Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

1 Introduction

> *The responsibility of those who exercise power in a democratic society is not to reflect inflamed public feeling but to help form its understanding*
>
> *Felix Frankfurter (former Supreme Court Justice) (1928) Carved in stone on the wall of the Federal Court House, Boston*

Summary

In this chapter we explain why one needs to evaluate environmental costs and benefits. Cost–benefit analysis (CBA) is necessary for many choices relating to public policy, especially in the field of environmental protection, to avoid costly mistakes. Even when other, non-monetary criteria must also be taken into account, a CBA should be carried out whenever appropriate. Without a monetary evaluation of damage costs one can only do a cost-effectiveness analysis, as illustrated in Section 1.3. In Section 1.4 we explain how to determine the optimal level of pollution abatement, as a simple example of the use of a CBA. Impact pathway analysis (IPA), the methodology for quantifying damage costs or environmental benefits, is sketched in Section 1.5. The internalization of external costs is addressed in Section 1.6.

1.1 Why quantify environmental benefits?

The answer emerges through asking another question: “how else can we decide how much to spend to protect the environment?” The simple demand for “zero pollution” sometimes made by well-meaning but naïve environmentalists is totally unrealistic: our economy would be paralyzed because the technologies for perfectly clean production do not exist.[1]

---

[1] If you don’t believe it, try to think of an economic activity that does not involve pollution. Maybe growing tomatoes in your yard and selling them at the local farmer’s market? But few people live within walking distance of the local farmers’ market, and even if you do, most of your customers have to drive or at least use a bicycle – and don’t forget the pollution emitted during the production of a bicycle. Chemical and physical processes

In the past, most decisions about environmental policy were made without quantifying the benefits. During the 1960s and 1970s increasing pollution and growing prosperity led to increased demand for cleaner air, and at the same time there was sufficient technological progress in the development of equipment such as flue gas desulfurization to allow cleanup without prohibitive costs. The demand for cleanup became overwhelming and environmental regulations were imposed with no cost–benefit analysis.

Not only would the scientific basis for environmental cost–benefit analysis (CBA) have been inadequate in the past, but much simpler criteria seemed satisfactory for making decisions. Conditions in cities like London were initially so bad, and effects on health so serious, that major action was taken on the assumption that this was for the common good (an assumption borne out by subsequent analysis). The classic example is the Great London Smog of 1952, during which 4000 additional deaths were recorded over what would ordinarily have been expected. Another criterion was based on the idea that a toxic substance has no effect below a certain threshold dose. If that is the case, it is sufficient to reduce the emission of a pollutant to below the level where even the highest doses remain below the threshold. Based on this idea standards for ambient air quality were developed, for example, by the World Health Organization, and governments imposed regulations that forced industry to reduce emissions to reach these standards.

However, the situation is changing. Epidemiologists have not been able to find no-effect thresholds for air pollutants, in any case not at the level of an entire population. For example, the most recent guidelines from the World Health Organization say that there seems to be no such threshold for PM (particulate matter). The available evidence suggests that exposure–response functions (ERF) are linear at low dose for PM, and probably for other air pollutants as well.[2] In particular, for the neurotoxic impacts of Pb the ERF is at least linear without threshold, and it may even be above the straight line at low dose. Linearity is already generally assumed for substances that initiate cancers.

At the same time, the incremental cost of reducing the emission of pollutants (called the “abatement cost”)[3] increases sharply as lower

---

are by their very nature not “pure,” i.e. they always produce at least some byproducts in addition to what we want. We can and should reduce pollution as much as is practical (in a sense to be defined below) but zero pollution is not feasible in an industrialized society.

[2] One implication of linear no-threshold ERFs is that the traditional preoccupation with pollution peaks is not really relevant: it is the long-term average exposure that matters. Of course, since on average the peaks are proportional to the long-term average exposure, reducing the peaks also reduces the average exposure.

[3] Some authors, for instance IPCC, use “mitigation” instead of “abatement.”

Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

emission levels are demanded. Thus the question "how much to spend?" acquires an increasing urgency, while the natural criterion for answering it by reference to a threshold has vanished. Even worse, we are facing a proliferation of small risks as ever more sensitive scientific methods identify ever greater numbers of substances that can have harmful effects, possibly (or probably, in the case of many carcinogens) without a safe threshold. Thus we have to deal with a new paradigm, and monetary evaluation of environmental benefits is required, to make our decisions consistent with our preferences. Optimal decisions are not obvious because of the complexity of the links.

Many people have objected to environmental CBA, feeling that one cannot assign monetary values to items such as a beautiful landscape, an endangered species or human life. This objection is based on a fundamental misunderstanding of what is involved in the monetary evaluation. In reality it is not the intrinsic value of the item in question, but society's collective willingness to pay (WTP) to avoid losing the item. For instance our WTP (even our ability to pay) to avoid an anonymous premature death is limited, even if we feel that the value of life is infinite. In any case, we have to make decisions, and a judgment about monetary values is implicit in our decisions. For example, if a city refuses to replace a railway level crossing by a bridge, at a cost x to avoid y traffic deaths, its "value of life" is less than x/y; if the bridge is built, the implied value is at least x/y.[4] Environmental CBA makes implicit judgments explicit. Stakeholders are free to disagree with the analysis, but they need to justify why they disagree.

Ultimately, the objective of a CBA of proposed policies or regulations is to render the decisions more consistent, in particular to avoid inconsistencies of the type where a billion is spent in one sector to avoid the loss of a life year, while refusing to spend a thousand for the same thing in another sector – inconsistencies amply documented by Tengs and Graham (1996), Lutter *et al.* (1999) and Morrall (2003). Tengs and Graham calculate that in the USA a more consistent allocation of resources could save about 0.5% of GDP, without any reduction in the protection

---

[4] The unfortunate term "value of statistical life" (VSL) used by economists often evokes hostility, "You cannot put a price on life" being a typical reaction. But that is a total misunderstanding of the problem. It is not "and how much for your grandmother?" The objective is not to determine the intrinsic value of life, of a beautiful landscape, of a cultural monument or a species threatened by extinction; rather it is the WTP to avoid the loss of the good in question. The WTP (including ability to pay) is limited, even for people who say that the good is priceless. Really VSL is the "willingness to pay for avoiding the risk of an anonymous premature death," and we prefer the term "value of prevented fatality" (VPF) which is more appropriate and less likely to evoke negative reactions. Another good term is "value of (mortality) risk reduction," which has been proposed in the USA.

Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

of the population. Inconsistent valuations are especially likely when regulations are imposed in response to the latest “risk of the day” that happens to attract intense attention in the media (dioxins, mad cow disease, asbestos, electromagnetic fields etc.).[5]

Without monetary valuation of environmental goods one can do a cost-effectiveness analysis (CEA), i.e. rank choices with comparable outcomes, for instance options for reducing PM_{10} emission, or one can compare years of life saved by reducing air pollution versus years of life saved by reducing water pollution. But how can one compare choices with incommensurate outcomes, such as closing a factory to avoid pollution or keeping it going to avoid unemployment? Paying for putting particle filters on diesel buses to reduce particulate emissions or continuing to suffer the health impacts of the particles in our cities? Raising the price of cars to make them cleaner? General principles such as sustainable development or the precautionary principle provide no guidance (except in their most extreme and totally impractical interpretation of demanding zero pollution) because the difficulties lie in the specifics of each situation.

The extra cost of a cleaner environment must be paid, ultimately by the tax payer or consumer. For example, if a factory is forced to spend more for environmental protection (or pay a tax on pollution), this cost is passed on to the consumer – and if the cost is too high to be charged to the consumer because of competition from countries with less strict regulations, the owner of the factory has less incentive to continue the investments necessary to keep the factory up to date and will choose other more profitable investments instead; eventually the factory becomes unprofitable and is closed. Even if immediate tradeoffs do not cross budget categories, ultimately the money we spend on reducing pollution is not available for other good causes, such as the education of our children.

