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

Introduction

In CONCAWE *Review* Vol. 14 No. 2, Autumn 2004, a general introduction was given to the cost benefit analysis methodology (CBA) in which the net economic cost of certain decisions is evaluated by expressing all costs and benefits in monetary terms. This methodology was applied in the Clean Air For Europe (CAFE) programme which looks at future air pollution abatement measures in Europe.

One of the issues highlighted in the previous *Review* article will be discussed here in more detail, namely the complexity of assigning a monetary value to changes in human health impacts due to air pollution and the way this has been done in the CAFE CBA. Two aspects of this will be examined: the choice of the right metric (or 'unit of measurement') to express the health impacts, and the issues around assigning an actual value to this metric.

A matter of the right metric: VOLY versus VPF

Two concepts are often used to assign a monetary value to changes in human mortality. A metric that is often used is called the Value of a Statistical Life (VSL) or, to use a more neutral term, the Value of a Prevented Fatality (VPF). The VPF is the amount of money that a community of people is willing to pay to lower the risk of one anonymous instantaneous premature death within that community (e.g. by certain traffic safety measures). Whereas to save a specific individual in danger usually no means are spared, the VPF is about lowering the risk of premature death in the statistical sense and this leads to a finite value for VPF.

VPF is calculated by dividing the amount of money that people are willing to pay by the change in mortality risk (see box). It will be clear that VPF is the correct metric within a context where we can speak of *observable* deaths, e.g. in traffic accidents.

The Value of a Prevented Fatality (VPF)

Suppose that, in a certain community of people, traffic measures are proposed that will decrease the chance of having a fatal traffic accident by 1 in 10,000 for every individual in that community. Members of that community would be willing to pay for making traffic safer because they all run the risk of having a fatal accident and it would be a benefit for them to make this risk smaller. Suppose that it has been found in some way or another (we will discuss this in more detail in the main text below) that people are prepared to pay on average € 50 per person for such traffic safety measures. Then the VPF is calculated by dividing the amount of money that a person is willing to pay by the change in mortality risk for this person. So in this example the VPF value is € 50 divided by 1/10,000 which gives € 500,000. In a community of say 200,000 people the traffic measures are expected to save 20 people (200,000 times 1/10,000) and it would therefore be justified to pay 20 times the VPF (€ 10 million in our example) for these traffic measures. The effect of the traffic measures would, of course, be observable by looking at the decrease in fatal traffic accidents after implementation of the measures.

However, in the context of air pollution, the use of the VPF metric is far less obvious. Rather than causing observable instantaneous deaths, the health impact of air pollution, especially of particulate matter (PM), can be described much more adequately in terms of a shortening of the *life expectancy* of people (often called chronic mortality). Because of this, an alternative metric proposed in more recent times is the Value of a Life Year (VOLY), which is the amount of money associated with an increase in a person's life expectancy by one year. The actual calculation of VOLY is similar to that of VPF, with the change in mortality risk now being replaced by a change in life expectancy.

There is considerable discussion in the scientific literature on the use of these two metrics. As argued by the researchers of the Commission sponsored ExternE project, it is *impossible* to tell from the information available in epidemiological studies whether a given exposure has resulted in a small number of people losing a large amount of life expectancy or in a lot of people losing a small amount of life expectancy. In this case only the average number of years of life lost can be calculated. In our opinion this is a convincing reason to use VOLY as the only relevant metric in the context of chronic mortality caused by air pollution, where health effects are hugely dominated by PM, as is the case for the CAFE programme.

The CAFE CBA methodology does not make a clear choice for the VOLY metric. Instead both metrics (VPF and VOLY) are used to present sets of (different) results which, in our opinion, is not only confusing but also wrong for the reason discussed above.

