Economic Valuation of the Health Benefits of Reduction in Air Pollution

Improvements in human health are a major reason for implementing programs to reduce air pollution. This note discusses how economists place a monetary value on reductions in premature death and illness from air pollution, and how the monetized value of health benefits from reducing air pollution can be useful to policymakers. Studies that estimate the monetary value of health benefits associated with a reduction in ambient concentrations can draw attention to the need for air pollution control policies and can be used as inputs into cost-benefit analyses of air pollution control programs.

Reductions in ambient levels of the common air pollutants (such as particulate matter [PM] and ozone) have been associated with reductions in premature mortality from heart and lung disease, as well as reductions in chronic bronchitis, asthma attacks, and other forms of respiratory illness (for relationships between air pollution and health outcomes, see Briefing Note No. 11 [1]). This note presents the methods used to perform economic valuation of changes in illness and premature mortality and discusses the appropriateness of transferring health benefit estimates from studies in other regions to South Asia. This is followed by illustrations of how the monetary value of health benefits associated with improvements in air pollution can be useful to policymakers.

Valuing Reductions in Illness

What is being valued?

Improving air quality should reduce the number of episodes of acute illness (such as asthma attacks) experienced each year, as well as the number of cases of chronic respiratory illness that occur. To economists the value of avoiding an illness episode, such as an asthma attack, consists of four components: (1) the value of the work time lost due to the attack (by the asthmatic or an unpaid caregiver or both); (2) the medical costs of treating the attack; (3) the amount an asthmatic (or, in the case of a child, the child’s parents) would pay to avoid the pain and suffering associated with the attack; and (4) the value of the leisure time lost due to the attack (by the asthmatic or a caregiver).

If the asthmatic were to bear all costs of the attack (including lost work time and medical costs) his or her stated willingness to pay should reflect all four components of value. If, in contrast, the asthmatic has health insurance and paid sick leave, he or she will not bear all medical costs and productivity losses. These are, however, legitimate economic costs and must be included in the value of an illness episode.

Calculating the value of avoided illness

How are the four components of the value of avoiding illness measured? Medical costs and productivity losses are often estimated by asking about the type of treatment sought during an illness episode, and by asking how long the episode lasted and for how many days the patient (or a family caregiver or both) were unable to perform their usual duties. Lost work time is then valued at the wage rate and medical costs are imputed based on the full social costs of providing the care, not just the costs to the patient. Economists usually estimate the value of pain and suffering avoided and the value of leisure time gained by direct questioning: that is, people are asked what they would pay to avoid the discomfort and inconvenience of an illness of a specific type and duration. This approach is referred to as the contingent valuation method (CVM) or the stated preference method.

When estimates of the value of pain and suffering and lost leisure time are unavailable, medical costs and productivity losses are often used to provide a lower bound to the value of avoiding illness. This is referred to as the cost-of-illness (COI) approach to valuing morbidity. Medical costs are referred to as the direct costs of illness and productivity losses as the indirect costs of illness. In the case of a serious but infrequent illness, such as a stroke, reducing air pollution reduces the risk of a person having a stroke. Thus what should be estimated is what a
person would pay to reduce his or her risk of having a stroke. In practice, the COI approach is often used to value serious illnesses, such as a heart attack or stroke, since empirical estimates of what people are willing to pay to avoid the pain and discomfort of these conditions tend to be lacking.

Valuing Reductions in Premature Mortality

What is being valued?

Studies of the air pollution effects on premature mortality predict how many fewer people are likely to die if air pollution is reduced. For example, a 10 percent reduction in PM$_{10}$ (particles smaller than 10 microns) in Delhi, India, might result in 1,000 fewer deaths each year. We refer to the 1,000 fewer deaths as the number of statistical lives saved by improving air quality. What this means is that the risk of dying is reduced by a small amount for all people living in Delhi and that these risk reductions add up to 1,000 fewer deaths. To illustrate, if reducing air pollution in Delhi results in 1,000 fewer deaths in a population of 10 million, this is equivalent, on average, to reducing risk of death annually by 1 in 10,000 (0.0001) for each person in the population (calculated from dividing 1,000 deaths by 10 million people, or 0.0001)

Since reducing air pollution reduces risk of death by a small amount for each person in an exposed population, what economists wish to estimate is what each person in the population would pay for this small risk reduction. If this willingness to pay (WTP) were added across all 10 million residents of Delhi, it would represent the value of saving 1,000 statistical lives. Dividing the total willingness to pay by the number of statistical lives saved yields the average value of a statistical life (VSL). People's willingness to pay (WTPs) for small risk reductions are usually stated in terms of the VSL—the sum of WTPs for risk reductions that save one statistical life.

