Chapter 1

Defining the economic cost of health impacts

This chapter begins with a restatement of the economic first principles informing the "valuation" of life and health and, therewith, the "cost" of mortalities and morbidities. It shows that a standard method is available by which to measure the cost of mortality – the "value of statistical life" (VSL). While there is work to be done in order to establish standard measurement methods regarding morbidity, it is possible to proceed with an indicative estimate of the additional cost imposed by morbidities drawn from the best available evidence.

This study reports on the economic cost of the health impacts of air pollution from road transport – on a global scale but with special reference to People's Republic of China (hereafter "China"), India and the OECD world.

Any report on the "economic cost" of impacts on human health, be it from air pollution or any other source, involving as it does a "valuation" of life and of health, needs to explain as clearly as possible what precisely is meant by the terms "value" and "cost". This is a non-trivial task. For the use of these terms is frequently misunderstood.

The world is not yet free of the illusion that the wealth of the world subsists in gold (or some other form of money): the "chrysohedonistic illusion". Even though an explicit rejection of this view characterises the founding works of economic science in the mid-eighteenth century following through to today,[1] long after gold has given way to paper money, it is all too frequently supposed that what economists really mean by "value", or by "cost", is a given sum of money.

It is therefore as well to begin by stating that this is not so: money is not the thing being measured but the instrument with which we measure it. Of course, money plays several roles wherever it is present; and rival schools of economic thought hold rival views on the roles that it plays. In the context of the present analysis, however, and irrespective of these otherwise rival views, all economists can agree that money serves here merely as a common unit of account, an imperfect instrument with which to measure certain non-monetary phenomena: namely, the several various items that all of us as individuals "value" in the ordinary sense of the word.[2]

So, what is it that we as individuals value and that economists as observers seek to measure? They include:

- consumption – and, with it, the sacrifice of some items of consumption in order to secure others, including the sacrifice of current consumption in the act of investment in order to secure greater future consumption
- leisure – and the sacrifice of some leisure in the act of labour in order to secure consumption
- health – and the sacrifice of some part of consumption in order to secure health
- life – and the sacrifice of some part of consumption in order to preserve it.

"Value" as used here – also called "utility" – is simply a measure of these items that we all value in the ordinary sense of the word; and "cost" is a measure of their loss, absolutely or as a means of securing other valuable items. The task of the economist then becomes one of *aggregating* at a social level these millions of individual valuations *at their marginal rates of substitution*.

1.1. Mortality: The value of statistical life

In the case of the ultimate impact on health – mortality – economics today possesses a singular, and singularly elegant, *standard method* by which to measure the cost of this impact from a given source: that is to say, to measure the loss of the valued item – life – at the level of society as a whole. This is the "value of statistical life" (VSL), as derived from aggregating individuals' willingness to pay (WTP) to secure a marginal reduction in the risk of premature death.

OECD (2012) describes the basic process of deriving a VSL value from a WTP survey:

> The survey finds an average WTP of USD 30 for a reduction in the annual risk of dying from air pollution from 3 in 100 000 to 2 in 100 000. This means that each individual is willing to pay USD 30 to have this 1 in 100 000 reduction in risk. In this example, for every 100 000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of USD 30 over 100 000 people gives the VSL value – USD 3 million in this case. It is important to emphasise that the VSL is not the value of an identified person's life, but rather an aggregation of individual values for small changes in risk of death (OECD, 2012).

As such, the economic cost of the impact being studied becomes the VSL value multiplied by the number of premature deaths; the economic benefit of a mitigating action becomes the same VSL value multiplied by the number of lives saved.

In addition, following an extensive research effort led by the OECD (OECD, 2012; Biausque, 2010; Braathen, 2012; Hunt and Ferguson, 2010; Hunt, 2011), including a rigorous meta-analysis of VSL studies (OECD, 2012), starting with 1 095 values from 92 published studies, both researchers and policy makers now possess a set of OECD-recommended values for average adult VSL. In units of 2005 USD, the recommended range for OECD countries is USD 1.5 million – 4.5 million, the recommended base value is USD 3 million.

