Cost-benefit analysis and air quality policy

Cost-benefit analysis (CBA) is an important tool for estimating societal costs and benefits.

The place for CBA studies

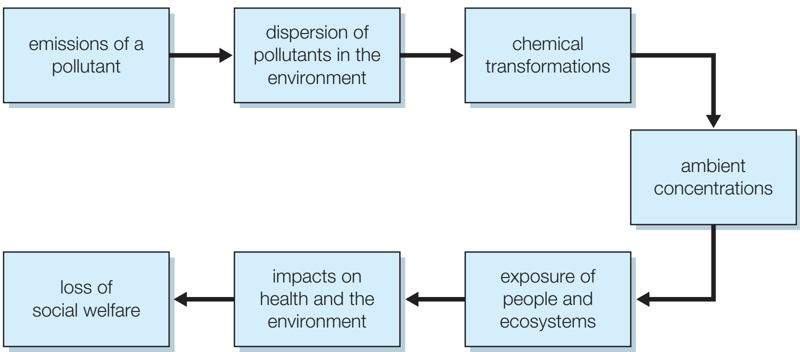
Air quality policy measures implemented in the past decades have successfully reduced national pollutant emissions in all European countries. Not surprisingly, it now becomes more difficult to identify additional measures that will lead to meaningful emission reductions and air quality improvements, and costs associated with such measures tend to escalate. CBA is used to evaluate whether the societal benefits of a particular policy option will exceed its societal costs, but does not explore alternatives to this option. To ensure that policy development is robust, it is important therefore to take a broader view and consider whether money spent to address one societal 'risk' may provide greater societal benefits if used elsewhere.

Although this article focuses on CBA as one of the tools used to compare the societal costs and benefits of air quality policy, this tool is focused, by its very nature, on single issues. It does not lead directly to an assessment of whether better outcomes could be achieved by using the same expenditure to address other societal risks.

Air pollution is a consequence of many types of economic activity, including industrial production, transport, agriculture, energy production, and so on. There is now a long history of developing cleaner production techniques and clean technology options to reduce pollution from these and other sectors. The widespread use of these technologies has led to considerable improvements in European air quality in recent decades.

Nevertheless, ambient air pollution remains a societal concern due to remaining emissions. In some areas, especially within cities where emissions from transport, industries, and other commercial and domestic sources are concentrated, pollutant levels too frequently exceed air quality standards. The pollutants most often associated with adverse health impacts include NO_x, SO_x, ozone and particulate matter (PM). Based on measurement practicalities, PM is most frequently defined by particle size, with the fraction having an aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) considered to be the most harmful to human health. However, $PM_{2.5}$ can originate from many sources and can have different chemical compositions with a varying degree of risk to human health, as was discussed in CONCAWE *Review* Vol. 21, No. 1.

Figure 1 Causal chain for modelling the societal costs of air pollution



Analysing the costs of air pollution

Analysing the societal costs of air pollution involves a number of steps, as shown in Figure 1. First, the way in which emissions are dispersed from their primary sources and subsequently transformed in the atmosphere must be modelled. Every pollutant has specific chemical characteristics and will follow a different pathway as a function of its emission source, prevailing wind conditions, temperature and other pollutants. The exposure of people to these pollutants will depend on individual behaviour, for example the time that a person spends indoors and outdoors, the time spent commuting, and so on. Similarly, the environmental impacts of pollutants will depend on local characteristics. For example, different ecosystems have different capacities to absorb pollutants from the atmosphere.

Next, societal impacts must be understood and quantified. Human health impacts will depend on the exposure to pollution as well as on the health and lifestyle of each person. Environmental impacts will depend on the type of ecosystems involved and how these ecosystems are used by people (often expressed as 'ecosystem services'). Finally, changes in health and environmental quality are usefully expressed in monetary terms in order to assess the societal benefits of various emission reduction measures.