Links can be subtle and unexpected. When evaluating a decision, one should not forget the consequences of the alternatives and the induced effects. For example, lowering the limit for the allowable emission of dioxins from waste incinerators will avoid some cancer deaths, but it

---

[5] Usually there is little correlation between the magnitude of a risk and the amount of media attention, or it may even be negative, since small risks are more difficult to quantify: the greater the uncertainty, the more disagreement there is between the experts – and the greater is the entertainment value for the media. Much of the apparent irrationality of risk perception arises from binary thinking, a simple shortcut to help us to deal with the complexities of most decisions: A is safe, B is not, . . . Most of the time such shortcuts are better than getting paralyzed by an attempt to weigh quantitative criteria. But trouble comes when we are finding more and more small risks. Most potential new risks are nonzero and we, or the media, tend to assign them to the “not safe” category. So we have the cognitive illusion of living in an ever more dangerous world.

Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

will raise the cost of waste disposal. And poverty also kills, as demonstrated by numerous studies. The reasons are poor education, unhealthy housing, inability to pay for medical services, etc. For example, in the USA, Keeney (1994) has found that for each $5 to 10 million of cost imposed by a regulation there will be on average one additional premature death due to this cost. Lutter *et al.* (1999) estimate that a $15 million decrease in income is associated with the loss of an additional statistical life, and therefore, regulations that cost more than $15 million per expected life saved are likely to cause a net increase in mortality.

The value of clean air is not infinite. With excessive pollution control the costs are not worth the benefits. There is a socially optimal level of pollution – which decreases with increasing prosperity and technological progress. The link to prosperity is complex. People with different levels of income and in different situations will rightly have different priorities for its allocation: access to food, clean water and shelter will, for example, come ahead of most people's priority for clean air. Problems arise when the actions of one group impact unequally on others. Of particular relevance here are the risks linked to climate change, where those living on a dollar a day will be at higher risk than those who are richer and contribute far more to greenhouse gas emissions. Likewise, the costs and benefits of air pollution abatement are different for different income groups.

1.2 Cost is not the only criterion for decisions

A cost–benefit analysis (CBA) should not be a simple automatic criterion for environmental decisions. The results have to be used with care because the uncertainties can be large, and it can be too easy to manipulate assumptions to get the result that one particular group might want to see.

Furthermore, other considerations may be as important as cost, particularly equity (who pays and who benefits?). For many options for reducing air pollution the distribution of costs and benefits among the population is sufficiently uniform so as not to raise serious equity issues. But there are exceptions, for instance, if low emission zones are created in cities by prohibiting the use of older, more polluting vehicles: the benefits accrue to all while the costs fall on the owners of the excluded vehicles. If suitable compensation schemes cannot be devised, a policy option may be problematic even if the total benefits are clearly larger than the total costs.

For the choice of energy systems, one should also take into account issues such as supply security, the right to impose risk on future generations (nuclear waste or global warming), the dangers of proliferation and the acceptability of a large accident. Such issues involve societal value judgments, beyond the costs one can quantify. That is not an argument

Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

against monetary valuation. Rather, the appropriate approach is to quantify the costs as much as possible for input into the decision process. For example, one may be able to evaluate equity implications explicitly in monetary terms, as is being done for the implications of a carbon tax, by evaluating how the tax burden would be distributed among different socio-economic groups. Equity issues tend to weigh heavily in the decisions of elected officials, because they want to be re-elected.

The question of acceptability complicates any quantification of mortality risk. Mortality risk can differ in the nature of the death (e.g. by accident, by cancer or by other illness) as well as in attributes that influence the perception of a risk, for instance:

- is the risk voluntary or involuntary?
- is the risk natural or manmade?
- to what extent is it associated with an activity that is considered to be socially desirable?
- how much control does an individual have over the exposure or consequences?

Such attributes affect the importance that people place on avoiding a particular risk. This can confound even a direct comparison of risks in physical units (number of deaths or years of life lost), quite apart from any controversies surrounding the value in monetary terms.

However, such limitations do not render a CBA useless. If the analysis has been carried out with care, clearly stating the underlying assumptions, it brings hidden consequences into the open and helps focus the debate onto the facts. In particular, it can indicate whether a proposed decision reflects true preferences or merely a cognitive illusion.

