

Economic Valuation of Life and Health

2.1 Introduction

‘Life is priceless.’ Most people would probably agree with this statement. However, decisions affecting lives are not only made by individuals but (necessarily) also by parliaments and public authorities on a regular basis. This implies weighing up the preservation and lengthening of human life against the input of scarce resources (i.e., money). Examples for such decisions in the public sector can be found not only in health care but also in many other sectors, especially those related to transportation and the environment.

Countries with a national health service or national health insurance usually let political authorities decide on new pharmaceuticals, new therapies, and new medical devices to be covered by the plan. As a rule, cost-increasing product innovations prevail that bring about therapeutic advantages, often by reducing the risk of early death in a certain population at risk. Such new products involve additional expenditure. Cost-reducing process innovations, by contrast, are rare and shall not be dealt with here.

For instance, the provision of a mobile coronary unit with total costs of several million dollars may help to treat heart attack patients on the spot, serving to significantly reduce the number of those dying prior to arriving at the hospital. Long-term drug therapy of hypertonic patients using anti-hypertensives may prevent a heart attack as well, at a considerable cost to the economy for research and development of pharmaceuticals. Another well-known example is the installation of dialysis equipment for patients with chronic kidney failure.

Outside health care, there are numerous other examples where ‘life’ and ‘costs’ have to be pitted against each other. Communities and countries have to decide whether notorious sites of accidents, for example narrow blind curves, should be eliminated by widening and straightening the road. In residential areas, the opposite can be appropriate, i.e., planting trees and installing bumps may reduce risks for playing children by lowering driving speed. All those measures of course involve additional expenditure from the public purse.

Environmental policy provides additional cases in point. Costly ‘redundant’ safety systems in nuclear power plants do not only diminish the likelihood of catastrophes with thousands of deaths but also the emission of radiation exposing the population to an increased risk of suffering from leukemia (as in the case of Chernobyl in 1986). Costly filters retaining sulphur dioxide and other harmful substances from the combustion of coal serve to improve the quality of air and reduce the incidence of respiratory disease.

In all the areas of application mentioned so far, rational decisions cannot be made by authorities unless there is a comprehensive and precise valuation of future advantages (and possibly disadvantages) resulting from a specific measure taken, permitting comparison with the present value of the cost stream associated with the project. To be helpful to decision makers, costs and benefits should ideally be commensurable, i.e., have a common unit of measurement. As the cost of the project is usually measured in monetary units, it makes sense to measure all benefits in the same way. Of course, this implies that the prolongation of human life or the improvement of the state of health due to the realization of a project must be valued in money units as well. A valuation of health and, a fortiori, human life in terms of money, however, meets with considerable objections. For this reason, economists have developed alternative methods of evaluation which are not based on monetization. These approaches, their potentials and their limitations will be the subject of this chapter as well.

This chapter is organized as follows. Section 2.2 gives a general overview of the different approaches to the economic evaluation of health. Section 2.3 is devoted to the method of Cost-Utility Analysis, Section 2.4 to Cost-Benefit Analysis. Section 2.5 compares these two approaches and considers Social Welfare Analysis as an alternative.

2.2 Approaches to the Economic Evaluation of Health

The various approaches to economic evaluation of health compare the benefits of a health intervention to its cost. With regard to the benefits of the intervention, three alternative units of measurement can be distinguished,

- (1) natural units on a one-dimensional scale;
- (2) units of a cardinal utility function which maps the multi-dimensional concept of health into a scalar index;
- (3) units of money.

Measuring benefits in natural units. The ‘natural’ scale can either be a clinical parameter such as the lowering of blood pressure by x mmHg, or the length of life in years. Measurements of this type are meaningful only in cases where the alternatives (e.g., performing an intervention or not) differ in only one specific effect and have no side effects. In the first example given above, the comparison could be between different anti-hypertonic drugs without side effects, and in the second example, traffic interventions which can prevent fatal road accidents.

The corresponding method of evaluation is called *Cost-Effectiveness Analysis* (CEA). Consider first independent interventions, i.e., interventions whose costs and benefits are not affected by other interventions. Examples are hip replacements and heart transplants. The index of comparison is the ‘average cost-effectiveness ratio’ (ACER). If effectiveness is measured by length of life, it is defined as

$$\text{ACER} = \frac{\text{costs in units of money}}{\text{benefits in life years gained}}.$$

If interventions are mutually exclusive (e.g., two incompatible medications for the same condition), one needs to consider the rate at which higher expenses can purchase additional benefits. For this reason, ‘incremental cost-effectiveness ratios’ (ICERs) are used [see WEINSTEIN (2006)]. The ICER of an intervention is defined as the ratio of incremental costs and incremental benefits compared to the next most effective intervention,

$$\text{ICER} = \frac{\text{additional costs}}{\text{additional benefits in natural units}}.$$

The example in Box 2.1 illustrates how ICERs are calculated.

Note that the average cost-effectiveness ratios for independent interventions can also be regarded as incremental because they are compared with the alternative of ‘doing nothing’. All interventions can therefore be ranked according to their incremental cost-effectiveness ratios. Interdependencies between the benefits and costs of interventions can be taken into account by defining combinations of interventions as the unit of comparison [see WEINSTEIN (2006, p. 476)].

Prior to a ranking, it is important to exclude dominated alternatives in the case of mutually exclusive interventions and to recalculate the ICERs. An obvious case is an intervention that is more costly and less effective than an alternative. Furthermore, if the ICER of an intervention is larger than the ICER of a more expensive intervention, it is ruled out by ‘extended dominance’, provided that it is possible to scale down interventions proportionally [WEINSTEIN (1990)]. The example in Box 2.1 illustrates the argument.

The limitations of cost-effectiveness analysis are obvious.

- (a) CEA implicitly assumes that it is ethically irrelevant how the life years gained are distributed among the members of society. This criticism, however, applies to all methods of economic evaluation discussed in this section.
- (b) CEA is not suitable for comparing interventions that differ in more than one effect. If, e.g., a traffic regulation does not only reduce the number of deaths but also the number of injuries, CEA cannot be applied because it has no way to aggregate multi-dimensional effects.
- (c) While CEA yields a rank order of measures, it does not answer the question of whether or not the highest-ranked measure should be performed at all. The only practical case for which CEA provides a meaningful answer to this type of

Box 2.1. Calculating Incremental Cost-Effectiveness Ratios

Consider a condition affecting 100 patients that can be treated by three mutually exclusive health care interventions *A*, *B* and *C*. Intervention *A* costs €300,000 and increases life duration per patient by 0.3 years, implying a total of 30 life years gained. Intervention *B* yields 40 additional life years at a cost of €500,000 while intervention *C* costs €600,000 and yields 50 additional life years. All interventions can be scaled down proportionally. For example, it costs €6,000 to treat one patient with intervention *C*. The life duration of this patient increases by 0.5 years.

