these health effects drawn from different studies, the social costs of morbidity consistently appeared to be as significant as those of mortality.

The approaches to measuring the physical impact and health costs of pollution outlined above represent the cutting edge of research in this area. Although carefully scrutinized in the light of the best available evidence from toxicological, epidemiologic, and economic work, these approaches are inevitably surrounded by some degree of uncertainty and controversy. They are presented to respond to the need of Bank staff and consultants to strengthen the economic analysis of pollution control projects and policies and to help in advising policymakers on the necessary level of targets and interventions. Application of these approaches to a specific context of any particular project or study requires careful interpretation, and the limitations of the analysis should be fully understood before making conclusions and recommendations on its basis.

Annex. Measuring and Valuing the Morbidity Effects of Air Pollution

Table A.1. Morbidity Effects for Key Air Pollutants

Health effects	*PM_{10} (per μg/m³)*	*SO_2 (per μg/m³)*	*NO_2*	*1-hour ozone (per ppm)*
Respiratory hospital admissions per 100,000 population	1.2 (Ostro 1994) 0.294 (Maddison 1997)	0.201 (Maddison 1997)	0.165 per ug/m³ (Maddison 1997)	0.77 (Ostro 1994) 0.429 (Maddison 1997)
Asthma attacks per 100,000 asthmatics	3,260 (Ostro 1994) 6,499 (Maddison 1997)			6,800 (Ostro 1994) 7,356 (Maddison 1997)
Emergency room visits per 100,000 population	23.54 (Ostro 1994; Maddison 1997)			
Restricted activity days per 100,000 adults	5,750 (Ostro 1994; Maddison 1997)			
Lower-respiratory illnesses per 100,000 children	169 (Ostro 1994; Maddison 1997)			
Respiratory symptoms per 100,000 adults	18,300 (Ostro 1994; Maddison 1997)			5,475 (Ostro 1994; Maddison 1997)
Chronic bronchitis per 100,000 adults	6.12 (Ostro 1994; Maddison 1997)			
Cough days per 100,000 children		1.81 (Ostro 1994; Maddison 1997)		
Chest discomfort days per 100,000 adults		1,000 (Ostro 1994; Maddison 1997)	1,000 per ppm (Ostro 1994)	
Minor restricted activity days per 100,000 adults				3,400 (Ostro 1994; Maddison 1997)
Eye irritation per 100,000 adults				2,660 (Ostro 1994; Maddison 1997)

Note: ppm, part per million; PM_{10}, particulate matter 10 microns or less in aerodynamic diameter; SO_2, sulfur dioxide; NO_2, nitrogen dioxide; μg/m³, micrograms per cubic meter.

Table A.2. The Social Costs of Morbidity

Morbidity effect	*Study*	*Duration (days)*	*Valuation type*	*Value per case (1993 U.S. dollars)*
Respiratory hospital admissions	Cropper and Krupnick 1989	9.5	Cost of illness	7,248
Emergency-room visits	Rowe et al. 1986	1	Cost of illness	242
Severe chronic bronchitis	Viscusi et al. 1991	15,596	Willingness to pay	1,030,000
Bad asthma days	Rowe and Chestnut 1985	9.5	Willingness to pay	578
Cough day	Tolley et al. 1986	1	Willingness to pay	35
Eye irritation	Tolley et al. 1986	1	Willingness to pay	38

Notes

1. Only estimates based on studies using PM_{10} are cited here, because PM_{10} is a better proxy for fine particulates than other measures (e.g., TSP; black smoke, or BS) employed in a variety of studies. A number of estimates have been produced across studies that use different measures of particulate matter. In producing these estimates, TSP is usually converted to PM_{10}, using a factor of 0.55, and BS and COH are considered equal to PM_{10}. These estimates are less reliable, however, because variations in the levels of TSP or other measures of particulates may be quite different from those for PM_{10} and even more different for $PM_{2.5}$. As more studies using $PM_{2.5}$ become available, the analysis will have to focus on those studies.

