Chapter 11
Cost-Benefit Analysis

Jutta Roosen

> *The basic rationale of cost-benefit analysis lies in the idea that things are worth doing if the benefits resulting from doing them outweigh their costs.*
> *Amartya Sen (Cost-benefit analysis, The University of Chicago Press, Chicago, 2001, p. 98)*

Every society is facing a number of risks and their regulation requires many considerations. From an economic standpoint, it can be said that risks impose a cost on society. Avoiding and regulating risks equally engenders costs. In order to help public decision makers come to terms with these trade-offs, economists have developed the method of cost-benefit analysis. It is based on the simple idea that things are worth doing when the benefits from doing them are greater than their costs. As simple as this basic idea is, as tricky and controversial are the implications of putting it into practice. Issues of controversy relate to valuing environmental benefits, determining the value of human health and life, balancing the interest of current and future generations by discounting, and dealing with the biases of subjective risk perception when defining a rational risk policy. This chapter will introduce the basic assumptions underlying cost-benefit analysis and the procedures involved in conducting one.

Keywords Cost-benefit analysis · Discounting · Non-market valuation · Value of a statistical life

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The Facts

- Cost-benefit analysis is rooted in the ethics of utilitarianism: things are of value because they are valued by humans in their pursuit of happiness and well-being.
- Cost-benefit analysis allows for the systematic consideration of all effects of a public project or policy. All costs and benefits are evaluated in monetary terms and hence are comparable.
- Cost-benefit analysis also considers the effects of projects on the environment, nature, and human health.
- The choice of the discount rate is of crucial importance for the outcome of a cost-benefit analysis. Small changes in the discount rate can lead to large changes in the outcome of the analysis. This is because the rate enters via an exponential discounting exercise.
- While the basic idea of cost-benefit analysis is widely accepted, many issues of implementation are hotly debated. Hence it is of crucial importance to make explicit all assumptions of the analysis and to make outcomes of different project valuations comparable.
- Cost-benefit analysis does not ignore the implications of behavioral sciences. It is a response to the bounded rationality of decision makers, trying to make public policy accountable to principles of rationality.

1 Introduction

Methylmercury, an organic form of mercury, is a toxic compound that alters fetal brain development when there is significant prenatal exposure (EFSA [18]). Exposure results from fish consumption and in particular concerns children of women who consume large amounts of fish before and during pregnancy. These children have a significant vulnerability to the adverse neurological effects of methylmercury (Budtz-Jorgensen et al. [13]). Levels of mercury in the environment have increased considerably over the last century. The most important anthropogenic sources of mercury are coal-fired power plants. When atmospheric mercury created during the coal burning process is deposited on surface water, bacteria convert it to the organic form, methylmercury. It then enters the food chain of aquatic life and accumulates in fish tissues. Moreover, methylmercury bio-accumulates in the food-chain leading to high mercury concentrations in predatory fish such as tuna, mackerel, and shark (Shimshack et al. [38]).

Because of its valuable nutrition properties (omega-3 fatty acids, proteins, vitamins and minerals) fish has taken centre stage in regulatory debates on food safety and nutrition (Caswell [14]). Policies dealing with methylmercury include power-plant regulation by capping mercury emissions. Because of the persistence of mercury in the environment, limiting emissions will not suffice for managing this risk and consumption advisories are an important means to limit exposure to contaminated fish for groups at risk (pregnant women, women of childbearing age and young children). Risk advisories, however, may also have spill-over effects to consumer groups not at risk (men and children at older ages), hence causing them to forego benefits of fish consumption such as omega-3s that are considered of importance to cardiovascular health. Balancing all these benefits, costs and risks of regulatory choices demand a careful analysis of all effects involved. In such cases, economists turn to cost-benefit analysis, comparing and aggregating all impacts valued in monetary terms.

Before entering into the description and discussion of cost-benefit analysis, a second example may be of interest. Pimentel et al. [31] have estimated the cost of soil erosion and benefits of conservation technologies. Soil erosion is a major environmental and agricultural problem around the world. Unsustainable agricultural practices lead to wind or water erosion that threatens the fertility of agricultural soils. Beyond this productivity impact, wind erosion can lead to pollution with fine-particulate matter, with an effect on human health because fine particles—solid or liquid—can get deep into the lungs and cause serious health problems such as aggravated asthma and increased respiratory symptoms (EPA [19]). Fine particles also lead to impaired views and damage material and countryside. Water erosion on the other hand can lead to soil run-off into streams and lakes and cause biological and recreational damage there. Again, public decision makers must consider what to do about soil erosion. Conservation practices are available, but may lead to reduced yields and profits in agriculture. Weighing of these costs and benefits of soil conservation can be done by cost-benefit analysis.

Cost-benefit analysis is a method of applied economics employed to evaluate public projects that involve investments and costs and returns over time. It helps the public decision maker to decide whether a project should be carried out or not or which project should be selected when several are under consideration. Basically the idea is to judge if public resources are used efficiently (not just effectively) and hence, if the costs of a project can be justified by its benefits. Cost-benefit analysis can be performed on all sorts of different projects. It can be applied to infrastructure projects such as the construction of a new road or railway. Even when judging educational projects, cost-benefit analysis can be useful. For example the OECD regularly publishes an evaluation of investment in higher education in its member countries (OECD [29]). Cost-benefit analysis also allows for assessing environmental regulation, such as a ban on specific pesticides or the conservation of an endangered species. One must however consider an important aspect of cost-benefit analysis: it is appropriate only for projects that are marginal for the public decision maker. Marginal means the project is relatively small in the overall portfolio of public projects. This is the case with the soil erosion or methylmercury example considered above. However, there may also be non-marginal projects such as those where the investment is of the size of a large share of the gross domestic product (GDP) of a country or projects for limiting and mitigating climate change, the impact of which may not be considered marginal. In these cases general assumptions of cost-benefit analysis on the risk aversion of the public decision maker and the income effect are no longer applicable. Hence particular care must be taken when conducting welfare assessments under such circumstances.

Cost-benefit analysis is also useful for health-related projects. For example, it can be used to address the question whether the benefits of cancer screening over large segments of the population outweigh the costs (cf. Chap. 17, [42]). Here ethical and methodological considerations on the evaluation of non-market goods become particularly thorny. Is there a monetary value to a human life, and how can we go about the evaluation of human life? In order to avoid such questions, medical professionals often prefer to replace cost-benefit analysis by cost-utility analysis or cost-effectiveness analysis. However, cost-benefit analysis not only provides information on the attractiveness of one medical treatment compared to other medical treatments. It helps the public decision maker to know if the investment in a health program is overall efficient, and furthermore if it is more efficient or less efficient compared to other projects such as investments in infrastructure or education.