To model the causal chain shown in Figure 1, two steps are particularly important. First, sophisticated models, such as RAINS/GAINS, are used to relate the emission, dispersion, transformation and resulting concentrations of different air pollutants to their health and environmental impacts. In this step, the effectiveness and cost of different emission reduction measures are also evaluated. Second, a monetary evaluation of the health and environmental benefits is carried out by using statistical relationships between the concentrations and effects of air pollutants and by attributing specific costs to each effect. Expressing human health and mortality impacts in terms of an economic cost is controversial because it involves making assumptions about society's willingness to pay for a reduction in mortality risk, a statistical quantity which is not easily explained.

CBA studies on European air pollution

Three CBAs that evaluated European air pollution policies were completed in 2011 by AEA Technology, the European Environment Agency (EEA), and the EU-funded research project EC4MACS (European Consortium for Modelling of Air Pollution and Climate Strategies). It is useful to examine some of the important uncertainties in these studies, especially those related to the analysis of the costs of air pollution, and consequently the benefits from reducing pollution.

The AEA report (AEA, 2011) estimated the net economic benefits of a series of scenarios for pollution control. These scenarios were developed by IIASA in the context of the Gothenburg Protocol to the UNECE Convention on Long Range Transboundary Air Pollution (CIAM, 2011). The EEA report (EEA, 2011) was based on a technical paper prepared by the EEA's Topic Centre on Air Pollution and Climate Change Mitigation. This report assessed the costs to health and the environment resulting from pollutants emitted from European industrial facilities including power plants and other major industrial sites reporting via the European Pollutant Release and Transfer Register (E-PRTR).

Only an interim report was available from the EC4MACS project that presented an outlook of the likely development of air pollutant emissions and their economic costs to 2030 based on forecasts of economic development and the implementation of existing legislation on EU air pollution control measures.

These three assessments, in particular the AEA and EC4MACS reports, acknowledge that a significant reduction in ambient air pollution concentrations has been achieved for almost all air pollutants in the past decades as a consequence of environmental policies and changes in energy use and economic activity. Nevertheless, these assessments also signalled to policy makers that further emission reductions would result in net economic benefits on a societal basis. As analysed below, however, there is a high degree of uncertainty in these CBAs, especially regarding the analysis of the economic costs of air pollution.

Methodology gaps and uncertainties

Recent analyses of the costs of air pollution in Europe are extensions of the Clean Air for Europe (CAFE) methodologies that were developed in the 1990s and are now part of the EC4MACS toolkit. Although there is a statistical association between air pollution and health, such as cardiovascular and respiratory problems, there is still uncertainty on three main issues: (i) the appropriate relationship between ambient air pollution and health effects; (ii) the economic costs of pollution-related health impacts; and (iii) the magnitude and costs of environmental impacts. These points are discussed below.

Ambient air pollution and health effects

Some key assumptions from the CAFE methodology have been incorporated into the recent CBAs. These include: (i) equal health impacts are assumed for all types of PM that originate from human activity while no health impacts are assumed for PM from natural sources, such as sea salt; (ii) there is no threshold level below which PM is not harmful to health; and (iii) there is a 6% increase in human mortality risk for every 10 µg/m^3 increase in long-term $PM_{2.5}$ concentration exposure.

The association between PM concentration and mortality risk and other health impacts is based on statistical analysis (Künzli *et al.*, 2000). One aspect that is generally acknowledged to lead to additional uncertainty is how the age distribution of the exposed population influences health risks. It is also uncertain how the chemical composition of the $PM_{2.5}$ fraction influences health impacts. For example, all particles in the

$PM_{2.5}$ fraction may not be equally harmful to human health (see also CONCAWE *Review* Vol. 21, No. 1). These sources of uncertainties should be reflected in sensitivity analyses of the cost and benefit assessments, and this has not been done in the three CBA studies cited above.

Economic costs of health impacts

In the monetisation of health impacts, the most critical issue is the value of health benefits that are attributed to better air quality. In the CAFE programme, the costs of premature mortality were assessed to be about 70% of the total costs of air pollution in Europe as a result of the monetary value assigned to a Year of Life Lost (YOLL)[1]. It was recognised at the time that the interpretation of health benefits based on avoided mortality (monetised using the Value of a Statistical Life or VSL) was inappropriate but the CAFE CBA included this as an alternative measure.

[1] See CONCAWE *Review* Vol. 21 No.1 for a discussion on YOLL.