2, A potentially useful approach is to integrate the health status index literature with the willingness-to-pay morbidity valuation literature. The health status index literature attempts to measure perceptions of well-being on a cardinal scale from 0 (death) to 1 (perfect health). Once the relationship between the health status index and willingness to pay is found, willingness to pay can be predicted for any condition (which can be described using the health status index), even conditions for which no valuation experiments are available. This approach has been taken in TER (1996) and Maddison et al. (1997).

References and Sources

Cropper, Maureen L., and Alan J. Krupnick. 1989. "Social Costs of Chronic Heart and Lung Disease." Resources for the Future, Washington, D.C.

Cropper, Maureen, and Nathalie Simon. 1996. "Valuing the Health Effects of Air Pollution." DEC Notes 7. World Bank, Washington, D.C.

Cropper, Maureen L., Nathalie B. Simon, Anna Alberini, and P. K. Sharma. 1997. "The Health Effects of Air Pollution in Delhi, India." Policy Research Working Paper 1860. World Bank, Development Economics Research Group, Washington, D.C.

Dockery, Douglas W., C. A. Pope, X. Xiping, J. Spengler, J. Ware, M. Fay, B. Ferris, and F. Speizer. 1993. "An Association between Air Pollution and Mortality in Six U.S. Cities." *New England Journal of Medicine* 329(24): 1753–59.

Esrey, S.A., et al. 1993. "Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Trachoma." *Bulletin of the World Health Organization* 69(5): 609–21.

Maddison, D. 1997. "A Meta-analysis of Air Pollution Epidemiological Studies." Centre for Social and Economic Research on the Global Environment. London: University College London and University of East Anglia.

Maddison, D., et al. 1997. "Air Pollution and the Social Costs of Fuels." World Bank, Environment Department, Washington, D.C.

Margulis, S. 1991. "Back of the Envelope Estimates of Environmental Damage Costs in Mexico." Latin American Region Discussion Paper. World Bank, Washington, D.C.

Mitchell, R. C., and R. T. Carson. 1989. "Using Surveys to Value Public Goods: The Contingent Valuation Method." Resources for the Future, Washington, D.C.

Murray, Christopher J. L., and Alan D. Lopez, eds. 1996. *The Global Burden of Disease.* The Global Burden of Disease and Injury Series, 1. Harvard School of Public Health. Cambridge, Mass.: Harvard University Press.

Ostro, Bart. 1994. "Estimating the Health Effects of Air Pollution: A Method with an Application to Jakarta." Policy Research Working Paper 1301. World Bank, Policy Research Department, Washington, D.C.

————. 1996. "A Methodology for Estimating Air Pollution Health Effects." WHO/EHG/96. Geneva, World Health Organization.

Pope, C.A., M., Thun, M. Namboodiri, D. Dockery, J. Evans, F. Speizer, and C. Heath. 1995. "Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults." *American Journal of Respiratory and Critical Care Medicine* 151: 669–74.

Rowe, R., and V. Chestnut. 1985. "Oxidants and Asthmatics in Los Angeles: A Benefits Analysis." U.S. Environmental Protection Agency, Washington D.C.

Rowe, R., et al. 1986. "The Benefits of Air Pollution Control in California." Energy and Resource Consultants Inc., Boulder, Colo.

Schwartz, Joel, and Douglas Dockery. 1992. "Increased Mortality in Philadelphia Associated with Daily Air Pollution Concentrations." *American Review of Respiratory Disease* 145: 600–604.

TER. 1996. "Valuing Morbidity: An Integration of the Willingness to Pay and Health Status Index Literatures." Durham, N.C.

Tolley, George, et al. 1986. "Valuation of Reductions in Human Health Symptoms and Risk." In *Contingent Valuation Study of Light Symptoms and Angina.* Washington, D.C.: U.S. Environmental Protection Agency.

Viscusi, W. Kip. 1993. "The Value of Risks to Life and Health." *Journal of Economic Literature* 31: 1912–46.

Viscusi, W. Kip, et al. 1991. "Pricing Health Risks: Survey Assessments of Risk-Risk and Dollar-Risk Tradeoffs." *Journal of Environmental Economics and Management* 21(1): 32–51.

World Bank. 1993. *World Development Report 1993: Investing in Health.* New York: Oxford University Press.

————. 1997. "Brazil: Managing Pollution Problems —The Brown Environmental Agenda." Washington, D.C.