Intervention	Cost in €000	Gain in Life Years	ICER in €000	
			with <i>B</i>	without <i>B</i>
<i>A</i>	300	30	10	10
<i>B</i>	500	40	20	–
<i>C</i>	600	50	10	15

For intervention *A*, the next most effective intervention is to do nothing. The ACER and the ICER of *A* therefore coincide and are equal to €10,000 per life year gained. The ICER of *B* is obtained by calculating the ratio of incremental costs and incremental benefits compared to the next most effective intervention, i.e., intervention *A*. We obtain $(€500,000 - €300,000)/(40\text{yrs.} - 30\text{yrs.}) = €20,000$ per life year gained. Intervention *B* is thus able to save an additional life year at a cost of €20,000 compared to intervention *A*. By contrast, using the ACER for intervention *B* of €12,500 per life year gained would lead to an overestimate of cost effectiveness because one does not consider that intervention *A* can generate 75 percent of the health gain of *B* at only 60 percent of the cost.

To obtain the ICER of *C*, costs and benefits need to be compared with intervention *B*. This yields an ICER of $(€600,000 - €500,000)/(50\text{yrs.} - 40\text{yrs.}) = €10,000$ per life year gained which is below the ICER of *B*. Intervention *B* can therefore be ruled out by extended dominance and should be removed from the choice set because an upgrade from intervention *A* to *C* requires less additional expenditure per life year than an upgrade from *A* to *B*. The ICER of intervention *C* must therefore be recalculated. Comparing intervention *C* with *A* yields an ICER of €15,000.

To see why intervention *B* is not cost effective, assume that the budget for the treatment of the 100 patients is €330,000. This allows to treat some patients with the more effective interventions *B* and *C*. If *B* were chosen, 15 patients could be treated with *B* while 85 patients receive treatment *A*. This yields a gain of $15 \times 0.4 + 85 \times 0.3 = 31.5$ life years since all interventions can be scaled down proportionally. Combining treatments *A* and *C*, by contrast, allows to treat 10 patients with *C*, implying $10 \times 0.5 + 90 \times 0.3 = 32$ additional life years.

question is when a fixed budget is to be allocated among a fixed set of possible measures. In this case, the recommendation to be derived from the result of CEA is to start with the measure with the lowest incremental cost-effectiveness ratio and to continue until the budget is exhausted. Of course, this fails to address the question of how the size of the budget is to be determined in a rational way.

Measuring benefits in units of cardinal utility. Here the multi-dimensionality of the concept of health is taken care of by including all effects of an intervention – in particular, lengthening of life and changes in health status but also side effects – in the evaluation by assigning them appropriate weights. To this purpose, several methods have been developed, which will be presented in detail in Section 2.3. The best-known and most frequently used utility index is called ‘quality-adjusted life years’ (QALYs).

To derive QALYs, all conceivable health states are evaluated on a 0 to 1 scale, where the state of death is assigned the value 0 and perfect health, the value 1. The other values are defined in such a way that for any number x between 0 and 1, a representative individual is indifferent between the following alternatives, “survive one year in a health state with a utility index of x ” and “survive the fraction x of a year in a state of perfect health”. In this way, all health effects of an intervention are made comparable, permitting them to be aggregated into a single number which can be interpreted as the ‘gain in QALYs’.

Evaluation based on utility units is known as *Cost-Utility Analysis* (CUA). The index of comparison is defined in analogy to CEA. For independent interventions, ‘average cost-utility ratios’ (ACURs) are appropriate,

$$\text{ACUR} = \frac{\text{costs in units of money}}{\text{benefits in utility units}}.$$

For mutually exclusive intervention, ‘incremental cost-utility ratios’ (ICURs) are used. They are defined in analogy to ICERs in Cost-Effectiveness Analysis, i.e., the ICUR of an intervention is given by the ratio of incremental costs and incremental benefits compared to the next most effective intervention,

$$\text{ICUR} = \frac{\text{additional costs}}{\text{additional benefits in utility units}}.$$

From this ratio, it can be seen that utility must be cardinally measurable. Otherwise, differences in utility units would have no meaning.¹

¹ Cardinal utility functions are unique up to a positive affine transformation. Ratios of utility differences are therefore specified. This implies, for example, that it must be possible to say that the utility difference between measures A and B is twice as high as the utility difference between measures C and D . Ordinal utility functions, by contrast, are unique up to a positive monotonic transformation. In this case, only the utility ordering of the interventions is determined.

Compared to CEA, CUA has the advantage of being applicable both to medical interventions of different types as well as non-medical interventions because it makes effects measured on different (e.g., clinical) dimensions comparable by mapping them into a single utility index. Apart from this difference, however, CEA and CUA are very similar. For this reason, CEA and CUA are sometimes not distinguished from each other in the literature. For example, WEINSTEIN (2006) uses the term ICER to denote incremental cost-utility ratios.

Cost-Utility Analyses can be employed to construct ‘league tables’ of medical interventions which can be used to demonstrate that a similar increase in QALYs can be achieved at very different costs. An example is shown in Table 2.1. This type of information is useful to political decision makers who are responsible for allocating resources within the health care sector.

Cost-Utility Analysis has its limitations, too. Apart from the fact that it might be ethically relevant how the additional QALYs are distributed among the members of society, these are the following.

- (a) It must be decided *whose* utility function is used to evaluate the various health states;
- (b) Like CEA, CUA provides only a rank order of measures but does not help to decide up to which cost-utility ratio an intervention should be performed. While this question can be answered in the presence of a fixed budget, the determination of the optimal size of the budget is left as an open issue.

Even if there is agreement about the optimal size of the budget, it is far from trivial to determine the optimal set of health care interventions. Indivisibilities of interventions and size effects limit the use of the league-table approach, calling for mathematical programming techniques [see DRUMMOND ET AL. (2005, p. 129)]. Furthermore, information on the costs and health gains of all current and potential interventions is necessary to allocate the budget efficiently. In practice, however, this information is not available and league tables can only be constructed based on the existing evaluations, providing only limited guidance for decision-makers.²

As an alternative, threshold values for cost-utility ratios have been employed. For example, the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom uses two different thresholds [see NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE (2008, p. 58–59)]. ICUR values below £20,000 per QALY usually warrant that an intervention is adopted. For ICUR values between £20,000 and £30,000, further considerations must support the intervention, e.g., whether it adds additional benefits not captured by the change in QALYs. Finally, an intervention with an ICUR above £30,000 requires “an increasingly stronger case” with regard to additional factors supporting the intervention.

² BIRCH AND GAFNI (1992) propose a method to compare the increase of health caused by a new intervention to the combinations of interventions which are given up to fund the new intervention. This approach ensures that the new intervention leads to a net health improvement.