The remit of this study is to apply these VSL values to the problem at hand: the problem of the health impacts of air pollution from road transport. There is, however, a need to pause to add a few words on the meaning and purpose of the standard method. For this in turn sets sharp limits to what can

and cannot be done in this report. In particular, it shows up the folly, not to say absurdity, of attempting to *combine* the standard method with alternative methods of calculating the "costs" of mortality that have an entirely different meaning and purpose.

The reasoning informing the standard method is simple enough and may be simplified even further for the purpose of presentation as follows (Biausque, 2010; OECD, 2012). Suppose that each individual has an expected utility function, EU, relating the utility of consumption over a given period, U(y), and the risk of dying in that period, r, of the form:

$$EU(y, r) = (1 - r)\, U(y).$$

The individual's WTP, to maintain the same expected utility in the event of a reduction in the level of risk from r to r' is the solution to the equation:

$$EU(y - WTP, r') = EU(y, r).$$

VSL is the marginal rate of substitution between these two valued items, consumption and the reduction in the risk of dying, such that:

$$VSL = \delta WTP/\delta r.$$

For the present, the two main points to note are these. First, the value that the standard method seeks to capture is the value (in this case, the value of the reduction in the risk of dying) *to the individual*; it is not, for example, the value of postponed revenue to the undertaker or the value of higher pension expenditure by the government. And second, the task of the economist is one of aggregating valuations *by individuals* at their marginal rates of substitution; it is not one of imposing valuations from above.

It is worth recalling here the words of Jacques Drèze, the originator of the standard method, in reflecting on its origins in an interview more than forty years later:

> In 1960, two French engineers were wondering how much should be spent on investments enhancing road safety. So they tried to define the economic value of a life saved. They suggested measuring that economic value by the future income of a potential victim … and stumbled on the question: should the value of future consumption be subtracted, in order to appraise society's *net* loss? I realised at once that this very question pointed to the basic flaw of the approach: people want to survive and consume, not starve! Going back to the root of the problem, I introduced what is known today as the "willingness to pay" approach to valuing lives in safety analysis. How much would an individual be willing to pay in order to reduce his probability of accidental death? That is for the individual to decide, given his resources … [and] the subjective importance he attaches to survival… Road safety being a public good, individual willingness to pay should then be aggregated as in the

Lindahl-Samuelson theory of public goods (Dehes, Drèze, and Licandro, 2005).

It follows that alternative methods of calculating the "cost" of mortality which seek neither to capture the value to the individual nor to register and aggregate the valuations by individuals cannot substitute for the standard method; nor can they be simply combined with the standard method to produce composite estimates.

This is not to deny that these alternative methods can offer interesting policy-relevant information. But that information needs to be treated separately from the information yielded by the standard method. To do otherwise is almost a category error.

For example, an incidence of pollution that results in the premature deaths of working-age people has an impact on the national accounts through the loss of output and wages; those responsible for studying and forecasting gross domestic product (GDP) changes have an interest in measuring this impact. Clearly, however, a calculation that stops counting at retirement age and places a zero value on the death of a person of 65 years is not counting the same thing as the standard method. It should not occasion surprise that this national-accounts' measure of the "cost" of mortality frequently produces very different estimates to those produced by the standard method.[3]

Similarly, the attempt to derive "WTP values" and "VSL values" from "revealed preference" rather than "stated preference" – for example, by reference to wage levels in dangerous jobs – can reveal interesting information on the degree of bargaining power, or the lack thereof, possessed by particular segments of the workforce.[4] What they do not reveal is what is registered by the standard method: the valuation by individuals of their WTP to reduce the risk of death.

As shown below, these issues of compatibility also have a bearing on the valuation of morbidity. But so far as concerns the valuation of mortality, the conclusion drawn here is simple. The standard method, safely grounded as it is in the first principles of economic science, will suffice for the task at hand; the rest can be set aside.