1.3 Cost-effectiveness analysis

To show what can and what cannot be done without evaluation of damage costs, let us look at cost-effectiveness analysis (CEA). This quantifies the costs and the effectiveness of methods for achieving a goal, for instance, reducing the emission of a pollutant, and then ranks them according to their improvement/cost ratio. As an example, we show in Fig. 1.1 the marginal abatement costs for greenhouse gas emissions for various technology options in the EU, as calculated by IIASA (the International Institute for Applied Systems Analysis) (2010). For each option, IIASA determined the cost and the potential reduction if the option were implemented in the entire EU. Of course, one should implement the less expensive options before the more expensive ones. Therefore, they are presented in order of increasing cost (from left to right), and the *x*-axis shows the cumulative emission reduction if the various technology

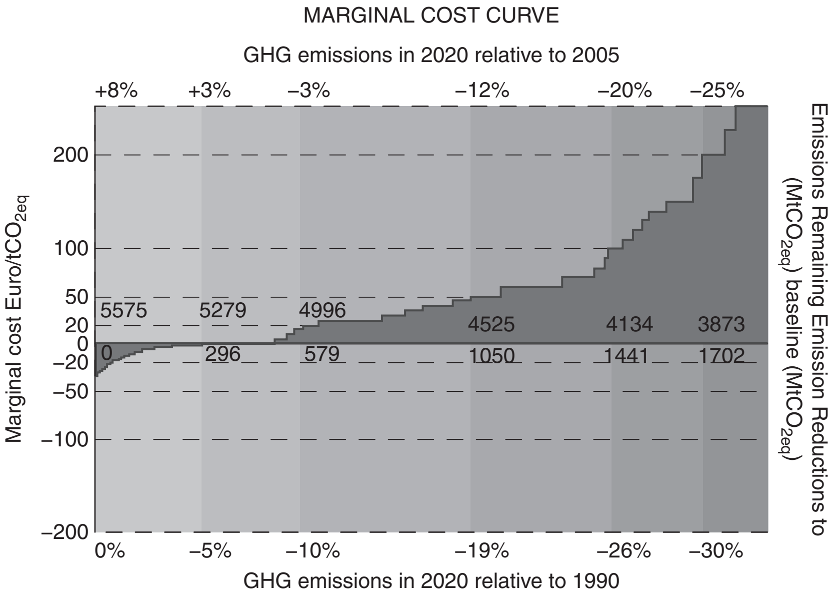

Fig. 1.1 Example of cost-effectiveness analysis: marginal abatement costs for various technology options in the EU. From IIASA (2010), reproduced with permission from the International Institute for Applied Systems Analysis (IIASA).

choices are implemented in the order of increasing cost. In this particular example of a CEA, the *x*-axis labels are a little complicated because the emission reduction is shown in several different ways (as % reduction relative to 1990 and 2005, as cumulative reduction in $\mathrm{Mt_{CO_{2eq}}}$/yr,[6] and as remaining emissions).[7]

According to these data, up to 296 $\mathrm{Mt_{CO_{2eq}}}$/yr can be avoided at negative abatement cost, because there are options that bring net savings. If the damage cost were equal to 50 €/$\mathrm{t_{CO_2}}$ (100 €/$\mathrm{t_{CO_2}}$) the emissions could be reduced by as much as 1050 $\mathrm{Mt_{CO_{2eq}}}$/yr (1441 $\mathrm{Mt_{CO_{2eq}}}$/yr).

---

[6] The notation $\mathrm{CO_{2eq}}$ indicates that all greenhouse gases are included and expressed as equivalent $\mathrm{CO_2}$ emissions.

[7] Note that the abatement costs are uncertain because for the most part they involve new technologies. Over time, as these technologies are applied more and more, their costs will decrease thanks to learning. For that reason, abatement cost curves for the near term, such as Fig. 1.1, show much higher costs than cost curves that are projected to the more distant future, with assumptions about learning rates, such as the marginal abatement cost curve in Fig. 1.2b.