Several economic valuation methods have been developed to estimate both VSL and the Value of a Life Year (VOLY) on the basis of price effects observed in the market, for example in the form of additional compensation for professions that experience a relatively high mortality risk. These methods are not applicable to air pollution risk mitigation, however, and the most common approach today is to estimate VOLY based on 'stated preferences'. This means that opinion surveys are used to ask a large number of people to state their 'willingness to pay' (WTP) for a risk reduction leading to a possibly longer life expectancy.

This method has two important drawbacks (e.g. Cummings and Harrison, 1995). First, as with any survey, the 'stated preferences' approach is sensitive to how the question is formulated. Second, the WTP survey is hypothetical because those surveyed don't actually have to pay anything and they know that they will not be asked to pay. Therefore, there is a risk that the WTP expressed will be too high, either for strategic reasons or because there is not enough consideration given to the actual ability to pay. In addition, the amount of money that most people would be prepared to pay to achieve a small increase in life expectancy is relatively more than they would pay for a longer increase, and more than they would pay for a short increase if they are in poor rather than good health. Thus, even within a survey, there are variations in the derived VOLY value based on the risk reduction choice. These uncertainties are expressed through the sometimes widely varying VOLY estimates that have been found in both European assessments and in the scientific literature.

A notable step forward on the understanding of VOLY was made in a recent scientific study (Desaigues *et al.*, 2011) as part of the NEEDs project. This study analysed theoretical aspects of VOLY and reported on the outcome of a recent WTP survey that determined VOLY in nine European countries. Desaigues *et al*. argued that the mean value from a WTP survey, and not the median, should be used as a VOLY. On this basis the recommended VOLY was €41,000 for the EU15 countries + Switzerland and €33,000 for new EU member countries. These differences in WTP reflect the role of population selection when conducting a WTP study.

The question about the most appropriate single value from a WTP survey to use for VOLY is not yet resolved. CONCAWE believes that neither the mean nor the median value is appropriate. The problem associated with choosing a single value from a WTP study is discussed in the following article in this *Review* and a novel approach is proposed.

The VOLY value proposed by Desaigues *et al*. (the mean from the WTP survey responses) is much lower than those used in the three cited CBAs. In these three studies, the mean WTP values were almost four times higher. In addition, the three cited CBA studies are seriously flawed in their use of premature mortality and VSL as alternatives to YOLL and VOLY to represent an uncertainty range for monetised health impacts. A proper analysis of the uncertainty in VOLY values should be completed in order to more realistically assess the monetised benefits of air pollution control measures.

Environmental impacts

The recent CBA studies have also quantified the costs of environmental damage, including both damage to the 'built' environment (buildings and infrastructure) and damage to the natural environment (ecosystems and crops). In general, estimated damages to the built environment are small compared to those in the natural environment.

There are several important uncertainties when analysing the costs of air pollution damage in the natural environment. First, ecosystems are under stress from many factors. Some of these are naturally occurring such as temperature extremes, excess or limited water, and limited availability of nutrients. Other stress factors include overgrazing or harvesting of wood and other resources. The relationship between different stress factors and ecosystem responses will be different for each species, so untangling the impact of air pollution in such complex systems is difficult (Grimm *et al.*, 2008). Interactions between pollutants and the environment are further complicated because ecosystem biotic and abiotic factors change significantly over time due to ecological processes. In addition to temperature variations on a daily and seasonal basis, there are also longer-term developments that affect the ecosystem over many years or decades. These time-dependent variations affect both polluted and pristine ecosystems so that no single point in time or space can be defined as being truly representative of the environment as a whole.

In natural ecosystems, the costs of air pollutants can be related to a decrease in the economic benefits supplied by ecosystems due to air pollution-related changes. However, the relationship between the state of the ecosystem and the economic benefits that can be expected from these ecosystems is not well understood (Daily *et al*., 2009). Furthermore, ecosystems are complex and dynamic systems and the response of an ecosystem to a change in air pollutants is difficult to predict. Costs could potentially arise from impacts on timber production, carbon sequestration, production of non-timber forest products, and so on. Better estimates for such costs may be revealed when more complete assessment methodologies are available. These complications are well recognised in the cited CBA studies, which only partially analysed environmental impacts. As is also the case for environmental impacts, the absence of a robust analysis of uncertainties in these CBA studies limits their relevance for policy decisions.