The basic idea of cost-benefit analysis is that one can use monetary values to evaluate a project. That means that all costs and benefits are evaluated in terms of money. These monetary values are not only used for market aspects of the project, but also for non-market goods. Take the example of installing a wind farm. The flows of money involved are those of the investment costs at the beginning of the project. There are also running costs of maintaining the wind farm over time and there is certainly the benefit of the electricity generated. In this example, costs and benefits can easily be evaluated by using the market costs of the necessary investment, the maintenance costs and the generated electricity evaluated at market price. Certainly, a project is attractive if over the lifetime of the project the generated benefits are greater than the accruing costs, and there are a number of decision rules that can be used in order to verify if the project is attractive or not.

However, there are a number of difficulties that arise when doing cost-benefit analysis. First, costs as well as benefits occur over time. To make this flow of costs and benefits comparable over time, they have to be discounted to net present value (*NPV*). While discounting seems a simple mathematical exercise, the ethical implications of discounting are quite large. Economists have hence fiercely debated the choice of the appropriate discount rate. Second, benefits and also costs occurring in the future are uncertain. One hence has to resort to expected utility analysis (cf. Chap. 3, [40]). Finally, benefits and costs can also involve non-market goods. Consider again the example of the wind park. There may be the benefit of reduced CO_2-emissions versus damage to wildlife such as birds. For those non-market goods, market prices are not available and the value of the benefits and damages (costs) would need to be estimated. Section 4 of this chapter will briefly introduce the methods that are available for the valuation of non-market goods.

The idea of cost-benefit analysis has a long tradition and dates back to large engineering projects as illustrated by a publication by Jules Dupuit in the mid-19th century. It was formally introduced in the regulatory process in the United States for works by the Army Corps of Engineers by the Flood Control Act of 1936 (Persky [30]). In the great infrastructure projects before and during the New Deal policy of the Roosevelt administration the Army Corps of Engineers developed rules to assess projects, also accounting for non-economic impacts. Since then, the idea of cost-benefit analysis has evolved and while today a standard procedure in the United

States, it is gradually being practiced more in EU regulation. Since the treaty of Maastricht (1992), the Community has to take into account costs and benefits of action and lack thereof when preparing its policy on the environment. However, only slowly is a body of good practice being established in the European regulatory process (Renda [34]).

Before entering into the details of cost-benefit analysis, a few words are in place regarding its role in a book on risk and security. As illustrated by the examples above, many of the regulatory questions involve risks. However, these risks occur at the level of single individuals. For society as a whole many of these risks are expected damages that can be calculated as the probability multiplied by the size of damage. The general assumption is that the regulator is not risk averse (cf. Chap. 3, [40]) and that it suffices to consider expected costs and benefits. Stated otherwise and in reference to Chap. 1, [47], the US Army Corps of Engineers applied a deterministic concept of risk when introducing cost-benefit analysis in relation to their projects. Only very recently are probabilistic and equity considerations taking more room in the debates. In this sense, cost-benefit analysis can be seen as a tool to support better risk management, based on the results of thorough risk analysis.

2 Doing a Cost-Benefit Analysis

In principle, the process of cost-benefit analysis is similar to that of any private investment appraisal. However, the public decision maker, e.g. the government of a country, is a large decision maker and may take into account particular considerations for discounting the future in a wide portfolio of projects. Furthermore, because the public decision maker must also account for market failures such as those caused by public goods and externalities, specific considerations apply for the evaluation of costs and benefits.

Public goods are for example clean air, a bridge over a river, or a scenic view. A defining characteristic for public goods is that they are not excludable, i.e. everybody can consume them, and non-rival, i.e., an additional person consuming the good does not reduce the consumption of others. Take the example of clean air in a city. Everybody living in the city will benefit from good air quality (non-excludable). Clean air is also not depleted if other people consume it too, for instance tourists visiting the city, so clean air is a non-rival good. For a bridge crossing a river it is the same. Everybody can use it (non-excludable), and the utility of using it does not decline when others use it as well (non-rival).[1] Certainly in this example one could propose a road toll, so that only those who have paid can cross the bridge. As such the good would become excludable. However, given the non-rivalness in consumption a toll would lower social welfare. This is the rational for public goods being

[1] Non-rivalness may be limited by congestion. This can concern the example of the bridge when it comes to traffic jams or the example of clean, fresh air, when a small room with many people is considered.

provided by the public and paid for by taxes rather than by charging prices as is the case for private goods.

Externalities are closely related to public goods. They result from market activities; however, they are not valued in the market. Similar to public goods, they are not excludable. Externalities can be negative, such as the air pollution caused by a coal power plant. The plant operator will consider material capital and labor costs when taking production decisions. He will also consider the price of electricity that determines revenue. He will, however, not consider the air pollution caused by the plant, even if it leads to impaired views, respiratory diseases or accumulation of mercury deposits. These are costs that accrue to society, but these will not have to be covered by the plant operator. Hence these costs are external to the firm's production decision. An externality can also be positive. Take the example of a vaccine. A vaccine is used to protect an individual from a communicable disease; however, by taking the vaccine the disease pressure in a society can be considerably reduced so that other people also benefit. This balancing of private and public benefits is one explanation for the observation of decreasing vaccination rates after a disease is considered overcome, leading to new outbreaks such as the polio-outbreak reported in Central-Asia (WHO [46]). The individual benefit of vaccination has declined (lower probability to contract a disease), but by lower vaccination rates society may put this accomplishment at risk (increased probability for the disease to come back). Section 4 will explain how a value for public goods and externalities can be estimated. First of all, we will look at the economic foundations of cost-benefit analysis.

Cost-benefit analysis seeks to identify projects that make society better off. It is rooted in welfarism and utilitarianism, so what matters to society is the well-being of people. For example, nature as such can matter to social welfare, but only in so far as it matters to people and their utility.