Table 2.1. League Table of Medical Interventions in Terms of Cost per QALY Gained (United Kingdom, £ in 1990 prices)

Medical Intervention	Cost per QALY
Cholesterol testing and diet therapy only (all adults, aged 40-69)	220
Neurosurgical intervention for head injury	240
GP advice to stop smoking	270
Neurosurgical intervention for subarachnoid haemorrhage	490
Anti-hypertensive therapy to prevent stroke (ages 45-64)	940
Pacemaker implantation	1,100
Valve replacement for aortic stenosis	1,140
Hip replacement	1,180
Cholesterol testing and treatment	1,480
Coronary artery bypass graft (left main vessel disease, severe angina)	2,090
Kidney transplant	4,710
Breast cancer screen	5,780
Heart transplantation	7,840
Cholesterol testing and treatment (ages 25-39)	14,150
Home haemodialysis	17,260
Coronary artery bypass graft (one vessel affected, moderate angina)	18,830
Continuous ambulatory peritoneal dialysis	19,870
Hospital haemodialysis	21,970
Erythropoietin treatment for anaemia in dialysis patients (assuming a 10 percent reduction in mortality)	54,380
Neurosurgical intervention for malignant intracranial tumors	107,780
Erythropoietin treatment for anaemia in dialysis patients (assuming no reduction in mortality)	126,290

Source: MAYNARD (1991)

The threshold rule is simple but it is not evident that following this approach will guarantee that the budget is used in a way that maximizes health benefits [see BIRCH AND GAFNI (2006a, 2006b)]. This would call for a threshold which measures the marginal opportunity cost of resources of the budget, a variable which can only be determined if all current and potential interventions are taken into account. Furthermore, the threshold would need to be recalculated whenever the budget changes and if new interventions are adopted. So far, however, thresholds have not been derived along these lines and it remains unclear to what extent following a threshold rule serves to increase health benefits given the available resources.³

³ An alternative is to define a threshold based on willingness to pay for a QALY (see Section 2.5.1). In effect, the method of evaluation becomes Cost-Benefit-Analysis, implying an endogenous budget for health care. It is also possible to calculate benefits in units of money by multiplying the gain in QALYs with willingness to pay for a QALY. The net benefit criterion of Cost-Benefit-Analysis can then be applied [see DRUMMOND ET AL. (2005, p. 130–132)].

Measuring benefits in units of money. Using money to measure outcomes means that extension of human life and changes in the quality of life are assigned a money equivalent. After expressing both positive and negative effects of an intervention in money terms, *Cost-Benefit Analysis* (CBA) can be applied. Of the three evaluation methods presented here, it is the only one which is suitable to evaluate each intervention separately. An intervention is worthwhile if the ‘average cost-benefit ratio’ (ACBR) is below one, i.e., if

$$\text{ACBR} = \frac{\text{costs in units of money}}{\text{benefits in units of money}} < 1.$$

An equivalent decision rule is

$$\text{net benefit} \equiv \text{benefits in units of money} - \text{costs in units of money} > 0.$$

If there is a stream of net benefits over time, future net benefits need to be converted into present values by using an appropriate discount rate. The sum of discounted net benefits yields the ‘net present value’ as a generalized decision criterion [see BOADWAY AND BRUCE (1984, p. 294–295)].

In the case of several mutually exclusive interventions with a positive net benefit, the one with the highest net benefit should be adopted. An equivalent approach is to calculate ‘incremental cost-benefit ratios’ (ICBRs) and to apply a threshold value of one. The ICBR of an intervention is defined by the ratio of incremental costs and incremental benefits compared to the next most effective intervention,

$$\text{ICBR} = \frac{\text{additional costs}}{\text{additional benefits in units of money}}.$$

Dominated alternatives need to be excluded. Of the remaining interventions with an ICBR below one, the intervention yielding the highest benefits is also the one with the highest net benefit. ICBRs are usually dispensable, however, because it is much easier to calculate net benefits directly.

In contrast to both CEA and CUA, the method of CBA does answer the question how much money should be spent on interventions that prolong life and enhance quality of life. It is usually justified by the welfare economic criterion of ‘potential Pareto-improvement’ (‘Kaldor-Hicks criterion’), which we will discuss in greater detail in Section 2.4.4.

Conclusion 2.1. *Cost-Effectiveness Analysis (CEA) only serves for a comparison of measures with uni-dimensional effects. Cost-Utility Analysis (CUA) also allows comparisons among measures with several heterogeneous effects. To indicate whether a measure is desirable, both methods require a fixed budget for health care. By contrast, Cost-Benefit Analysis (CBA) provides an evaluation of life and health in terms of money and thus permits to assess every project separately.*

The prevailing method to evaluate benefits in CBA relies on subjective utility theory and uses aggregate willingness to pay of the persons involved as a money measure of utility. By contrast, both CEA and CUA focus on the effects on health status. Thus, these are fundamentally different approaches to the evaluation of health care interventions. In the remainder of this chapter, we therefore focus on the basic differences between the two most commonly applied methods, CUA and CBA, without further discussing CEA because of its limited applicability.

2.3 Cost-Utility Analysis

2.3.1 Concepts of Utility Measurement

Several utility concepts have been developed to summarize the multi-dimensional effects of an intervention in a scalar index. Among the best-known are the following.

(1) Disability-Adjusted Life Years (DALYs)

This concept was first developed in 1993 in the World Development Report of the World Bank [see WORLD BANK (1993), for a detailed exposition MURRAY (1994)]. DALYs measure the loss of life years in full health starting from a standardized life expectancy of 80 years for men and 82.5 years for women. Morbidity weights determined by experts are then used to assess states with less than full health. Moreover, different weights apply to years lived in different ages. The top weight is assigned a year spent at the age of 25 years. The utility of an intervention is measured by the number of DALYs prevented. DALYs are used, e.g., by the WHO to compare population health in different countries.

(2) Quality-Adjusted Life Years (QALYs)

The concept of a QALY is based on the work by KLARMAN ET AL. (1968), who first captured explicitly the number of life years gained and changes in the quality of life in a single index. As with DALYs, each health state is assigned a morbidity weight. However, these weights are regularly determined by surveying the people concerned by the intervention. The number of QALYs of a person is found by multiplying the expected duration of a health state with its morbidity index and summing up these numbers. The utility of an intervention is given by the number of QALYs gained.

(3) Healthy-Years Equivalent (HYE)

This concept by MEHREZ AND GAFNI (1989) is based on 'health profiles'. Individuals are asked how they evaluate the likely sequence of health states caused by an intervention. In particular, they are asked how many years in perfect health they would find equally attractive as the profile in question.

DALYs, QALYs and HYEs differ in the two following aspects.

(a) Who evaluates the quality of life

In the DALY concept, the quality of life is assessed by experts, whereas in the case of the other two concepts, evaluation is by potential or actual patients. The latter approach is more appropriate because (potentially) affected individuals are best able to value their own health; moreover, they are the ones who ultimately finance public health care expenditures. By way of contrast, experts have a special competence only with respect to technical aspects of medicine. Therefore, the DALY concept seems to be hardly adequate as a basis for decision-making. Accordingly, it is mainly used for international comparisons.

(b) Whether or not the temporal sequence of health states is taken into account

In DALYs and QALYs, the order in which health states occur plays no role. By contrast, the HYE concept evaluates the profile of health states, which results from an intervention, as a whole. Therefore, HYE are in principle to be preferred, but at the same time they are considerably more costly to measure because a whole health profile requires a lengthy description. For this reason, HYE have rarely been applied so far.