Conclusions

The three CBA studies cited in this article have two main deficiencies. First, they adopt a single and very high value for VOLY, which is not in line with recent scientific literature. Second, they do not conduct a rigorous analysis to account for important uncertainties in the cost-benefit analysis process. It is essential, therefore, for the CBA used in policy development to reflect up-to-date scientific insights and to include a rigorous analysis of uncertainties and their implications. Studies of this sort will guide a cost-effective reduction in health and environmental impacts while maintaining the global competitiveness of European industry.

References

AEA, 2011. *Cost Benefit Analysis for the Revision of the National Emission Ceilings Directive: Policy Options for Revisions to the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution*. European Commission framework contract ENV.C.5/FRA/2006/0071.

CIAM, 2011. *Cost-effective Emission Reductions to Improve Air Quality in Europe in 2020: Scenarios for the Negotiations on the Revision of the Gothenburg Protocol under the Convention on Long-range Transboundary Air Pollution.* Background paper for the 48th Session of the Working Group on Strategies and Review. Geneva, April 11–14, 2011. Version 2.1—March 31, 2011. Centre for Integrated Assessment Modelling (CIAM) and International Institute for Applied Systems Analysis (IIASA).

Cummings, R.G. and G.W. Harrison (1995), The measurement and decomposition of nonuse values: a critical review. *Environmental and Resource Economics*, 5: 225–47.

Daily, G.C., S. Polasky, J. Goldstein, P.M. Kareiva, H.A. Mooney, L. Pejchar, T.H. Ricketts, J. Salzman, and R. Shallenberger. 2009. Ecosystem services in decision making: time to deliver. *Frontiers in Ecology and the Environment*, 7: 21—28.

Desaigues, B., Ami, D., Bartczak, B., Braun-Kohlová, M., Chilton, S., Czajkowski, M., Farreras, V., Hunt, A., Hutchison, M., Jeanrenaud, C., Kaderjak, P., Máca, V., Markiewicz, O., Markowska, A., Metcalf, H., Navrud, S., Nielsen, J.S., Ortiz, R., Pellegrini, S., Rabl, A., Riera, R., Scasny, M., Stoeckel, M.-E., Szánto, R. and Urban, J., 2011. Economic valuation of air pollution mortality: A 9-country contingent valuation survey of value of a life year (VOLY). *Ecological Indicators*, 11 (3): 902–910.

EC4MACS, 2011. *Greenhouse gases and air pollutants in the European Union: Baseline projections up to 2030*. EC4MACS Interim Assessment. European Consortium for Modelling of Air Pollution and Climate Strategies.

EEA, 2011. *Revealing the costs of air pollution from industrial facilities in Europe*. European Environment Agency, Copenhagen, 2011.

Grimm, N.B., Foster, D., Groffman, P., Grove, J.M., Hopkinson, C.S., Nadelhoffer, K.J., Pataki, D.E. and Peters, D.P.C., 2008. The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. *Frontiers in Ecology and Environment* 2008; 6(5): 264–272.

Künzli, N., Kaiser, R., Medina, S., Studnicka, M., Chanel, O., Filliger, P., Herry, M., Horak, F. Jr., Puybonnieux-Texier, V., Quénel, P., Schneider, J., Seethaler, R., Vergnaud, J-C., Sommer, H., 2000. Public-health impact of outdoor and traffic-related air pollution: a European assessment. *Lancet* 356: 795–801.

See also the following CONCAWE *Review* articles:

Cost Benefit Analyses: some basic concepts and issues (CONCAWE *Review* Vol. 13, No. 2)

Evaluation of health impacts in an environmental cost benefit analysis: the challenge of allocating a monetary value to changes in human health due to air pollution (CONCAWE *Review* Vol. 15, No. 2)

Cost Benefit Analysis for air quality policies: an update and an IPPC Directive case study
(CONCAWE *Review* Vol. 17, No.1)

Reducing the concentration of fine particulates in ambient air (CONCAWE *Review* Vol. 21, No.1)