Assume we have a social welfare function that is a functional of all the individual utility functions of a society consisting of N people, $W_0 = \Phi(U_1(c_1), U_2(c_2), \ldots, U_N(c_N))$. Here, c_i denotes an index of consumption for individual $i = 1, 2, \ldots, N$ in the society and $U_i(c_i)$ denotes the resulting level of utility for individual i (with $\frac{\partial U_i}{\partial c_i} > 0$ and $\frac{\partial^2 U_i}{\partial c^2} \leq 0$). One can think of c_i as a money-value index, an aggregate of current and future consumption including private and public goods.[2] The welfare function is assumed to be differentiable, increasing ($\frac{\partial W_0}{\partial U_i} > 0$) and concave ($\frac{\partial^2 W_0}{\partial U_i^2} \leq 0$) in individual utility levels.[3]

[2]Consumption can be taken as a conglomerate of all different consumption goods, including public goods and externalities. Alternatively, it could be a placeholder for a vector of all goods/bads consumed (including public goods, environmental amenities, health etc.) that affect human well-being. When considering only private goods lifetime consumption will be constraint by lifetime income, closely related to wealth of an individual, i.e., $U(W)$ in Chap. 3, [40]. However, in welfare economics, personal well-being is most often considered to depend on consumption (not income), because not all types of consumption require expenditures.

[3]The assumption of concavity implies a societal preference for equality. The closer the welfare function is to a linear function, the easier it is to balance utility of somebody very poor against utility of somebody very rich.

Now suppose a project A is implemented, changing the consumption levels of people by Δc_i. Hence social welfare if implementing project A becomes

$$W_A = \Phi\big(U_1(c_1 + \Delta c_1), U_2(c_2 + \Delta c_2), \dots, U_N(c_N + \Delta c_N)\big). \tag{1}$$

At the social welfare level, we can conclude that a project increases social welfare if $W_A - W_0 > 0$. There exists one major difficulty in this assessment: for many projects some members of society will gain and others will lose. This means there are people who gain with $U_i(\Delta c_i) > 0$ and people who lose with $U_i(\Delta c_i) < 0$. Cost-benefit analysis deals with the question of how to trade off utility increases by those who gain against utility decreases of those who lose.

Welfare analysis has been conceived to draw welfare conclusions in such situations where a public project/policy is under consideration. The social welfare function is a powerful analytical tool in this regard; however it is not easily determined. As a matter of fact, Arrow [9] has proven that a social welfare function may not even exist (for an accessible treatment the reader may consult Mueller [27, pp. 384–399]).[4] Hence in order to judge welfare impacts, the economist and mathematician Vilfredo Pareto (1848–1923) suggested a criterion to make such efficiency judgements. The *Pareto* criterion states that a project/policy is considered *welfare enhancing* if nobody loses and at least some members of society are made better off (the strong Pareto criterion). A weak version of the Pareto condition is that a policy change is desirable if everybody in society is made better off (Johansson [22]).[5]

The Pareto criterion makes a lot of sense. Everybody can probably agree to the weak version of the criterion, and if there is no envy, then there will also be no opposition against the strong version of the Pareto criterion. However, the Pareto criterion has one important weakness: most projects do not only have winners: some members of society will lose. Consider the example of an infrastructure project such as the construction of a new airport runway. While the region may benefit as a whole, those living close to the airport will suffer from augmented noise and pollution. Because of this need to weigh off gainers and losers, Hicks (1939) and Kaldor (1939) proposed a *compensation criterion* in two independent publications. Take the case where a project under consideration moves the economy from a consumption level $(c_1, c_2, \dots, c_N)$ to $(c_1 + \Delta c_1, c_2 + \Delta c_2, \dots, c_N + \Delta c_N)$. According to Kaldor the project is desirable, if it is *hypothetically* possible to redistribute income (and hence consumption) such that everybody becomes better off with the project than without the project. The Hicks criterion states that a project is desirable if it is not possible that the losers bribe the gainers to forego the project (Johansson [22]). In this sense both criteria take the stance that compensation must theoretically be possible.

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[4] Kenneth J. Arrow received the Nobel prize jointly with John R. Hicks in 1972 "for their pioneering contributions to general economic equilibrium theory and welfare theory". In its award ceremony speech the prize committee stated with regard to Arrow's contribution "This conclusion, which is a rather discouraging one, as regards the dream of a perfect democracy, conflicted with the previously established welfare theory" [28].

[5] The weak Pareto criterion is weaker in the sense that every project that passes the weak test also passes the strong test, but not vice-versa. Obviously, fewer projects will pass the weak test.

The two versions of the compensation criterion take a different baseline perspective. Kaldor starts his analysis from the situation before the project, whereas Hicks considers the wealth distribution after the project.

The compensation criterion is quite useful because it now allows ranking projects that could not be ranked by the Pareto criterion. Note that the compensation criterion speaks only of the hypothetical possibility of compensation and not about implementation. This is because both authors (Kaldor and Hicks) as well as many other economists consider the question of efficiency separately from the question of distribution. They were foremost concerned with how resources should be used to achieve a maximum level of welfare.

The compensation criterion brings us close to the idea of cost-benefit analysis. However, one more crucial assumption is needed: cost-benefit analysis makes the assumption that the marginal utility of money is constant. What does this mean? It means that a loss of one Euro has the same impact on utility for all individuals. Hence we make the assumption that $\frac{\partial U_i}{\partial c_i} = \lambda$ for all i. In practical terms, it implies that taking away one Euro from one person and giving it to another person leads to changes in utility for these two people that net out.

The compensation criterion demands that those who gain can compensate those who lose to accept the project (or those who lose cannot bribe those who gain to forego the project) and hence requires that the question of distribution can potentially be solved in a way such that everybody is better off. As a result it is possible that everybody achieves a higher level of utility. If we furthermore assume a constant marginal utility of money, then we can state that the benefits of the project (in monetary terms) must be able to cover the costs of that project. Hence a project passes the cost-benefit test, if the benefits are greater than the costs.

Having discussed the economic foundation of cost-benefit analysis, the chapter will now consider procedural issues. That is, how to define a project and its effects? How to summarize benefits and costs over time and what is the appropriate discount rate? Finally, how to deal with uncertainty?

This section follows Hanley et al. [3] in dividing a typical cost-benefit analysis into six steps:

1. Definition of the project
2. Identification of the impacts of the project
3. Evaluation of the impacts
4. Calculation of the net present value
5. Application of the net present value test (or similar tests)
6. Conduct of a sensitivity analysis

All six steps are discussed one by one.