In the following, we concentrate on QALYs, which are by far the most popular measure of health states. For instance, the National Institute for Health and Clinical Excellence (NICE) in the United Kingdom uses QALYs to compare different drugs and measure their clinical effectiveness.⁴ In particular, we focus on the implicit assumptions concerning the preferences with respect to health.

2.3.2 The QALY Concept

2.3.2.1 Calculating QALYs

Using interviews (typically with health workers), utility weights for the various health states are determined (see Section 2.3.3). For this purpose, the weight for the state of perfect health is calibrated to the value 1, while the state of death is assigned the value 0. Using these values, a year spent in the respective health state is weighted to obtain quality-adjusted life years (QALYs). Quality adjustments can then be performed, in which the expected duration of a health state is multiplied by the respective utility weight and the resulting products are added together.

Figure 2.1 illustrates the logic of QALYs in two cases,

- (a) an increase of the length of life by x years, which have to be spent in a worse health state, e.g., H_1 ;
- (b) a change in the health state from, let us say, H_2 to H_3 , which lasts for x years.

⁴ See SCHLANDER (2007) for a study of economic evaluations by NICE.

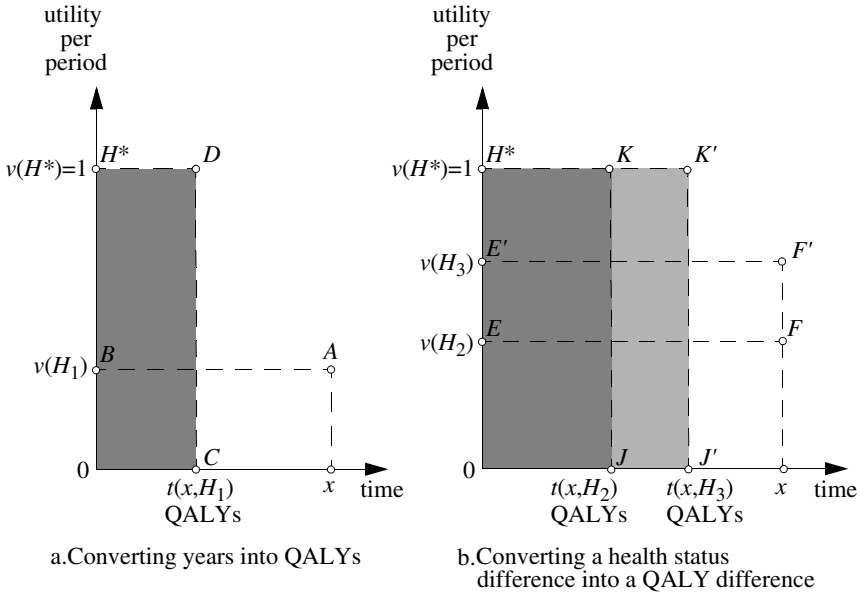


Fig. 2.1. QALYs as the Link between Length of Life and Health Status

Case (a) is depicted in Figure 2.1a. The utility of spending x years in state H_1 is given by the area of the rectangle $0xAB$. The same utility can be achieved by spending $t(x, H_1)$ years in perfect health ($0CDH^* = 0xAB$). The number of QALYs which correspond to x years in the state H_1 is therefore given by $t(x, H_1) < x$.

Now it is only a short step to the solution of a problem of type (b): let $t(x, H_2)$ be the number of QALYs corresponding to x years in state H_2 , while $t(x, H_3)$ denotes the number of QALYs corresponding to x years in a better state H_3 . The difference $t(x, H_3) - t(x, H_2)$ thus represents the number of life years gained in perfect health, which is equal in value to the underlying change of health status from H_2 to H_3 for x years. Figure 2.1b illustrates. First, x years lived in state H_2 are converted into $t(x, H_2)$ QALYs using the equality of areas $0xFE$ and $0JKH^*$. Next, x years lived in state H_3 are turned into $t(x, H_3)$ QALYs because of the equality of areas $0xF'E'$ and $0J'K'H^*$. The QALY difference, measured by the area $JJ'K'K$, then reflects the health status difference (area $EFF'E'$) as evaluated by the affected individual. Therefore, the instruments available for valuing prolongations of life can also be applied to evaluating changes of health status, provided that the utility of different states of health was determined and converted to 'years in perfect health' using the function $t(\cdot)$.

Conclusion 2.2. *The concept of 'quality-adjusted life years' (QALYs) allows to make changes in the quality of life and changes of the length of life comparable.*

2.3.2.2 Decision-Theoretic Foundation

The QALY concept is easy to apply. Once utility weights have been determined, the evaluation of a specific intervention is straightforward. However, since QALYs are used to support decisions regarding the allocation of resources in health care, they should have a sound decision-theoretic foundation. Therefore, we analyze in the following how QALYs can be justified in the light of expected utility, the most common theory of decisions under uncertainty.⁵ While expected utility is not without problems as a descriptive theory of behavior under uncertainty,⁶ it can serve as a normative guide to rational decision making, provided one accepts that choices should satisfy the axioms on which the theory is founded.

We start from a simple version of the QALY model, where there is no discounting of the future and no risk aversion with respect to the length of life. Ways to take these factors into account will be discussed later. For simplicity, let all health states $H_h, h = 1, \dots, m$ be *chronic*, i.e., the health state does not change up to T_h . This assumption is used only to simplify the exposition and is no inherent characteristic of the QALY model. The combination (H_h, T_h) occurs with probability π_h . Thus, an individual is confronted with a lottery of chronic conditions $(\pi_h, H_h, T_h), h = 1, \dots, m$. Assume that preferences satisfy the von-Neumann-Morgenstern axioms. If the utility of spending T_h years in the chronic condition H_h is denoted by $u(H_h, T_h)$, the preferences of the individual are therefore represented by expected utility⁷

$$EU = \sum_{h=1}^m \pi_h u(H_h, T_h). \quad (2.1)$$

To reduce expected utility to the number of QALYs, the utility function must take the form

$$u(H_h, T_h) = v(H_h) T_h. \quad (2.2)$$

Using (2.2), equation (2.1) simplifies to

$$EU = \text{QALYs} = \sum_{h=1}^m \pi_h T_h v(H_h), \quad (2.3)$$

i.e., expected utility equals the sum of the utilities of the various health states, weighted by their duration and the probability with which they occur.

⁵ BLEICHRODT AND QUIGGIN (1997) also examine QALYs using the general rank-dependent utility model. MIYAMOTO (1999) provides a general treatment of QALY models under expected utility and rank-dependent utility assumptions.

⁶ In particular, the independence axiom has been criticized on the basis of experimental results. It states that if two lotteries L_1 and L_2 are mixed to the same extent with a third lottery L_3 , then the preference ordering of the resulting lotteries is the same as the ordering of L_1 and L_2 and therefore independent of the third lottery. The most famous challenge to the independence axiom has been posed by ALLAIS (1953) and is known as the Allais paradox [see, e.g., LAFFONT (1989, p. 14)].

⁷ See, e.g., LAFFONT (1989, Chapter 1) and MAS-COLELL ET AL. (1995, Chapter 6) for a proof of the expected utility theorem.