1.2. Morbidity: In search of a standard method

Economics today does *not* possess a singular, let alone singularly elegant, standard method by which to measure the cost of morbidity from a given source: that is, to measure the loss of the valued item, health. Nor do researchers and policy makers possess anything like a set of OECD-recommended values for the several and various morbidities that can arise from a given source.[5]

In part, this lack reflects the current state of research and its limitations. As noted below, there are two lines of research in this field. There is a reasonably well-established tradition of developing a plural rather than singular method of calculating the various costs of morbidities – but this has not yet arrived at a clear consensus on exactly what needs to be calculated or the values at which they are to be calculated. There is also a more recent line of research which seeks to arrive at a composite cost estimate – but this is nowhere near a state of maturity sufficient to generate either a consensus on method or a set of agreed values across the OECD world.

This lack also reflects a material difference in the subject matter of the two fields. There is a material difference between the "cost of mortality" and the "costs of morbidity" – or rather, several material differences. For the latter item is, in reality, *plural* in several respects.

Whereas mortality is, in the nature of things, a singular and well-defined endpoint, morbidities entail a *plurality of endpoints* – indeed, a very large range of endpoints, varying greatly in the extent of severity, and complicating enormously the task of eliciting and aggregating individual WTP values.

In addition, whereas the cost of mortality is, in an immediate and unconditional sense, borne by the individual who dies, a case of morbidity can entail the imposition of costs on *a plurality of agents* – to begin with, the individual who is suffering ill-health and the many who are involved in the organisation and execution of formal and informal care of the one who is ill.

Finally, the individual who is suffering ill-health suffers *a plural loss of utility*: not only the "pain and suffering" imposed by the illness but also the loss of some part of consumption (and leisure) in expending income (and time) in "averting" and "mitigating" activities in response to current and prospective morbidities.

Therefore, and insofar as morbidity imposes a loss in utility on a plurality of agents as well as a plural loss of utility on the one who is ill – and without departing in the least from the distinction between economic calculation and other forms of calculation, such as national accounting that is so critical to a correct understanding of VSLs – it is entirely legitimate to calculate the costs of morbidity in a plural manner: as the sum of separate elements of cost.

In a more or less recent paper for the OECD, Hunt and Ferguson (2010) set out the elements of this sum:

> The economic costs of the health impacts of air pollution can then be given by the sum of three different categories:
>
> 1. *Resource costs*: Represented by the direct medical and non-medical costs associated with treatment for the adverse health impact of air pollution plus avertive expenditures. That is, all the expenses the individual faces with visiting a doctor, ambulance, buying medicines

and other treatments, plus any related non-medical cost, such as the cost of childcare and housekeeping due to the impossibility of the affected person in doing so;

2. *Opportunity costs*: Associated with the indirect costs related to loss of productivity and/or leisure time due to the health impact;
3. *Disutility costs*: Refer to the pain, suffering, discomfort and anxiety linked to the illness.

It should be noted that the "loss of productivity" referenced above, and regardless of exactly how it is estimated, should be read here as the loss of income and hence consumption for the affected person and the affected person's household – as distinct from the loss of valued-added in the employer's accounts or in the national accounts. In this manner, each of these elements as well as their sum can be defined in conformity with the economic first principles set out in this chapter.

Unfortunately, this line of research has not yet had time to establish itself as a standard method, with a high degree of agreement on the definition of the elements to be calculated and the values at which they are to be calculated. There are several issues that need to be resolved, including but not restricted to the following (Hunt and Ferguson, 2010; and Hunt, 2011):

- the definition of distinct endpoints – without which WTP values make little sense since the disutility of the pain and suffering involved in "illness" can range from trivially low to very high;
- the need for consistency between methods for estimating the different cost elements;
- the obvious need to avoid double-counting;
- but also, and just as importantly, the need to be comprehensive – in particular, the need to include WTP values for disutility, rather than restrict the definition of costs to "resource costs" and "opportunity costs" alone, and to include both lost income and lost leisure in opportunity costs rather than restrict the definition of opportunity costs to lost income alone.

Nonetheless, this is a line of research that is safely grounded in economic first principles and should in the fullness of time be able to deliver the goods: that is, a standard method to calculate the costs of morbidity.