1. Definition of the Project There can be all types of projects considered via cost-benefit analysis. First it is important to define the limits of the project and its standing. "Standing" considers the issue of whose benefits and costs should count in cost-benefit analysis (Pearce et al. [5]). As a basic rule, all nationals should be included, whereas benefits and costs to non-nationals must be included according to specific considerations. Here it needs to be considered (a) if the project relates to international policy issues such as acid rain or climate change and (b) if there are ethical considerations for counting benefits and costs for non-nationals.

2. Identification of the Impacts of the Project A project has many implications on the use of resources and the creation of impacts. For example, if a coal power plant is constructed, electricity is generated (benefit) but air pollution may increase (cost). These costs of air pollution may be hard to estimate: they may include changes in human health and mortality (cf. the example of mercury exposure in the introduction). Labor and capital are used in the construction and contribute to the cost of the project. Alternatively, consider a new agricultural regulation that may limit the extent of soil erosion (benefit). Reduced soil erosion will have private benefits to land owners because the yield potential will be preserved for the future. Avoiding erosion also has a public benefit, because river-water quality will be improved. The costs of such a policy are born by farmers, who will have to invest in soil conservation technology.

3. Evaluation of the Impacts All identified impacts have to be valued in monetary terms. Suppose a project A leads to a flow of benefits and costs over time. The project starts in year $t = 0$ and runs for T years. We denote benefits evaluated as monetary benefits as B_t and costs as C_t for $t = 0, 1, \dots, T$. In general, it is recommended to evaluate all benefits and costs in *real* monetary terms. That is, all money flows have to be deflated or evaluated at *current* prices ($t = 0$). The valuation of costs and benefits is easy if private goods are concerned. The value of these goods can be measured by their market price. The issue of valuing nonmarket goods (public goods, externalities etc.) is more complicated. Economists have proposed different valuation methods, notably the contingent valuation method, the hedonic pricing method and the travel-cost method. Those will be discussed later in this chapter; for now we assume that there are ways to calculate also the benefits and costs when market prices are not available.

For an example the reader is referred to Table 1. The project has a life-time of 20 years ($t = 0, \dots, 19$) as shown in column 1. Columns 2–3 show the benefits and the costs of the project. The project is characterized by large investment costs in the first two years (100 each) and a major maintenance cost in year 10 (50). At the end the project ($T = 19$) is decommissioned with a cost of 50. Benefits accrue from year 2 onwards, with an exception of year 10, because the project has to be shut down for maintenance. After that the project is showing age with a decreasing flow of benefits over the second half of its lifetime.

4. Calculation of the Net Present Value At each point in time, the net value (NV) of the project can be calculated as $NV_t = B_t - C_t$.

As in any investment project, we have to account for the opportunity costs of time. This is done by discounting the flow of benefits and costs with the discount

Table 1 Example of cost-benefit analysis calculations, $d = 0.05$

t	B_t	C_t	NV_t	Discounted B_t	Discounted C_t	NPV	NPV at $i = r$
0	0	100	−100	0.00	100.00	−100.00	−100.00
1	0	100	−100	0.00	95.24	−95.24	−89.85
2	40	10	30	36.28	9.07	27.21	24.22
3	50	10	40	43.19	8.64	34.55	29.01
4	50	10	40	41.14	8.23	32.91	26.07
5	50	10	40	39.18	7.84	31.34	23.42
6	50	10	40	37.31	7.46	29.85	21.05
7	50	10	40	35.53	7.11	28.43	18.91
8	50	10	40	33.84	6.77	27.07	16.99
9	40	10	30	25.78	6.45	19.34	11.45
10	0	50	−50	0.00	30.70	−30.70	−17.15
11	40	10	30	23.39	5.85	17.54	9.24
12	40	10	30	22.27	5.57	16.71	8.30
13	40	10	30	21.21	5.30	15.91	7.46
14	40	10	30	20.20	5.05	15.15	6.70
15	30	10	20	14.43	4.81	9.62	4.02
16	30	10	20	13.74	4.58	9.16	3.61
17	20	10	10	8.73	4.36	4.36	1.62
18	20	10	10	8.31	4.16	4.16	1.46
19	0	50	−50	0.00	19.79	−19.79	−6.54
Sum				424.54	346.95	77.59	0

$NPV = 77.59$, $BCR = 1.22$, $IRR = 0.11$

Example taken from Conrad [15]

rate d. As can be seen in Table 1, discounted benefits are calculated as $(1 + d)^{-t} B_t$ and discounted costs as $(1 + d)^{-t} C_t$. In the example, the discount rate is set at $d = 0.05$. Because money that is invested in one project cannot be used otherwise, we have to account for this opportunity forgone. Because costs and benefits accrue over time, the net present value (NPV) for the project is calculated as follows:

$$NPV = \sum_{t=0}^{T} (1 + d)^{-t} (B_t - C_t). \tag{2}$$

Discounting occurs here with compound interest, i.e., using an exponential function. This leads to specific properties of discounted values and has triggered extensive discussions on the appropriate choice of the discount rate d. Section 3 of this chapter will be devoted to this issue. Taking the example in Table 1 with $d = 0.05$, the NPV results as 77.59.

Table 2 Decision criteria in cost-benefit analysis when deciding on a single project

Decision criteria	Formula	Decision rule
Net present value	$NPV = \sum_{t=0}^{T}(1+d)^{-t}(B_t - C_t)$	$NPV > 0$
Benefit-cost ratio	$BCR = \frac{\sum_{t=0}^{T}(1+d)^{-t}B_t}{\sum_{t=0}^{T}(1+d)^{-t}C_t}$	$BCR > 1$
Internal rate of return	$\sum_{t=0}^{T}(1+r)^{-t}(B_t - C_t) = 0$	$r > d$

5. Application of the Net Present Value Test (or Another Test) The net present value test considers if the net present value of a project is positive or not. Benefits are greater than costs and hence the project is socially desirable if

$$NPV = \sum_{t=0}^{T}(1+d)^{-t}(B_t - C_t) > 0. \tag{3}$$

In the example in Table 1, the $NPV = 77.59$ obviously passes the net present value test and the project should be implemented.

An alternative test would be to calculate the benefit-cost ratio (*BCR*) and to check if the ratio is greater than 1:

$$BCR = \frac{\sum_{t=0}^{T}(1+d)^{-t}B_t}{\sum_{t=0}^{T}(1+d)^{-t}C_t} > 1. \tag{4}$$

Referring again to Table 1, the *BCR* results as 1.22. Here again, the decision rule suggests implementing the project.