Finding a value for VOLY

Once the correct metric to quantify the health benefits of certain improvements has been selected, there is still the issue of assigning an actual monetary value to the metric. This holds true for both the VPF and for the VOLY. Although there are methods to derive a VOLY value from a VPF value, it is generally accepted that if one needs to use VOLY it is preferable to use methods which find a VOLY value directly, i.e. by attributing a monetary value to a certain change in life expectancy.

There are several ways to estimate the actual VPF or VOLY value for a specific community. Here we only discuss a widely used survey technique in which respondents are asked to explicitly state monetary values for a hypothetical change in mortality risk (for VPF) or life expectancy (VOLY). This amount of money is often called the Willingness To Pay (WTP) and these survey methods are sometimes called WTP methods.

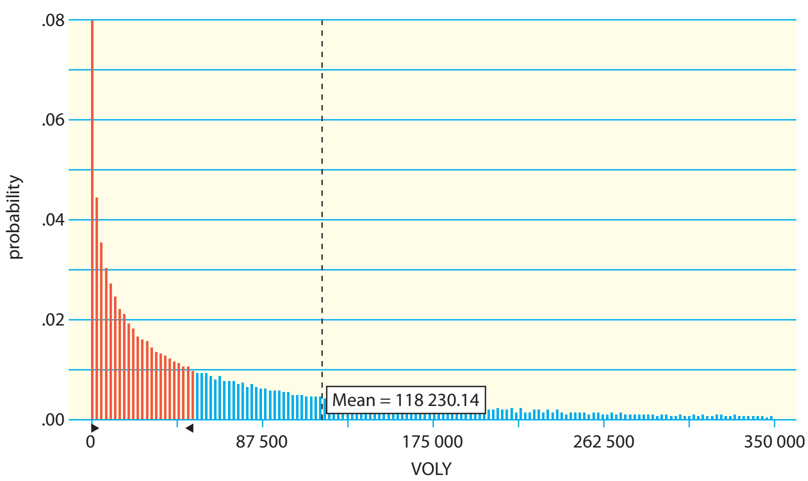
Of course this method has all the complexities of any survey technique in terms of asking the right questions, the extent to which the sample is representative, the possible bias because of age, social status, income or other factors. An additional major problem for VPF (or when deriving VOLY from VPF) is that the concept of risk proves to be difficult for people to understand. Evaluating very small changes in risk is difficult anyway, even for people who are familiar with probability concepts. The concept of a change in life expectancy is easier to grasp, which is another reason for asking directly about changes in life expectancy when trying to find VOLY, rather than asking about changes in mortality risk to establish VPF and then deriving VOLY from that.

The distribution of WTP values as given by respondents in a survey is not at all similar to the well-known normal (Gaussian) distribution, but is a highly skewed one. This is illustrated in Figure 1, which shows such a distribution found in the NewExt study, a European survey carried out to determine VPF as well as a derived VOLY. The horizontal axis gives the VOLY value (as calculated from the WTPs given by the respondents) and the vertical axis the probability of the answers, i.e. the proportion of respondents who indicated a certain VOLY. The red to blue change indicates the median value (the point of the 50/50% split of the answers) which is about € 52 000. The mean (average) value is indicated by the dotted line (€ 118 000).

The large difference between the mean and median is typical of these highly skewed distributions. For such distributions, using the median as a basis for estimating a representative value is a much more robust approach than using the mean, since the latter is very sensitive to a few large 'outliers'. The CAFE CBA methodology presents results for both mean and median. In our opinion this is again not only confusing but also incorrect, because the mean is not a robust estimator of a representative VOLY value.

The distribution of WTP values as given by respondents in a survey is is a highly skewed one. Figure 1 shows such a distribution as found in the NewExt study, a European survey carried out to determine VPF as well as a derived VOLY.

Figure 1 Forecast distribution of VOLY (NewExt study survey)



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In the scientific literature much work has been done to find a value for the VPF. However, there are only a few studies that aim to find a value for VOLY directly and, as explained above, this is the preferred method to bring out VOLY.