Cambridge University Press
978-1-107-04313-8 - How Much is Clean Air Worth?: Calculating the Benefits of Pollution Control
Ari Rabl, Joseph V. Spadaro and Mike Holland
Excerpt
More information

That kind of information is valuable because it indicates how much can be achieved and at what cost. But it does not indicate how much should be done. Cost-effectiveness analysis is necessary but is not sufficient in itself. To determine the optimal level, one also needs to know the damage costs.

A further problem is that CEA typically focuses on the cost of achieving one particular goal, without reference to other issues. For example, in the case given, no account is taken of other impacts of the measures introduced to reduce carbon emissions. Some of these will be beneficial, such as the reduction in regional air pollutant emissions (SO_2 etc.) associated with reduced fossil fuel use. Some of them will involve a tradeoff of the carbon abatement benefit with other risks, for example, those associated with nuclear power generation. Cost–benefit analysis therefore provides a mechanism for a much more comprehensive assessment of the impacts of policies.

1.4 The optimal level of pollution abatement

Taken as a whole, society must pay the cost of pollution abatement and suffer the damage cost of the remaining pollution. To find the optimum, one has to minimize the sum of the abatement cost $C_{\mathrm{ab}}(E)$ and the damage cost $C_{\mathrm{dam}}(E)$,

$$C_{\mathrm{tot}}(E) = C_{\mathrm{dam}}(E) + C_{\mathrm{ab}}(E) \qquad (1.1)$$

as a function of the emission level E of the pollutant. Setting the derivative of C_{tot} equal to zero one finds that the optimal emission level E_{opt} of the pollutant corresponds to the point where

$$\frac{dC_{dam}}{dE} + \frac{dC_{ab}}{dE} = 0 \quad at \quad E = E_{\mathrm{opt}}. \qquad (1.2)$$

Economists call the derivative of the cost a marginal cost, and say that the optimum is where the marginal damage cost is equal to the marginal abatement cost.

For the important case of pollutants with linear or near-linear dose–response functions (the case for the most important impacts of the classical air pollutants), the marginal damage cost is independent of E. For greenhouse gases the marginal damage cost increases with E. Figure 1.2 illustrates the optimization with an example, the abatement of worldwide CO_2 emissions. Of course, this is an extraordinarily complex problem (even without politics interfering with the search for the truth), and Fig. 1.2 presents an