A third way to assess if a project is desirable is to calculate the internal rate of return (*IRR*) on the project. The *IRR* is defined as the discount rate, r, at which the *NPV* of the project would exactly be zero, that is:

$$NPV = \sum_{t=0}^{T}(1+r)^{-t}(B_t - C_t) = 0. \tag{5}$$

A project is then socially efficient if $r > d$, which means that the rate of return on the project is larger than the rate of time-preference of society. For the example in Table 1, the *IRR* is $r = 0.11$, which is greater than $d = 0.05$. Again the rule suggests implementing the project.

Table 2 summarizes the decision criteria when deciding on a single project.

One may wonder why there are many alternative decision rules. In principle they give the same result, but there are particular situations when one decision rule outperforms the others. In general, economists recommend using the net present value test.

When selecting projects with a limited budget, the *BCR* is useful. Let the available budget for investment be M. A public decision maker can choose between L mutually non-exclusive projects, each incurring an investment costs $I_l, l = 1, \dots, L$ at the beginning of the project. E.g. for the project in Table 1 the investment costs would be the cost of 200 in years 1 and 2. Then sort all L projects by their *BCR*,

Table 3 Ranking projects

Project	Cost (C)	Benefits (B)	NPV (rank)	BCR (rank)
X	100	200	100 (1)	2.0 (3)
Y	50	110	60 (3)	2.2 (2)
Z	50	120	70 (2)	2.4 (1)

Source: Pearce et al. [5]

so that $BCR_1 \geq BCR_2 \geq \cdots \geq BCR_l \geq \cdots \geq BCR_L$. The projects selected should be $BCR_1, BCR_2, \ldots, BCR_{L0}$ such that $\sum_{i=1}^{L_0} I_l \leq M \leq \sum_{i=1}^{L_0+1} I_l$. That is the public decision maker should choose the projects with the largest BCR so that the available budget is sufficient to cover the investment costs of these projects.

Table 3 illustrates by example the advantage of the BCR rule when considering budget constraints.[6] There are three projects under consideration and they are not mutually exclusive. However, the public decision maker has a limited budget and hence can only realize projects that do not exceed a cost of 100. If projects were ranked according to the NPV criterion, project X would be ranked 1 and the available capital would be exhausted. According the BCR ranking, projects Y and Z would be realized (total cost equal 100). The total NPV of these projects is $130 (= 60 + 70)$. This is higher than the NPV of project X alone (100).

The internal rate of return is often used to calculate the return on an investment and compare it across sectors. For example, in its report "Education at a Glance" the OECD regularly publishes internal rates of return for individuals obtaining higher education as part of initial education (e.g. OECD [29]). The private IRR for tertiary education in Germany for instance is 11.5 % for men and 8.4 % for women. This is slightly below the OECD average at 12.4 % and 11.5 %. Using the internal rate of return exempts the analyst from making assumptions regarding the discount rate. The problem though is that solving for r requires the solution to a higher degree polynomial that can have multiple solutions.

6. Conduct of a Sensitivity Analysis Typically, cost-benefit analysis requires making predictions for the future. How will benefits evolve and how will the costs? Cost-benefit analysis requires a lot of data, many based on estimates. Uncertainty can be found around the individual prices and also the physical and social impacts. Electricity prices may increase or decrease over time. Machinery wear may increase the maintenance costs of equipment. Weather and climate uncertainties may influence the agronomic yield impact of soil conservation policy.

Given all these uncertainties it is necessary to conduct a sensitivity analysis on all parameters that enter the cost-benefit analysis. For instance in the example of Table 1, do you come to the same conclusions, when annual benefits increase or decrease by 10 %? Would the project still be desirable, were the maintenance cost in year 10 to double? Sensitivity analysis helps to check the robustness of the results. It means repeating the same analysis with different value estimates. This can be done

[6] A mathematical proof would maximize net benefits subject to the constraints.

Table 4 The *NPV* in dependence of discount rate d and time t

Discount rate d	*NPV* of 100 Euros after ... years				
	1	5	10	50	100
0.03	97.09	86.26	74.41	22.81	5.20
0.05	95.24	78.35	61.39	8.72	0.76
0.10	90.91	62.09	38.55	0.85	0.01

by considering a limited number of scenarios. Or it can be done in a systematic way by Monte Carlo simulation.

3 The Discount Rate

One number of crucial importance in cost-benefit analysis is the discount rate. It is used to calculate the *NPV* and hence to make costs and benefits that accrue over time comparable to each other. This single number is one of the most debated issues in cost-benefit analysis overall.

Discounting occurs because cost-benefit analysis originates from welfare economics and individual preferences. Those are summarized in the utility function and it has been observed that individuals prefer now to later. The discounting of future benefits hence should use the rate that expresses this time preference. Discounting occurs also because when investing today, we forego the opportunity to invest tomorrow. This opportunity cost of time should be considered in the discount rate. For a general treatment of intertemporal decision making the interested reader is referred to microeconomics textbooks such as Varian ([43], Chap. 19).

A typical way to determine this discount rate is to use the interest rate on long-term government bonds. Government bonds are issued by a country in order to borrow money. The interest rate that the government has to pay for borrowing money also shows the opportunity cost of time for conducting public projects. Compared to individual borrowers, the government bears lower risk premia and interest on its bonds because it can raise taxes in order to redeem these bonds.

Because discounting with discount factor $(1+d)^{-t}$ results in compound of interest and hence is exponential, it is crucial to consider the effect of choosing the discount rate d. Table 4 provides an example discounting 100 Euros at three different rates (0.03, 0.05 and 0.10) and over different time periods (1 year up to 100 years).

It can be observed that a higher discount rate yields a lower *NPV* and the impact of this discounting is larger the longer the time span. When discounted at a rate of $d = 0.03$, 100 Euro in year 1 will have a present value of 97.09, but 100 Euro in year 100 only have a present value of 5.20. The effect is even stronger for a larger discount rate, so that the present value of 100 Euro in year 1 discounted at a rate of $d = 0.10$ will have a net value of 90.91.