What is more unfortunate is that the search for a standard method has taken a turn in quite another direction, one which might never arrive at a destination that is capable of winning general agreement. This is the attempt to arrive *pari pasu* at a *composite* cost estimate of morbidity *and mortality*.

The reasoning informing this approach is as follows. The epidemiological literature can and does estimate mortality not only in terms of the number of premature deaths but also in terms of the years of life lost (YLLs) or life years

lost (LYLs): that is, adjusting for the age profile and also the pre-existing condition of those impacted by mortality. The same literature can, and sometimes does, estimate morbidity not only in terms of its multiple endpoints but also in terms of "quality-adjusted life years lost" (QALYs) – or, alternatively described, "disability-adjusted life years lost" (DALYs). Given this, if economists could arrive at a "value of a life year lost" (VOLYs) (sometimes described as "value of a statistical life year" – VSLY), they could derive values for QALYs as a co-efficient of VOLYs – and therefore determine a measure of the "economic cost" of morbidity as a co-efficient of the "economic cost" of mortality. Once this task is achieved, policy makers could be relieved of the burden of applying VSLs derived from WTP surveys as a measure of the economic cost of mortality.

Now if this approach were well-founded, then the recent meta-analysis of VSLs and related research effort by the OECD to establish recommended values – not to mention more than 50 years of progress in economic science since the pioneering work of Jacques Drèze – could well become redundant. There is, however, good reason to suppose that it is not well-founded.

First, as a matter of record, it should be noted – as indeed is noted in an important early paper for the US Environmental Protection Agency (US EPA) (Hubbell, 2002) – that the original interest of policy makers in the use of QALYs was as "an alternative method that can account for morbidity effects as well as losses in life expectancy, *without requiring the assignment of dollar values to calculate total benefits*". And as the US EPA Science Advisory Board advised at the time: whilst there was merit in using QALYs and therefore VOLYs in certain contexts and for certain purposes, "alternative measures, such as the VSLY or the value of a QALY, are *not consistent with the standard theory of individual WTP for mortality risk reduction*" (Hubbell, 2002).

Of the many ways in which the new approach can violate the letter and spirit of the standard theory, the following deserve special mention:

- Non-monetised QALYs, however useful they are to health professionals, reflect their valuations of the morbidity suffered by others – not valuations by representative individuals in the general population – and this will necessarily flow through into their monetisation.
- VOLYs are rarely derived from WTP surveys even today (Hunt, 2011) – even if it is in principle possible to do so – and therefore also reflect the valuations of external parties.
- However they are derived, VOLYs will necessarily produce results that differ from, and are inconsistent with, the results given by VSLs: the cost of the death of a group of people of a given age will automatically be counted as less than the death of a comparable group of younger people with otherwise

identical characteristics since the number of LYL for the former group will be less than that for the latter.

- Whether monetised or not, QALYs can involve an element of "double jeopardy". As described in Hubbel (2002): "If the QALY loss is determined based on the underlying chronic condition and life expectancy without regards to the fact that the person would never have been in that state without long term exposure to elevated air pollution, then the person is placed in double-jeopardy. In other words, air pollution has placed more people in the susceptible pool, but then we penalize those people in evaluating policies by treating their subsequent deaths from acute exposure as less valuable, adding insult to injury, and potentially downplaying the importance of life expectancy losses due to air pollution."
- The combination of counting LYL, rather than lives lost, and carrying through pre-existing conditions means that the VOLY-QALY approach "explicitly places a lower value on reductions in mortality risk accruing to older populations with lower quality of life" (Hubbel, 2002).

Now it would be dogmatic to conclude that the search for a composite method will necessarily fail to resolve these issues in a manner that is compatible with economic first principles. It is clear, however, that this search has not arrived at such a destination and cannot today offer a set of values that are in any way compatible with the OECD-recommended values for VSLs that this report is tasked to apply.