Calculating the value of a reduction in risk of death

Economists realize that people trade money for safety every day. Workers are willing to work in riskier jobs if they are compensated for it, and people are willing to pay for safer vehicles or for helmets to protect themselves when riding two-wheelers. WTP for a reduction in risk of dying is usually estimated from studies on compensating wage differentials in the labor market, or expenditures to reduce risk of death. These studies are usually referred to as revealed preference studies because they are based on actual behavior. A second source of estimates are stated preference studies in which people are asked directly what they would pay for a reduction in their risk of dying (also called CVM, referred to above in the context of valuing morbidity).

Studies of compensating wage differentials or expenditures on safety must determine what portion of the wage or what portion of the vehicle price represents payment for safety. This payment is then associated with the size of the risk differential to infer what people are willing to pay for it. For example, compensating wage studies empirically explain variations in the wage received by workers as a function of worker characteristics (age, education, skills) and job characteristics, including risk of fatal and nonfatal injury, in order to determine what portion of wage represents compensation for risk of death. In theory, the impact of small changes in the risk of dying on wages should equal the amount a worker would have to be compensated to accept this risk.

Compensating wage differential studies in the United States indicate that the VSL is approximately US$5 million (1990 US dollars) [2]. These studies may overstate the VSL for reductions in air pollution because people prematurely dying from air pollution in North America are much older than the workers in these studies whose average age is about 40. Conversely, the VSL for environmental risks may be higher because these risks are involuntary.

Unlike compensating wage differential studies, contingent valuation studies directly ask persons at risk what they are willing to pay for changes in life expectancy, and can be tailored to the age at which risk reductions occur and to the nature of the risks valued. They generally yield lower estimates of WTP than wage differential studies. These studies often have difficulty eliciting consistent values for small probability changes that are difficult for respondents to perceive and value.

When WTP estimates are not available, the human capital (human capital refers to knowledge and skills found in the labor force) approach can be used to obtain a lower bound to WTP. This approach values loss of life based on the foregone earnings associated with premature mortality. The notion is that people should be willing to pay at least as much as the value of the income they would lose by dying prematurely. This is not the theoretically correct approach to valuing a program that reduces the risk of dying, but does provide a useful lower bound to WTP [3]. Studies in the United States indicate the VSL is about 8 to 23 times larger than foregone earnings.

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1 For simplicity, this example assumes that all people in Delhi benefit equally from the air pollution reduction. In reality, people with heart and lung disease are likely to benefit more than others.

2 The goal of calculating the VSL is to estimate what people themselves would pay for risk reductions. The VSL is not intended to estimate the intrinsic value of human life.
Valuing Health Benefits in South Asia

Few studies have been published using data for South Asia that estimate WTP to reduce mortality or morbidity. This implies that monetization of health benefits must, in the immediate future, rely on transferring WTP estimates from one country to another or must calculate a lower bound to benefits based on foregone earnings (for mortality benefits) or the cost of illness (for morbidity benefits).

The standard approach to benefits transfer implicitly assumes that preferences are the same in the two countries, including attitudes toward risk when estimates of the VSL are transferred. WTP is assumed to differ only as a result of differences in income between the two countries. If this is true, U.S. WTP can be transferred to South Asia after accounting for income differences as shown in equation (1):

\[ WTP_{SA} = WTP_{US} \left[ \frac{Income_{SA}}{Income_{US}} \right]^e \] (1)

where \( Income_{SA} \) is the income in South Asia measured in US dollars and \( e \) represents the income elasticity of WTP: the percentage change in WTP corresponding to a 1 percent change in income. There is considerable uncertainty regarding the income elasticity of WTP, even within a country. A conservative approach to benefits transfer is to use an income elasticity of 1.0, including smaller and larger values for sensitivity analysis. For example, the transfer of a U.S. VSL of US$1 million to India using 1998 purchasing power parity\(^3\) income and an elasticity of 1.0 yields a VSL for India of US$69,000. Using the nominal exchange rate to convert the income in India rather than purchasing power parity would give a lower estimate, and is typically not done on methodological grounds. Overall, since the assumptions underlying benefits transfer may not be valid, it is always desirable to provide lower-bound estimates of the value of health benefits based on the COI approach for morbidity and the human capital approach for mortality, and to compare these with higher values based on the WTP and VSL approaches.

The Policy Relevance of Health Benefits Analysis—Example from Mexico City

To illustrate the usefulness of computing the monetary value of health benefits, the results of a study in Mexico City are given in Table 1 [4]. The study quantified the effect of 10 and 20 percent reductions in annual average population-weighted ozone and PM\(_{10}\) concentrations in Metropolitan Mexico City in the year 2010. The impact of each pollutant reduction was first expressed in terms of cases of illness and premature death avoided; then dollar values were assigned to health benefits.

Three approaches were used to value reductions in illness and premature mortality. The most conservative, giving the “low estimate,” was to value mortality using foregone earnings and morbidity using productivity losses plus medical costs, that is, COI. This should be viewed as a lower bound to the value of health benefits. A less conservative approach, giving the “central case estimate,” was to add estimates of WTP to avoid the pain and suffering associated with illness to the COI used in computing the low estimate of benefits, but to use foregone earnings to value reduced mortality. The “high estimate” used the same method of valuing avoided morbidity as the central case estimate but uses WTP (that is, the VSL) in place of foregone earnings to value avoided mortality.