Mathematically, this observation is quite obvious. On ethical grounds though, it leads to fierce debates. As shown in the example in Table 1, the typical cost structure of public projects implies that costs have to be born at the beginning of the project and benefits accrue only after a significant investment has been made. Hence, benefits are discounted for long time periods whereas costs are not. Certainly the public decision maker should account for the time preference of society and hence choose a positive discount rate. But what if projects run over very long time spans that cover several generations? This question has become the centre point of the discussion since economists have started to consider policies for mitigating and reducing climate change (for this debate see Arrow [10]; Stern [39]; Weitzman [45]; Gollier [20]; Gollier and Weitzman [21]). Climate change is an issue that may have implications for many generations to come and because of the implications of Table 4 the appropriate choice of the discount rate is of considerable importance and some argue for a discount rate of zero for reasons of intergenerational justice. Basically the question is whether we can justify that the costs of avoiding climate change born by the current generation are not as heavily discounted as are benefits enjoyed by future generations.

4 Estimating the Costs and Benefits of Nonmarket Goods

We have seen that cost-benefit analysis is quite similar to the appraisal of investment projects. The flow of costs and benefits is evaluated over the lifetime of the project and similar rules such as the *NPV* rule or the calculation of the *IRR* are applied. However, for public projects there is one important distinction. Often public goods and externalities are involved or even the primary motivation to start a public project.

Public goods and externalities were defined in Sect. 2 and by their very definition do not have a market value. Hence it is not possible to use market prices for evaluating costs and benefits related to them. But the fact that there are no market prices does not mean that there is no value. Economists have developed sophisticated methods to measure such values by estimating people's willingness to pay for non-market goods.

Consider the case of water quality in a lake. Water quality protects aquatic life, it enhances the scenic view for residents and tourists and it improves the quality of leisure activities in and on the lake like swimming or fishing. We return to the individual utility function to consider the value of such water quality. Utility in this case depends on the consumption of private goods that are accounted for by an individual's level of current wealth, W_i. It also depends on the environmental quality, e_0 (note that we drop the subscript i because water quality—a public good—is the same for everybody). Hence, utility can be described by $U_i(W_i, e_0)$. It is increasing in both arguments. Now suppose that water quality can be improved, e.g., through the regulation of run-off from agricultural fields into the lake by requiring a green corridor of 5 m along the fields bordering the lake and creeks running into it. Environmental quality would be enhanced to e_1. While the change in e refers to some kind of water quality indicator, we would be interested in the value of this water quality change to an individual. Since utilities cannot be compared across individuals, we would use a monetary evaluation of that change.

One measure of this utility change would ask for people's *willingness to pay* (*WTP*). This *WTP* is the maximum amount of money that people would be willing to forego to obtain the change in environmental quality. It is implicitly defined by the following equation:

$$U_i(W_i, e_0) = U_i(W_i - WTP_i, e_1). \tag{6}$$

On the left-hand side of the equation, a lower environmental quality e_0 leads to a lower utility compared to the right-hand side of the equation. The higher utility caused by the enhanced environmental quality e_1, however, is compensated through a decrease in wealth by the amount WTP_i. This WTP_i is the amount of money that individual i is willing to pay for the environmental improvement. Because it compensates the environmental improvement, it is also named *compensating variation*. This compensating variation may be relevant to determine the tax charge that people are willing to pay for agri-environmental programs that limit the amount of agricultural run-off. Note that water quality is a property of the water—hence the same for everybody. The value of that water quality measured in WTP_i, however, may differ between individuals.

Another way to measure the utility impact of such a policy is to use *willingness to accept* (*WTA*). It asks the question of what amount of money people are willing to accept to forgo the environmental improvement. In mathematical terms, this means

$$U_i(W_i + WTA_i, e_0) = U_i(W_i, e_1). \tag{7}$$

This increase in wealth by WTA_i on the left-hand side is equivalent to an increase in the environmental quality on the right hand side. It is hence also named the *equivalent variation*. On theoretical grounds, compensating and equivalent variation should be of similar size. However, empirical studies have found that *WTA* estimates are considerably larger than *WTP* estimates, in particular when environmental goods are concerned. Section 6 'Food for Thought' will return to this issue.

Now that we have a theoretical construct of the value of public goods and/or externalities, the question is how to quantify that value empirically. There are different methods available: the *hedonic valuation* method uses surrogate markets as does the *travel cost* method, which is often used for assessing the value of an environmental amenity such as lake water quality. Finally, people's values can be assessed using survey methods such as the *contingent valuation* approach. The hedonic valuation and travel cost method observe people's decisions in relation to the non-market good that is being evaluated. Hence these methods are called *revealed preference* methods, because they are based on preferences as they are revealed in people's decisions. The contingent evaluation method is based on *stated preferences*, that is, people state how they would decide in hypothetical scenarios that are described in the survey. The following paragraphs will describe the three methods in more detail.

The hedonic valuation method considers that goods consist of bundles of attributes (Lancaster [24]). The description of each of these attributes will define the value of the good. This product characteristics approach has been treated in a market setting by Rosen [35], hence establishing a basis for the hedonic valuation method. For example, if we seek an estimate of the *WTP* for lake water quality, we can refer to the housing market as a surrogate market. The price of a house may be determined by characteristics such as the size in square meters, the number of rooms, the age of the house and whether it has a garden. Also neighborhood characteristics may count, such as the distance to employment centers, the quality of the local school and public transport. Finally, environmental characteristics such as the view to a lake may also be an important determinant of the house price and it may change with the quality of the lake.

In order to find the value of such environmental quality characteristics, a regression analysis would link the prices of houses, P, to all these characteristics:

$$P = f(\textit{house-}, \textit{neighborhood- and environmental characteristics}). \tag{8}$$

The next section will provide an example for the hedonic valuation method when valuing risk to life and health.

The travel cost method uses people's travel choices to estimate the value of a public good such as lake water quality. It is one of the oldest environmental valuation techniques and it has been developed in the US in the context of valuing recreation in national parks (Hanley et al. [3]). The travel cost method makes use of the idea that environmental amenities are valuable for recreation activities and that recreation requires expenditures in terms of time and money. Monetary expenditures are needed for travel (car, gasoline, bus ticket) and also time is a scarce resource and hence has an opportunity cost. To implement such a travel cost method for the example above, visitors to the lake would be asked about the distance they had to travel and the time spent on travel and on the lake. Improvements in water quality could lead to an increase of visits by recreational fishermen and using the travel cost method the corresponding value could be estimated.