Since in expected utility theory, the utility function $v(\cdot)$ is cardinal and therefore determined only up to positive affine transformations, $v(\cdot)$ can be chosen without loss of generality in such a way that the utility of perfect health $v(H^*)$ is arbitrarily set at 1 and utility of death is set at 0. Consequently, the expected utility of an individual can be interpreted as the number of quality-adjusted life years.

From a decision-theoretic perspective, the simplicity of the calculation of QALYs is based on the particular form of the utility function in equation (2.2). This form requires that *preferences for health states are stable over one's entire life*, i.e., $v(H_h)$ does not depend upon the age of the individual.

Furthermore, the utility function $u(H_h, T_h)$ needs to satisfy certain fundamental assumptions. To begin with, equation (2.2) implies that individuals are *risk neutral with respect to length of life*, i.e., for a given health state, they are indifferent between a certain life length T and a lottery with uncertain length of life and life expectancy T . But risk neutrality with respect to length of life does not completely characterize the form of the utility function (2.2). In general, it only implies that in the absence of discounting the utility function has the following form,

$$\forall H \quad u(H, T) = g(H) + v(H)T \quad \text{with} \quad v(H) > 0. \quad (2.4)$$

Equation (2.2) requires in addition that $g(H)$ is zero for all health states H .

One solution is to impose the *zero-condition*, which says that all health states with a duration of zero are equivalent [BLEICHRODT ET AL. (1997), MIYAMOTO AND ERAKER (1988)]. Put formally,

$$\forall H \quad u(H, 0) = \text{const.} \quad (2.5)$$

MIYAMOTO ET AL. (1998) argue that the zero-condition is completely evident since all combinations of health states with zero duration are identical physical objects.⁸ An immediate consequence of the zero-condition is that $g(H)$ must be a constant in (2.4). Since the utility function must be cardinal, an arbitrary constant can be added without loss of generality. Hence, one can set $g(H) = 0$ in equation (2.4) to obtain equation (2.2). Risk neutrality with respect to length of life and the zero-condition are therefore sufficient to characterize QALYs.

In addition to risk neutrality with respect to length of life, mutual utility independence and constant proportional trade-off are stated as the assumptions underlying the QALY model [PLISKIN ET AL. (1980)]. Mutual utility independence holds if conditional preferences for lotteries over length of life given a health state are independent of the particular health status and vice versa.⁹ Constant proportional trade-off means that the share of life-years which the individual is prepared to sacrifice for a given improvement in quality of life is independent of the remaining life expectancy.

⁸ See MIYAMOTO (1999, p. 208) for a heuristic argument supporting the zero-condition.

⁹ See KEENEY AND RAIFFA (1976, Section 5.2) for the concept of utility independence.

BLEICHRODT ET AL. (1997) demonstrate that constant proportional trade-off and mutual utility independence are stronger assumptions than the zero-condition. Consider the constant proportional trade-off property,

$$\forall H, H' \text{ with } H' > H : \exists q \in (0, 1) \text{ such that } u(H, T) = u(H', qT) \forall T. \quad (2.6)$$

PLISKIN ET AL. (1980) show that this property is satisfied if (i) there is mutual utility independence and (ii) constant proportional trade-off holds for the best and the worst health state. For $T = 0$ in (2.6), one obtains that $u(H, 0)$ is equal for all health states, i.e., the zero-condition. Thus, it is not necessary to impose constant proportional trade-off and mutual utility independence to characterize QALYs. The weaker zero-condition is sufficient.

A further result by BLEICHRODT ET AL. (1997) is that risk neutrality with respect to length of life for all health states as in (2.4) holds if and only if (a) length of life is utility independent of health states, i.e., if preferences over lotteries over length of life for a fixed state of health do not depend on the particular health state, and (b) risk neutrality holds for perfect health only. Therefore, QALYs can alternatively be characterized by the assumptions (a) and (b) in addition to the zero-condition.

In Figure 2.2, the block arrows illustrate the sets of sufficient conditions for QALY preferences. In addition, the conditions implied by the QALY model are of interest. The thin arrows in Figure 2.2 show these necessary conditions for QALY preferences. First, it is easy to see that the zero-condition and risk neutrality are not only sufficient but also necessary conditions for the QALY model [BLEICHRODT ET AL. (1997, Theorem 1)]. Furthermore, QALYs imply constant proportional trade-offs with q in equation (2.6) corresponding to $v(H)/v(H')$. Finally, mutual utility independence is a necessary condition for QALY preferences. Length of life is utility independent of health status because of risk neutrality with respect to length of life. Irrespective of any fixed health state considered, lotteries with a longer life expectancy are preferred. Likewise, the conditional preferences for lotteries over health states do not depend on length of life. To see this, assume a fixed length of life T . Equation (2.3) then simplifies to

$$\text{QALYs} = T \sum_{h=1}^m \pi_h v(H_h). \quad (2.7)$$

Thus, if lottery (π_h, H_h, T) is preferred to lottery $(\hat{\pi}_h, \hat{H}_h, T)$, then it must also be the case that lottery (π_h, H_h, T') is preferred to lottery $(\hat{\pi}_h, \hat{H}_h, T')$ for any length of life T' different from T .¹⁰

¹⁰ A further result not displayed in Figure 2.2 is that risk neutrality and constant proportional trade-offs imply mutual utility independence.

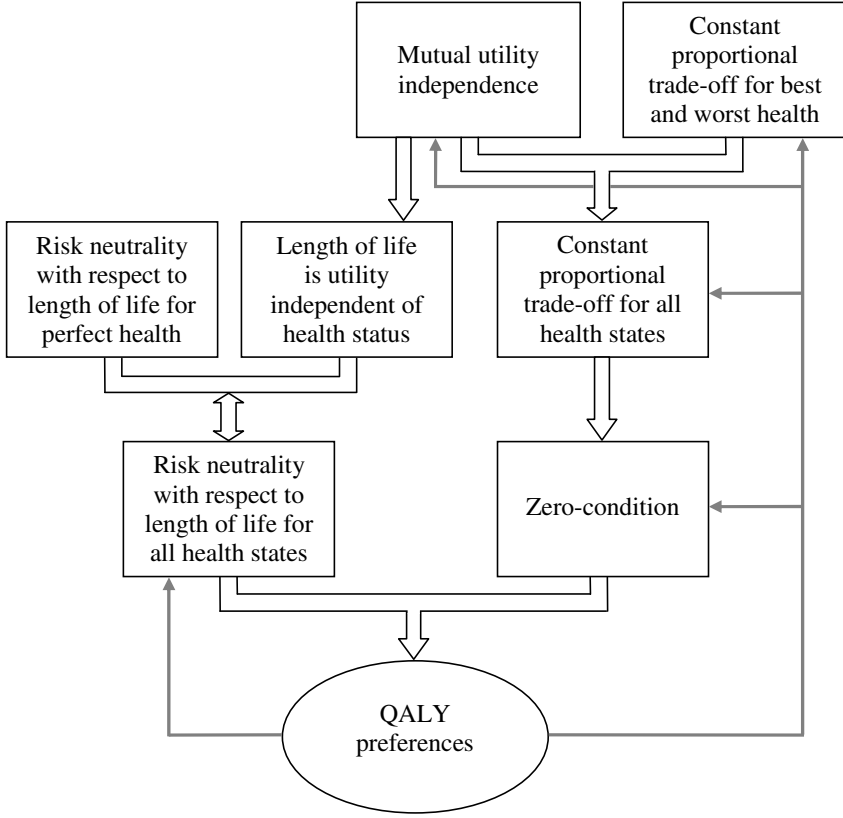


Fig. 2.2. Sufficient and Necessary Conditions for QALYs in the Expected Utility Framework