WTP estimates were transferred from studies conducted in the United States and Europe, using an income elasticity of WTP of unity and purchasing power parity incomes. The resulting VSL for Mexico City was approximately US$300,000 in 1999 US dollars.

The values of reducing PM\(_{10}\) and ozone by 10 percent and 20 percent appear in Table 1. Two features of the results warrant discussion. The first is that the dollar values of benefits associated with the 20 percent reduction scenario are exactly twice the values of the benefits of the 10 percent reduction scenario. In general, each additional 1 microgram per cubic meter (\(\mu g/m^3\)) reduction in annual average population-weighted PM\(_{10}\) will have approximately the same value, because the impact of a 1 \(\mu g/m^3\) change is assumed to be independent of baseline concentrations (see Briefing Note No. 11 [1] for discussion on differing baseline concentrations). In this case a reduction of 10 percent is equivalent to lowering PM\(_{10}\) by 6.4 \(\mu g/m^3\). This implies that, using the study’s central case estimate, a 1 \(\mu g/m^3\) reduction in PM\(_{10}\) is worth US$100 million (1999 US dollars) annually (US$644 million for COI+WTP divided by 6.4 \(\mu g/m^3\)).

The second point worth noting is that the value of the health benefits associated with a 10 percent reduction in ozone is much smaller than the value of the benefits of a 10 percent reduction in PM\(_{10}\) regardless of the approach used to monetize benefits. This is primarily because there are no studies relating reductions in long-term exposure to ozone to premature mortality. This does not imply, however, that programs to reduce the precursors of ozone (nitrogen oxides and volatile organic chemicals) or to reduce sulfur dioxide yield few health benefits. Both nitrogen oxides and sulfur dioxide may react with other

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\(3\) Purchasing power parity is a way to compare the costs of goods and services between countries. It is different from the official exchange rate and considers a rate of exchange that will give each currency the same purchasing power in its economy. In terms of purchasing power parity, local currencies in South Asia are worth much more than the official exchange rate.
substances in the atmosphere to form secondary particles. Programs to reduce oxides of nitrogen and sulfur are, therefore, likely to result in benefits from reduced particulate matter.

Table 1. Annual Health Benefits due to Ozone and PM$_{10}$ Reductions in Mexico City (In $10^6$ 1999 US$)

<table>
<thead>
<tr>
<th>Methodology for calculation</th>
<th>Air pollution reduction</th>
<th>Morbidity</th>
<th>Mortality</th>
<th>10%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits from ozone reduction</td>
<td>COI + WTP VSL</td>
<td>Human capital</td>
<td>116</td>
<td>232</td>
<td></td>
</tr>
<tr>
<td>Benefits from PM$_{10}$ reduction</td>
<td>COI + WTP VSL</td>
<td>Human capital</td>
<td>1,451</td>
<td>2,903</td>
<td></td>
</tr>
</tbody>
</table>

The use of benefit estimates in cost-benefit analyses

The estimates of health benefits, such as those computed in the Mexico City study in Table 1, could be used as inputs to a cost-benefit analysis of air pollution control strategies. To analyze the benefit of an air pollution control strategy one must first translate the control measures—for example, a program to convert diesel buses to compressed natural gas (CNG)—into changes in emissions of the common air pollutants, and then use air quality models to predict the change in ambient pollution concentrations associated with the control strategy. Once the changes in ambient concentrations associated with the control strategy have been estimated, they can be quantified and valued using the unit values derived in the health benefits analysis.

The final step in a cost-benefit analysis is to subtract the costs of the program (such as the cost of replacing diesel buses with CNG buses) from the benefits to determine the net social benefits of the program. Economists typically argue that control strategies should be ranked according to their net social benefits; this assumes that what matters is the total benefits to society versus the total costs to society of a program, even if the people who pay for the program are not the same people as those who benefit from it. The distribution of benefits and costs is, however, important information that should also be presented to policymakers, in addition to total benefits and costs.

Conclusions

- The economic benefits of reducing illness and premature mortality associated with air pollution are well defined, and empirical estimates of these benefits (for example, of the VSL) exist for industrial countries.

- In performing health benefits analyses for South Asia, reliance will have to be placed on benefits transfer in the immediate future. In addition, it should be possible to calculate a lower bound to benefits using the cost of illness and human capital approaches. Policy interventions that can be justified on the basis of lower-bound estimates of benefits are likely to be robust and merit serious consideration.

- Calculating the monetary value of health benefits associated with small (for example, 10 percent) changes in the common air pollutants is useful for two reasons: (1) it provides estimates of the value of a one unit reduction in each pollutant that can serve as input into a cost-benefit analysis of air pollution reduction strategies; and (2) it can indicate the relative benefits of controlling one pollutant versus another.

References


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