The contingent valuation method is a stated preference method. Here actual choices are not observed, but people are asked in surveys for their valuations. While economists generally prefer revealed preference methods to stated preference methods, the latter have some advantages. A salient feature is that preferences for non-existent attributes can be elicited. For instance, if one is interested in a *WTP* for food safety as one characteristic of the food supply, the hedonic pricing method is hard to implement. In general, all food available on the market is considered safe and there are no explicit risk differences that experts and consumers would agree upon. In such cases it can be useful to estimate *WTP* using the contingent valuation method. When doing so, it is important to consider realistic scenarios in the valuation survey for ensuring that respondents do not misinterpret or ignore attributes. It is a characteristic of the contingent valuation method that it allows for the evaluation of hypothetical scenarios. This advantage is at the same time a major disadvantage, because elicited values may suffer from biases that are related to the hypothetical nature of the survey. This hypothetical bias is only one problem of the resulting estimates; other biases are related to the strategic behavior of the respondent and conceptual mistakes in conducting the survey. Economists have hence developed extensive toolkits to avoid the pitfalls of the contingent valuation method and the interested reader is referred to books such as the one by Carson and Mitchell [1].

The hypothetical valuation based on the characteristics approach has eventually led to the development of (hypothetical) choice experiments. Choice experiments (CE) have been developed in the context of transport studies and now have been brought into many different applications in environmental valuation (Adamowicz et al. [7]), marketing (Lusk et al. [25]) or medical treatments (Kjaer and Gyrd-Hansen [23]). In CEs respondents are asked to make repeated choices between different consumption bundles, which are described by different attributes. Typically, one of these attributes is price. This procedure enables the researcher to estimate *WTP* for each attribute considered in the CE.

This section introducing *WTP* as a concept for finding a monetary value for impacts that do not have a market value makes very apparent the anthropocentric welfare foundations of economics. Things are of value because people value them. The value may be related to the use of the resource (use value), but it may exist also other reasons (non-use values). Consider again the example of lake water quality given above. There may be some fish species, not used in commercial or recreational fishing, threatened by the deterioration of water quality. There is obviously no use value to the fish species, nevertheless there will be a loss if the species is lost. To take this loss into account in a cost-benefit analysis, economists consider aspects such as existence values (Hanley et al. [3]). The option value considers the value of preserving a resource (here a species), because it may become valuable in the future. It is hence part of the total value of preserving existence of the species. The existence value counts for the fact that the mere existence of a species is important to people. It may be motivated by selfish reasons or altruistic motives. For example, moral or religious reasons lead people to value the existence of a species or people may want to preserve the species for their children and grandchildren. While considerably widening the scope of economic values, these values still maintain the anthropocentric view that things are valuable because they are valued by humankind.

5 The Value of Risks to Life and Health

Sometimes projects involve also impacts on human health and hence human morbidity and mortality. As an example, let us look at the regulation of arsenic in drinking water in the United States (cf. Sunstein [41]; Raucher et al. [33] and references therein). Under US law, the Environmental Protection Agency (EPA) set a Maximum Contaminant Level (MCL) of 10 μg/L in drinking water. Respecting this MCL can require considerable water treatment costs. Because of economies of scale, the costs of the regulation per household are much larger in small communities compared to those in large communities. The benefit of the regulation is an estimated reduction in bladder and lung cancer cases. Based on EPA estimates, Raucher et al. [33] calculate that a reduction from 15 μg/L to 10 μg/L would avoid 4,450 cases of cancer per 1 million people exposed to the elevated level of arsenic, about half of which (53 %) would be fatal over a 70-year time span.[7]

In this example, the assessment of costs is relatively straightforward. What about the benefits? The benefits are the avoidance of a risk to human life. How can such benefits be valued in monetary terms?[8]

Many people would argue that a human life has infinite value or is even invaluable. Hence, no monetary value can be assigned to a human life saved. However, people take decisions every day that decide about their risk to health and life: a worker when she decides to eat healthily or not, a car driver when he decides to speed on the motorway or not, or a student when she decides to run a red light to turn up on time to an exam. All these decision have a small, albeit real impact on the probability of surviving the day. This observation has been used by economists to value life in terms of a small change of the likelihood of death due to the cause under consideration (cf. the deterministic approach to risk as explained in Chap. 1, [47]). Methods as described in Chap. 16, [8] can be used to estimate the risk at the population level and changes therein.

Public decision makers take such decisions many times. They decide to ban or not a pesticide that has been shown to have an impact on agricultural workers' and consumers' health. They modify or not a dangerous intersection in a city, so as to reduce the number of deaths due to traffic accidents. They decide to impose a speed limit or not. Economists have used the observed public decisions to calculate the implicit value of reducing risk to life and health from such data. That is, they looked at all sorts of regulations, the number of lives saved by these regulations and their costs. For instance Cropper et al. [17] analyzed the determinants of pesticide regulation decisions in the time span of 1975 to 1989 by the EPA. They show that the EPA indeed balances cost and benefits. However, the costs per cancer case avoided amount to \$35 million for an applicator (farm worker) and to \$60,000 for consumers of pesticide residues in food. That means saving the life of an agricultural worker costs as much as saving the life of more than 500 consumers. Such large differences in valuation lead to inefficiencies, and more lives would be saved if projects were selected on more rational grounds.

We link this value of reducing risk to life and health to the expected utility model that was introduced in Chap. 3, [40]. The model is based on Cook and Graham [16]. Assume that the state-dependent preferences of an individual are represented by a von-Neumann-Morgenstern utility function $U(W, H)$, where W denotes wealth and H denotes the individual's health state.[9] In this case, we consider two health states: $H = 0$ if the individual is dead and $H = 1$ if the person is alive. To simplify notation, let $U_0(W) = U(W, 0)$ and $U_1(W) = U(W, 1)$ and assume that $U_1(W) > U_0(W)$ for all W. This means at any level of wealth the utility is always higher when alive

[7] Sunstein [41] underlines the uncertainties related to the health damage estimation and states that the number of lives saved by the regulation may vary between 0 and 112.

[8] In their analysis, Raucher et al. [33] assume a Value of a Statistical Life of US-\$7 million.

[9] Here we drop the subscript i to keep things simple.

rather than dead.[10] Let's also assume that utility increases with wealth, i.e., the first derivative $U_j' > 0$, but at a decreasing rate, i.e., the second derivative $U_j'' \leq 0$, for $j = 0, 1$.