There are two generalizations in which the assumptions of the QALY model are somewhat relaxed. First, discounting of future utility can be taken into account by replacing (2.2) by the following form of the utility function,

$$u_D(H_h, T_h) = \sum_{t=1}^{T_h} \beta_t^{t-1} v(H_h), \quad 0 \leq \beta_t \leq 1. \quad (2.8)$$

Here, β_t denotes the discount factor in period t . The number of QALYs is then given by

$$\text{QALYs}_D = \sum_{h=1}^m \pi_h \sum_{t=1}^{T_h} \beta_t^{t-1} v(H_h). \quad (2.9)$$

In contrast to the model without discounting, this approach assumes that the individual is risk neutral with respect to the discounted remaining length of life [see JOHANNESSON ET AL. (1994)].

Secondly, risk aversion with respect to length of life can be taken into account by replacing (2.2) by

$$u(H_h, T_h) = v(H_h)w(T_h), \quad (2.10)$$

where $w(\cdot)$ is increasing and strictly concave. Holding life expectancy constant, a certain length of life is always preferred to an uncertain one.¹¹ With the utility function (2.10), the number of QALYs is given by

$$\text{QALYs}_R = \sum_{h=1}^m \pi_h w(T_h) v(H_h). \quad (2.11)$$

Conclusion 2.3. *A decision-theoretic analysis based on expected utility theory shows that the concept of QALYs requires several assumptions, viz. preferences for health states must be stable over the whole life cycle, there must be risk neutrality with respect to length of life, and preferences must obey the ‘zero-condition’. To some extent, it is possible to relax these assumptions. For example, risk aversion with respect to length of life can be dealt with in a generalized QALY model.*

Empirical studies suggest that the requirements of the QALY model are violated to some extent [see DOLAN (2000) for a survey]. Therefore it has to be asked whether its main alternative, the HYE, is preferable. This method places far weaker restrictions on the utility function. For example, preferences for health states do not have to be stable over the life cycle. But HYE are extremely difficult to measure since all possible health profiles must be presented to respondents. In the attempt to determine the utility of an intervention, there is thus a conflict between accurate preference measurement and the costs of the interview study. The QALY method seems to be a pragmatic solution of this conflict. Whether other methods such as HYE indeed serve to measure preferences better, therefore constitutes an important topic for further research.

2.3.2.3 QALYs and Consumption

So far it has been assumed that the utility of the individual depends on health-related variables only. In reality, it is also affected by other factors such as consumption, which plays an important role in utility theory in general. Ceteris paribus, for expected utility to be measured correctly by QALYs, the utility function for health and disposable income y as an indicator of consumption must be separable,

$$U_t(y_t, H_{h,t}) = a_t(y_t) + b_t(y_t)v(H_{h,t}), \quad b_t(y_t) > 0, \forall y_t \quad (2.12)$$

with $H_{h,t}$ denoting the health state in period t .

¹¹ This model is further analyzed by BLEICHRODT AND PINTO (2005).

A sufficient condition for (2.12) to be satisfied therefore is that the valuation of health is independent of disposable income.¹²

If we assume as BLEICHRODT AND QUIGGIN (1999) that utility in the state of death must be zero regardless of disposable income y , we get $a_t(y_t) = 0$, and (2.12) simplifies to

$$U_t(y_t, H_{h,t}) = b_t(y_t)v(H_{h,t}), \quad b_t(y_t) > 0, \forall y_t. \quad (2.13)$$

Let $\pi_{h,t}$ be the probability of spending period t in health state h , and \hat{T} the maximum length of life. Furthermore, assume that life-cycle utility is the sum of per-period utilities and there is no discounting. Then expected utility of an individual is

$$EU = \sum_{t=1}^{\hat{T}} \left(\sum_{h=1}^m \pi_{h,t} U_t(y_t, H_{h,t}) \right) = \sum_{t=1}^{\hat{T}} \left(\sum_{h=1}^m \pi_{h,t} b_t(y_t) v(H_{h,t}) \right). \quad (2.14)$$

If $b_t(y_t) = b(y_t)$, i.e., the per-period utility function $b_t(y_t)v(H_{h,t})$ does not depend on t , and if disposable income is constant over time, i.e., $y_t = y \forall t$, equation (2.14) simplifies to

$$EU = b(y) \sum_{h=1}^m \sum_{t=1}^{\hat{T}} \pi_{h,t} v(H_{h,t}). \quad (2.15)$$

The expected time span which the individual spends in health state h is measured by the term $\sum_{t=1}^{\hat{T}} \pi_{h,t}$. Accordingly, $\sum_{h=1}^H \sum_{t=1}^{\hat{T}} \pi_{h,t} v(H_{h,t})$ can be interpreted as the number of QALYs and we obtain

$$EU = b(y) \text{QALYs}. \quad (2.16)$$

It becomes clear that QALYs can in principle be an independent argument of a standard utility function. But this result requires a number of restrictive assumptions. Specifically, if condition (2.12) is violated, if the per-period utility function changes over time, or if consumption is not constant, then the utility of changes in health-related variables cannot in general be captured by QALYs. In this case, an increase or a decrease in the QALYs of a person fails to indicate an improvement or deterioration of utility because changes in health cannot be evaluated independently of consumption behavior (see also Exercise 2.9).

Conclusion 2.4. *Taking into account that utility depends not only on health but also on consumption, restrictive assumptions are necessary to ascertain that QALYs capture all health-related benefits in a scalar index.*

¹² See KEENEY AND RAIFFA (1976, p. 226) on the definition of utility independence. A detailed derivation of the relationships described in this section can be found in BLEICHRODT AND QUIGGIN (1999).

2.3.2.4 Aggregation of QALYs and Collective Decision-Making

Cost-Utility Analysis serves to support collective decision-making. If QALYs are used, the rule of choice among a set of possible measures is to pick the one which maximizes *the number of* QALYs for a given budget. This rule is based on two fundamental value judgments.

- (1) The welfare of the affected person enters the collective decision rule exclusively through its QALYs gained.
- (2) It is irrelevant who experiences the increase in QALYs.