Against this background – the availability of a singular standard method for calculating mortality costs, a well-founded search for a plural method for calculating morbidity costs which is not yet complete, an also-incomplete search for a singular method which may be fatally flawed – the approach adopted in this report is to concentrate on the task at hand. As such, the study reports on both mortality and morbidity *impacts* of air pollution but calculates *costs* for mortality only, and using only the OECD-recommended values for VSLs – and then adds to this only a provisional indicative estimate of the additional cost imposed by morbidity.

It follows that if the OECD and its member-governments wish to calculate the economic costs of air pollution's impact on morbidity on a par with the calculation of the economic costs of air pollution's impact on mortality offered below, it is necessary to build an economically robust evidence-base on morbidity on a par with the economically robust evidence-base on mortality established in OECD (2012).

1.3. The dominance of mortality costs over morbidity costs

As is indicated below and in the discussion in Chapter 2, the costs of morbidity are large. As a result, it would indeed be advisable to capture more

precisely these costs and their constituent parts in order to develop more effective interventions to reduce them. But mortality costs are, and necessarily so, *much larger*. In any defensible calculation of "economic costs" properly defined, mortality dominates over morbidity as a share of the total economic cost of health impacts from air pollution.

The most recent OECD report to address this point sums it up as such: "overall health costs are dominated by the cost of premature mortality; the order of magnitude changes vary significantly between morbidity and mortality." (Hunt, 2011 and the discussion following Table 2.1.)

This finding has been established for a long time. *Inter alia*, Hunt (2011) cites a 1996 report estimating morbidity costs at 15-45% of total costs, with mortality costs accounting for 55-85%. More recent research, with more accurate values, tends to attribute a much higher share to mortality costs. Hunt (2011) cites the 2010 study by the US EPA of the benefits of the 1990 Clean Air Act Amendments, attributing 93% of the benefits to reductions in mortality (Hunt, 2011, Table 2.6).

This last point, the progressive attribution of a larger share of the total to mortality, is best shown by concentrating on a single programme and its progress. From Hunt and Ferguson (2010), we can extract the following data on an early iteration of the Clean Air for Europe (CAFÉ) Programme, showing the effects of adding in, first, non-mortality WTP values and, next, mortality WTP values.

Table 1.1. **CAFÉ Programme cost-benefit analysis (CBA), with and without WTP values**

Benefits in reduced damage costs	EUR billions, 2005	As a % of programme cost
Medical cost	0.38	
Lost production cost	3.06	
Crop losses	0.33	
Materials	0.19	
Total	**3.96**	**56**
Adding in non-mortality WTP		
Non-mortality WTP	10.40	
New total	**14.36**	**202**
Adding in mortality WTP		
Mortality WTP	29.09	
Grand total	**43.45**	**612**

Source: Data reported in Hunt, A. and J. Ferguson (2010), *A review of recent policy-relevant findings form the environmental health literature*, OECD, Paris.

If valued by the individual's WTP, the benefits in reduced mortality account for 67% of the grand total. And WTP values account for 72% of the remainder. In short, mortality costs dominate morbidity costs; and the values for (dis)utility dominate the values for resource costs and opportunity costs.

The most recent CBA for the Thematic Strategy on Air Pollution (TSAP) (Holland, 2012), which builds upon the CAFÉ Programme, estimates the baseline damage costs as follows:

Table 1.2. **TSAP cost-benefit analysis (CBA), with mortality in VOLYs and VSLs**

Baseline health impacts from air pollution in year 2030 (%)	
All mortality – LYL – in median VOLY – as a % of the total (with median VOLY)	69
All mortality – LYL – in mean VOLY – as a % of the total (with mean VOLY)	84
All mortality – number of deaths – in median VSL – as a % of total (with median VSL)	83
All mortality – number of deaths – in mean VSL – as a % of total (with mean VSL)	91

Source: Data extracted from Holland (2012), *Cost-benefit Analysis of Scenarios for Cost-Effective Emission Controls after 2020*, Version 1.02, November 2012, corresponding to International Institute for Applied Systems Analysis (IIAC) Thematic Strategy on Air Pollution Report #7, EMRC.