Given the baseline mortality risk π, expected utility results as

$$E[U] = \pi U_0(W) + (1 - \pi)U_1(W). \tag{9}$$

The individual would be willing to forgo a part of his wealth W if offered the opportunity to reduce the health risk π by an amount p. We call the maximum amount of money that a person is willing to spend on the reduction of mortality risk *WTP*. As introduced in Sect. 4, *WTP* is defined such that the increase in expected utility due to the decrease in mortality risk is exactly offset by the decrease in utility because of the decrease in wealth. Mathematically stated:

$$\begin{aligned} &\pi U_0(W) + (1 - \pi)U_1(W) \\ &\quad = (\pi - p)U_0(W - WTP) + (1 - \pi + p)U_1(W - WTP). \end{aligned} \tag{10}$$

On the left hand side of the equation we see the expected utility before the change in mortality risk and on the right hand side we see the expected utility after the change. Under specific assumptions regarding risk preferences, it can be shown that this *WTP* is increasing as a function of the reduction of risk. That would mean people would be willing to pay more for projects that would reduce the mortality rate to a greater extent.

In valuing risk to life and health, researchers have mostly resorted to the hedonic valuation method. One market that has been used as surrogate market for the risk to life and health is the automobile market. It is based on the idea that road safety is valuable because it avoids deadly accidents. But how to value this benefit? What is it worth to people to be safe on the road? There is no market for road safety where you could find a price determined by the interplay of demand and supply. The hedonic valuation method would look for a market good that can serve as a surrogate market, that is, one that also values safety on the road. An obvious choice is the market for cars. Cars come in all sorts of brands and types and one characteristic is occupant safety in accidents. They are regularly tested by crash tests and reports can be found in relevant automobile magazines. The hedonic valuation method makes the assumption that the safety of people in a car during a car accident enters into the price of a car. Atkinson and Halverson [12] have done this in a publication in 1990. They estimate the value of reducing risk to life at \$5 million per person (according to Viscusi and Aldy [44]). Another surrogate market for safety is the labor market. Jobs differ in their safety. A fire-fighter faces different risks compared to a white-collar worker. Differences in pay can be used to estimate workers' *WTA* risk using wage rates of different occupations correcting for educational and other job-related aspects. Viscusi and Aldy [44] give an overview of studies estimating the value of

[10] One could also argue that the utility of wealth when dead is zero. This would mean $U_0(W) = 0$. This assumption is often made. Relaxing the assumption means that we accommodate a bequest motive, that is people value bequeathing wealth to their children etc. at the end of their life.

reducing risk to life and health. Reviewing thirty studies based on US labor market data, they find estimates between $0.5 and more than $20[11] per life saved.

Returning to the example at the beginning of this section, you may still say, don't we all know that arsenic is a poison? Is there a reason not to get it out of the drinking water? One important aspect when managing risks and when conducting cost-benefit analysis is the issue of risk-risk trade-offs (Graham and Wiener [2]). Countervailing risks have to be considered. In a quest for better protection of the population, maximum contaminant levels of arsenic are fixed. However, the cost imposed on community water systems may be so high that other, more valuable opportunities for saving lives are foregone. Raucher et al. [33] discuss this point, in particular considering the lack of economies of scale of water treatment in small communities leading to higher cost per life saved.

6 Food for Thought

- The discount rate is crucial for projects that have intergenerational implications. Discuss the arguments in favour and against using a positive discount rate or a discount rate of zero when conducting cost-benefit analysis.
- In some countries the use of cost-benefit analysis is required for most policies but it is precluded when cancerogenic agents are the focus of the policy (e.g. pesticide bans etc.). Discuss the implications that such ruling may have.
- Consider and discuss reasons that may explain differences in *WTP* and *WTA* estimates.
- *WTP* evaluations are based on the subjective perceptions of the goods being evaluated. To exemplify the issues related to subjective risk perceptions, Pollack [32] has told the story of a town named Happyville. The citizens of Happyville have come to fear a contaminant in their drinking water well. The construction of water purification plant is hence proposed. The major of the city commissions a chemical analysis of the water in order to learn about the extent of water pollution. It turns out that there is no risk related to the water quality. Hence based on this objective risk evaluation no purification plant is needed as it would cause costs without creating a benefit. Nevertheless, the citizens of Happyville do not trust the scientific study and still insist on the purification plant.
- Using this or other examples, discuss the role of objective and subjective risk evaluation in willingness to pay estimates used in cost-benefit analysis. Are there reasons for considering subjective risk evaluations? How may this conclusion differ considering the possibility of people's reaction to the risk, e.g., drinking water risk compared to nuclear power risk? You may also refer to Salanie and Treich [36] to find arguments and look at Marette et al. [26] for an application.

[11] To make values comparable across different studies all results have been corrected for inflation to US-$ values for the year 2000.

7 Summary

Managing risk in modern societies requires the regulation of impacts on human health and the environment. However, the extent of regulatory activities in many countries has made it necessary to consider what is 'good' regulation and what is not. Cost-benefit analysis can help to answer this question. This chapter has introduced the reader to the theory and practice of cost-benefit analysis. It made the underlying assumptions explicit, introduced the procedures step by step and discussed critical issues for empirical applications. Certainly, regulation is not only a question of efficiency. Other issues are at stake such as equity considerations, risk trade-offs, uncertainty about future impacts and irreversibilities, moral concerns regarding the limitations of utilitarianism to just name a few.

The role that cost-benefit analysis can play for good public decision making cannot be overrated. Arrow et al. [11] published a short note on the role that cost-benefit analysis can play in environmental health and safety regulation. They argue that cost-benefit analysis is useful for comparing the favorable and unfavorable effects of policies in a coherent manner. Considering the economic effects of different policies is very important for society and hence government agencies should not be precluded from taking such considerations into account. All assumptions made in a cost-benefit analysis should be made explicit and underlying uncertainties should be described. Cost-benefit analysis can hence help to identify efficient policies.

Despite the argument in favour of cost-benefit analysis, government agencies should also have the possibility to override the conclusion of the cost-benefit analysis, if there are good reasons to do so. Cost-benefit analysis can exemplify the cost to society of not following the result of a cost-benefit analysis and society will be able to judge, if the benefit sought is worth this cost. For instance, equity considerations may preclude the implementation of certain regulations, even if this comes at a cost on efficiency grounds. Also environmental projects may be rejected if they put species at risk even if this has been accounted for in the cost-benefit evaluation.

Sunstein [6] argues in favor of cost-benefit analysis because public choices are inherently complex. Humans are subject to limits of rationality in decision making (see Chap. 3, [40]). Why should policy makers and regulators be exempt from such irrationalities? In fact, most likely they are not. Doing cost-benefit analysis can save the public from irrational policy making and help to save resources for uses that are in the best interest of society.

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