What are the arguments for and against these value judgments? With regard to (1) it was argued in Chapter 1 that the welfare of a person depends not only on health but also on other goods. This fact is taken into account by letting welfare (and not health) of the person enter the collective decision rule as an argument. In welfare economics, this corresponds to the principle of *welfarism*, which says that each person's individual utility is to be considered in a collective decision.¹³ From this point of view, the concept of QALYs is unsatisfactory because welfarism requires using the whole utility of a person as a basis for collective decisions. As was shown above, QALYs are only one argument in the utility function and even this is true only if the utility function has a certain structure.

Taking total utility into consideration is disputed by *extra-welfarists*.¹⁴ They argue that individual utility is not an adequate basis of collective decision-making but the purpose of these decisions is to provide the conditions for a good life, with health constituting a crucial prerequisite. Therefore, only QALYs should be used as preference-based health measure, neglecting other factors.

The second welfare judgment can be disputed on the grounds that the distribution of QALYs should play a role in the evaluation. The extreme opposite to the maximization of the sum of QALYs would be the maximin principle, which seeks to maximize the QALYs of those characterized by the lowest number of QALYs.

These and other positions can be expressed using a health-related social welfare function

$$HRSW = HRSW\{QALY_{s_1}, \dots, QALY_{s_n}\} \quad (2.17)$$

which depends on the QALYs of the affected persons $i = 1, \dots, n$ at birth.¹⁵ In Figure 2.3 this is illustrated for the two-person case. In the initial situation the QALYs at birth are given by $\bar{QALY}_i, i = 1, 2$. The QALY possibility curve *QPC* depicts the efficient distributions of QALYs between the two persons which can be achieved by

¹³ See BOADWAY AND BRUCE (1984, p. 5)

¹⁴ See CULYER (1989, 1990).

¹⁵ This approach was first proposed by WAGSTAFF (1991) [See also WILLIAMS AND COOKSON (2000)]. An alternative way to value health outcomes from a societal perspective has been developed by NORD (1999). It is based on questions in which members of a society are asked to compare health care interventions in terms of person trade-offs.

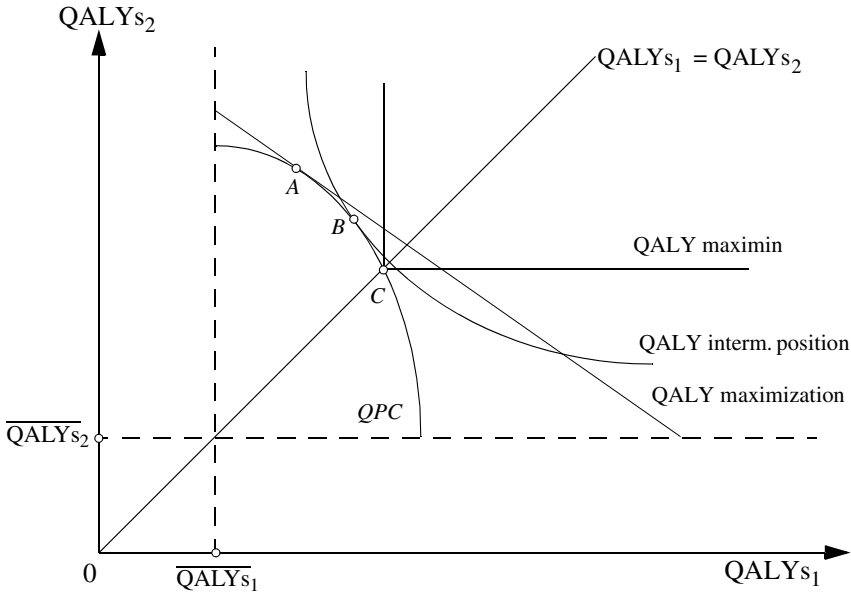


Fig. 2.3. The Conflict between Equality and Maximization of Total QALYs

health-improving interventions out of a given budget. The maximization of QALYs corresponds to a social welfare function with straight indifference curves of slope -1 , resulting in point *A* as the optimum. In this example, QALY maximization leads to an unequal distribution of QALYs. Person 2 would receive more QALYs than person 1 because the resources spent on her have the greater effect. By contrast, the maximin principle corresponds to a social welfare function with L-shaped indifference curves. The optimal allocation is given by point *C* in this case, with both persons getting the same number of QALYs.¹⁶ A social welfare function between these extremes has convex indifference curves that render a point like *B* optimal, which lies between *A* and *C*.

Figure 2.3 shows that it is possible in principle to account for the distribution of QALYs in a generalized Cost-Utility Analysis. However, this requires considerably more information than basic CUA. First, the exact location and shape of the

¹⁶ If it is not possible to increase the QALYs of a person above a certain level, the maximin principle may not yield a clear recommendation. Consider, e.g., that person 1 can only reach the level of QALYs corresponding to point *B* in Figure 2.3. In this case, the QALY possibility curve would drop vertically at *B*. The maximin principle would be indifferent between point *B* and all other distributions on the vertical line between *B* and the 45-degree line. This problem can be solved by applying the leximin rule which calls for the maximization of QALYs of the person who is second worst off in terms of QALYs after QALYs for the worst off have been maximized. This would render point *B* optimal. Unequal distributions of QALYs can therefore be justified by this extension of the maximin principle.

QALY possibility curve must be known. This is not necessary in the traditional CUA which only uses the gain in QALYs, not their distribution, as the decision criterion. Second, the health-related social welfare function expressing the preferences of the population with respect to the distribution of QALYs must be determined.

Conclusion 2.5. *Cost-Utility Analysis is not compatible with a welfarist position, which claims that collective decisions should be based on total utility of the affected persons. The use of QALYs can, however, be justified with an extra-welfarist position, according to which only health – as measured by QALYs – is relevant for particular collective decisions. The principle of maximization of QALYs can be criticized on the grounds that the distribution of QALYs should also play a role.*

2.3.3 Evaluating Health States

To determine the number of QALYs in a specific situation, it is necessary to measure the preferences of the individuals with respect to all possible health states. Several methods to accomplish this have been developed. The most frequently used are the the Rating Scale, the Time Trade-off, and the Standard Gamble methods.¹⁷

2.3.3.1 Rating Scale

A rating scale consists of a line with clearly defined end points describing the worst health state (usually taken to be death) and the best health state. In a survey, the respondents are asked to evaluate a certain health state by assigning a point on the line to it. After normalizing the line to a $[0,1]$ scale, the QALY weight for each health state can be read off as the corresponding value on the $[0,1]$ interval.

The advantage of the rating scale method is its easy application. However, it suffers from several sources of bias. Specifically, respondents refrain from placing health states near the end-points of the scale (end-of-scale bias), and they tend to space them equally across the scale (spacing-out bias) [see BLEICHRODT AND JOHANNESSON (1997)]. Its major disadvantage, however, is that it is hard to interpret, not being based on a choice among two or more alternatives. The next two methods do not share this drawback.

2.3.3.2 Time Trade-Off

In this procedure, the test persons are asked the following question, “Suppose you had a disease which would leave you in a state of H_h for T years if not treated. The only possible treatment is free and would cure you perfectly; however, it shortens the

¹⁷ For further methods see DRUMMOND ET AL. (2005, Chapter 6).