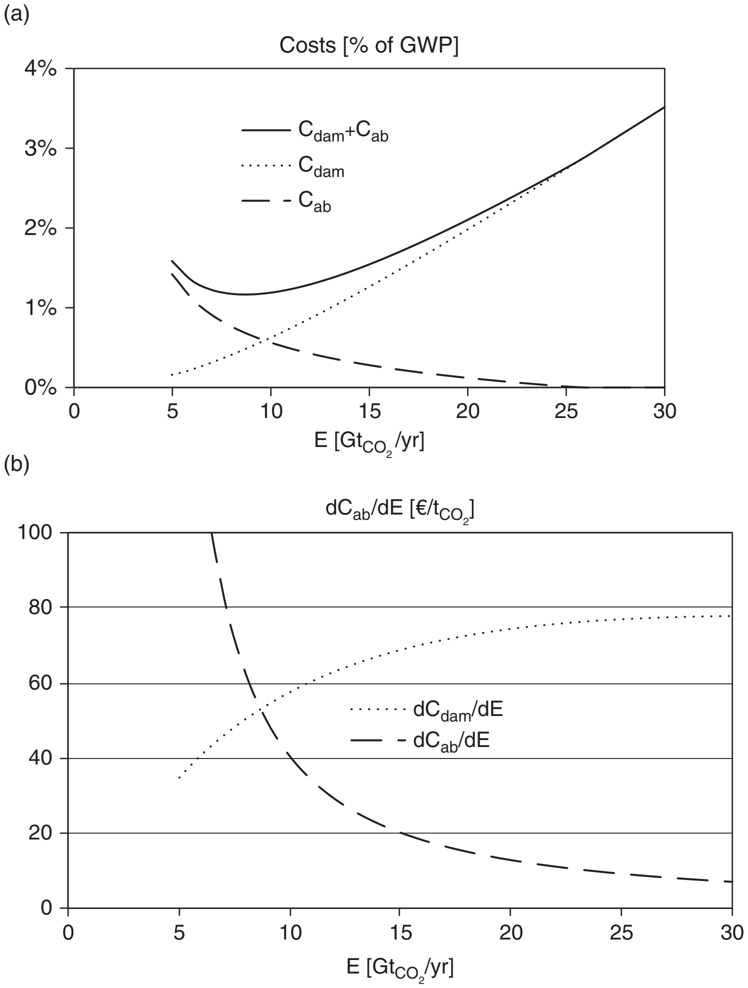

Fig. 1.2 Example of optimizing the emission level *E*: optimization of global CO_2 emissions, based on a simple steady-state analysis; (a) total costs, (b) marginal costs.

extreme simplification, based on a simple steady-state analysis (van der Zwaan and Rabl, 2008).[8] Part (a) shows the damage cost C_{dam} and the abatement cost C_{ab} as well as their sum and Part (b) shows their derivatives. The current emissions are 27 Gt_{CO_2}/yr. The optimal emission level is the one

---

[8] A more realistic dynamic analysis has been published by Rabl and van der Zwaan (2009), and some results can be found in Section 11.5.3.

that minimizes the total cost. It is the point where the marginal damage and the abatement costs are equal: 8.7 $GtCO_2$/yr (about a third of current emissions) under steady-state conditions. Of course in reality, the emissions and costs change over time and a more rigorous dynamic analysis is needed. Nonetheless, the key conclusion is quite robust, namely, that the emissions should be reduced by a factor of about three relative to the business-as-usual scenario; that conclusion has been confirmed by a more rigorous dynamic analysis by Rabl and van der Zwaan (2009).

Strictly speaking there should be a third term in the optimization: the cost of defensive or adaptive measures. For example, the damage caused by sea level rise due to CO_2 can be reduced by building dykes, and the damage to some materials due to SO_2 or O_3 can be reduced by appropriate surface treatments. If the damage, for a given emission level, can be reduced by defensive or adaptive measures, their cost, C_{def}, should be included in Eqs. (1.1) and (1.2) by considering C_{dam} as the net damage cost. For the classical air pollutants the potential for defensive measures is often so limited that it can be neglected in the optimization, but for greenhouse gases these are very important.

For another example, consider the National Emission Ceilings Directive of the EU. This directive fixed limits for the annual emissions of SO_2, NO_x, VOC and NH_3 for each member country, to be attained by 2010. In preparation for the negotiations leading to these limits, IIASA was asked to assemble abatement cost data for each country. The data for France are shown in Fig. 1.3; the points are from IIASA (1998), the line is

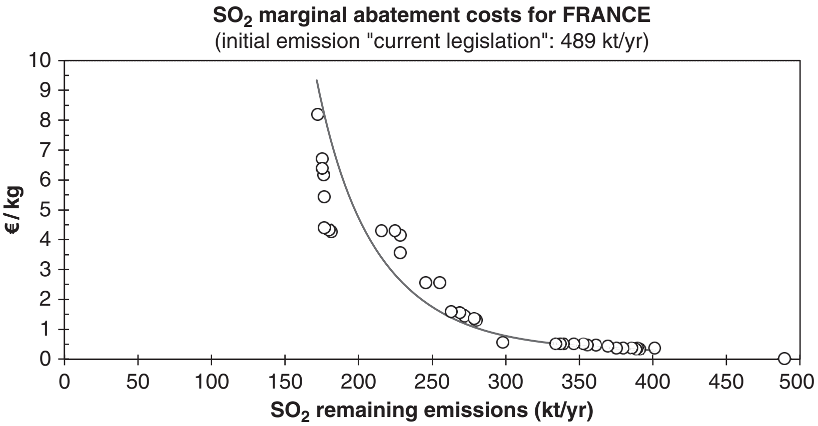

Fig. 1.3 Marginal cost of SO_2 abatement as a function of the total emissions of France. The solid line shows our curve fit to the data points of IIASA (1998).