Figure 2 presents the results of three studies directly eliciting VOLY: Defra (United Kingdom survey by Chilton *et al*. commissioned by Defra); Johannesson and Johansson (Swedish survey); and Morris and Hammitt (United States survey). The NewExt study is also included here, because it is the study used by the CAFE CBA to assign a value to VOLY. However, the NewExt study measures VPF and derives VOLY from that.

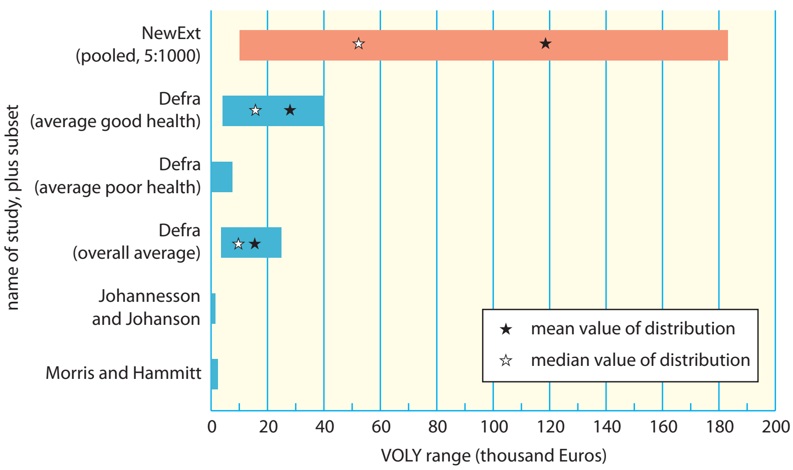
Because the whole VOLY range found in these studies can be very broad, as shown in Figure 1, Figure 2 shows the distribution range between the 20 and 80 percentiles. Mean and medians are also indicated in some cases.

The monetised health benefits calculated with the median NewExt value are four times higher than if the Defra value had been used. In our view this should be taken into account when interpreting the numbers coming from the CAFE CBA.

The Defra study is the most recent of these studies and it is interesting in that it asked three different groups of respondents (all from the United Kingdom) to state their WTP for one, three or six months' increase of life expectancy, both in good and poor health, respectively. So we have no less than six separate VOLY estimates from this study. There are several possible ways to aggregate the Defra results. Three of these are given in Figure 2: 'average' here means that we have averaged the underlying six distributions to give a new distribution.

What is clear from this figure is that when the CAFE CBA methodology selects the NewExt value for VOLY (mean or median) it uses a value which is much higher than the values coming out of the other studies. As an example, the median NewExt value (€ 52 000) is almost four times as high as the median Defra average for good health (€ 14 000), and this is not even the lowest estimator from the Defra results. This means that monetised health benefits calculated with the median NewExt value are four times higher than if the Defra value had been used. In our view this should be taken into account when interpreting the numbers coming from the CAFE CBA.

Figure 2 VOLY distributions (20 to 80 percentiles) according to three studies directly eliciting VOLY (NewExt study results are also included for comparison)



Concluding remarks

Estimating the monetary benefits to society of health improvements is a complex endeavour. To start with, it is essential to select the correct metric. In the context of air pollution by PM, we strongly believe that VOLY is the most appropriate concept. Interpretation of the numbers is also crucial: in particular with the highly skewed distribution functions, median values provide a much more robust representation of the results than mean values.

The CBA methodology adopted for the CAFE programme uses both VPF and VOLY represented by both median and mean values. In addition the actual values are derived from a single study (NewExt) which gives much higher numbers than all other comparable studies. This should be taken into account when interpreting the outcome of the CAFE CBA and it may mean that calculated benefits are grossly overstated and may in some cases not exceed the costs.

Full details, including all references, on what has been presented in this *Review* article can be found in CONCAWE report no. 4/06, *Analysis of the CAFE cost benefit analysis*.