On the basis of the OECD-recommended approach in OECD (2012) – calculating with mean VSLs – mortality costs claim a *91% share* of total costs in this European research, close to the *93% share* of total benefits reported for reductions in mortality in the US EPA study. In addition, the VSL values used in Holland (2012) pre-date the higher VSL values recommended in OECD (2012); applying the latter would yield a result *above 91%*.

Hence, the most recent evidence suggests that morbidity costs add to the total by *around 10% of the cost of mortality as given by mean VSLs*. And this is the estimate carried over as a provisional indicative estimate in the calculations of Chapter 2.

The further development of the plural method of calculating morbidity costs, including a more comprehensive calculation of WTP values, may well raise morbidity's share. But it is not credible to suppose that it would raise that share above that of mortality.

If despite this weight of evidence in the specialist literature, non-specialists are sometimes inclined to suppose that morbidity costs, and especially medical costs, are the dominant share of the economic costs of health impacts, it is only because of critical ambiguities in the use of the term "costs".

For example, a consultants' report for the US EPA from the turn of the century, reporting on "asthma costs" for 1997 (Chestnut, Mills and Agras, 2000), shows "direct costs" (medical expenditures in the treatment of illness)

to be greater than "indirect costs", and "morbidity costs" to be greater than "mortality costs". But this is only because "indirect costs" are defined here as being "the market value of lost productivity (e.g., wages)". The authors themselves clearly warn that this is *not* the appropriate measure.[6] But to no avail: even today, that paper is sometimes used to question this critical scientific finding of the dominance of mortality costs.

And yet: how could economic science find otherwise? In the language of economics, cost is not a sum of money; cost is the loss of what we value. We value consumption, leisure, health and life. Jacques Drèze says: "People want to survive and consume, not starve!" To this should be added: "People want to live, in health if possible, in sickness if need be. In sickness and in health, people want to live!"

It is only from the contrary perspective of an ancient chrysohedonism, predating not only the 50 years' of progress in valuation since the early work of Jacques Drèze, but also the 250 years' of progress in the understanding of value since Francois Quesnay and Adam Smith – only from this perspective of "counting the King's money" – that medical expenditures can loom larger than life. Economic science provides a very different calculation.

Notes

1. To keep it manageable, the referencing in this report is restricted to items published in the twenty-first century. But the veracity of this claim – that is, the universal rejection of chrysohedonism by all major schools of economics from the mid-eighteenth century to the present day – can be checked easily enough by consulting inter alia the works of Francois Quesnay, Adam Smith, David Ricardo, Karl Marx, Leon Walras and Kenneth Arrow.
2. This is also described as "use value" as distinct from "exchange value" in the language of the classical economists and as "utility" in neo-classical and present-day economics.
3. To repeat: this is not to say that the impact on GDP is not interesting or that it should be left unreported. But it needs to be reported separately; and so do the reasons for that separation. There is a parallel here with the issue of GDP impacts of public investment projects. In recent years, in the case of certain high-profile projects, the UK Department of Transport has reported results in terms of both economic evaluation and national accounts: that is, both cost-benefit results and GDP impacts. But it has taken care to present these calculations separately and to explain the reasons for it. See for example *UK Department for Transport (UK DfT)* (2006).
4. See for example the recent paper by Qin, Li and Lui (2013) on how workers' *lack* of bargaining power in certain sectors, including especially agriculture, can distort the results.
5. On the current state of research on the costs of morbidity, see in particular Hunt and Ferguson (2010) and Hunt (2011).

6. See Chestnut, Mills and Agras (2000), where the authors warn as follows: "It should be noted that COI [cost-of-illness] estimates are a useful measure of financial burden of disease, but they do not measure the monetary value of the full effect of disease on the welfare of the population and are therefore insufficient for a full cost-benefit analysis of public policies aimed at reducing morbidity or mortality. Willingness to pay (WTP) is the more appropriate measure of the change in welfare in cost-benefit analysis, because it reflects not just the financial effect but also the value people place on the effect on quality of life and longevity…. In addition, there is substantial evidence that WTP for reductions in mortality risk far exceed the expected value of lost earnings, which is the COI measure of the financial effect of premature mortality…"

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