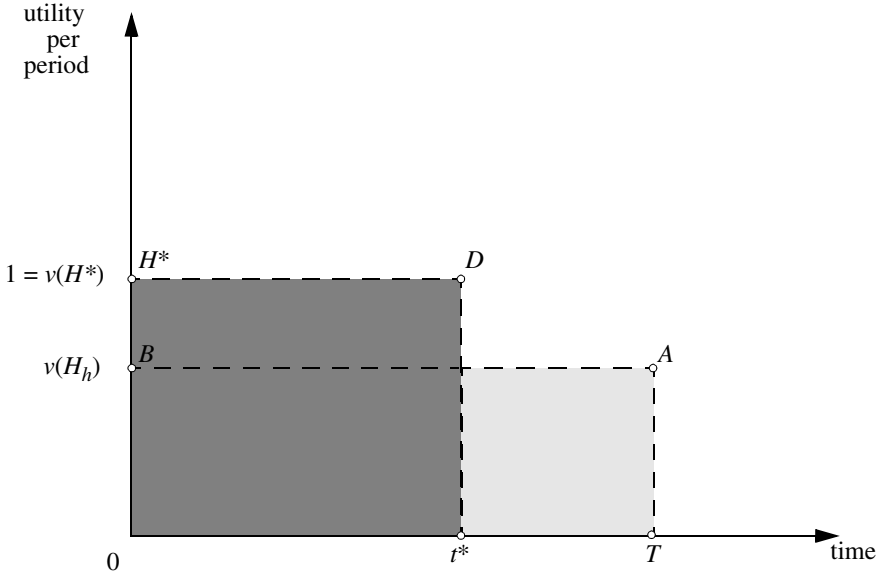


Fig. 2.4. The Time Trade-Off Method to Evaluate Health States

rest of your life span to t years.” In the following, life span t is varied until the person interviewed is indifferent between the alternatives ‘treatment’ and ‘no treatment’.

In the simple version of the QALY model with no discounting and no risk aversion, the point of indifference, $t^*(T, H_h)$, can be interpreted as follows. Without treatment, expected utility is $Tv(H_h)$, while with treatment, it is $t^*(T, H_h)v(H^*) = t^*(T, H_h)$, since the utility of perfect health, $v(H^*)$, was normalized to 1. Hence we obtain from indifference,

$$v_{\text{TTO}}(H_h) = \frac{t^*(T, H_h)}{T}, \quad (2.18)$$

i.e., the utility weight of health state H_h is equal to the ratio t^*/T . This ratio must be independent of T according to the QALY model. This follows from the constant proportional trade-off property (2.6) with $H' = H^*$ and $H = H_h$. As Figure 2.2 shows, constant proportional trade-offs are implied by the QALY model.

Figure 2.4 illustrates the method graphically. The procedure is analogous to the conversion of years in a less than perfect health state into QALYs, as in Figure 2.1a. The only modification is that the reference time span x is replaced by the remaining lifetime T . The value $t^*(T, H_h)$ in Figure 2.4 follows from the equality of the areas $OTAB$ and $0t^*DH^*$. The ratio $t^*(T, H_h)/T$ is then interpreted as the utility weight $v_{\text{TTO}}(H_h)$ for health state H_h .

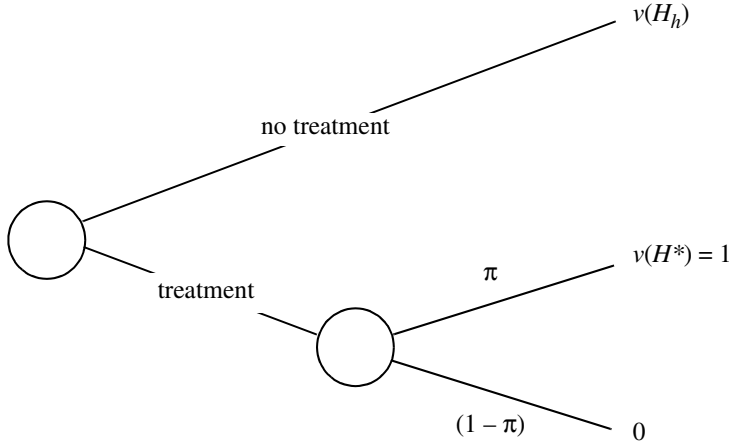


Fig. 2.5. The Standard Gamble Method to Evaluate Health States

Unlike the rating-scale alternative, the time trade-off method is rooted in expected utility theory. However, it yields unbiased measures of the utility weights only if respondents are risk neutral with respect to their remaining length of life. If they are risk averse, then indifference between the alternatives (H_h, T) and (H^*, t^*) implies in view of equation (2.10)

$$v(H_h)w(T) = v(H^*)w(t^*) = w(t^*), \quad (2.19)$$

and thus

$$v(H_h) = \frac{w(t^*)}{w(T)} > \frac{t^*}{T} \quad (2.20)$$

because of the concavity of w and $t^* < T$. In other words, risk aversion causes the fraction t^*/T to be a downward biased estimator of the ‘true’ utility weight $v(H_h)$.

2.3.3.3 Standard Gamble

Here, the following scenario is used, “Suppose you had a disease which would leave you permanently in state H_h without treatment. The only possible treatment is free and would cure you perfectly with probability π but lead to your immediate death with probability $1 - \pi$.” The probability π is now varied until the respondent is indifferent between the alternatives ‘treatment’ and ‘no treatment’ (see Figure 2.5).

The value of indifference, $\pi^*(H_h)$, can be easily interpreted within the simple version of the QALY model without discounting and risk aversion.¹⁸ With a remaining life span of \bar{T} , expected utility without treatment amounts to $v(H_h)\bar{T}$. With treatment, expected utility is given by $(1 - \pi^*) \times 0 \times 0 + \pi^* \times 1 \times \bar{T} = \pi^* \times \bar{T}$, as the utility of death is normalized to 0 and the utility of perfect health to 1. Hence the utility of health state H_h is equal to

$$v_{SG}(H_h) = \frac{\pi^* \times \bar{T}}{\bar{T}} = \pi^*, \quad (2.21)$$

i.e., the value π^* at which the respondent is indifferent can be interpreted as the utility weight of health status H_h . Note that π^* is independent of the remaining life span \bar{T} since conditional preferences for lotteries over health states are independent of length of life in the QALY model. This is a consequence of mutual utility independence which is a necessary condition for the QALY model (see Figure 2.2).

Like the time trade-off alternative, the standard gamble method is choice-based and firmly rooted in expected utility theory. Moreover, it is fully compatible with risk aversion with respect to length of life because the utility weight $w(\bar{T})$ would appear both in the numerator and the denominator of (2.21) and would thus cancel.

Conclusion 2.6. *If preferences of respondents satisfy the assumptions of the QALY model, with utility linear in length of life, the time trade-off and the standard-gamble methods lead to an analogous result in that they measure the utility weights of respective health states on a scale ranging from 0 (death) to 1 (perfect health). The standard-gamble method, however, is more general because it does not require utility to be linear in remaining length of life. By contrast, the rating scale method is less suitable since it lacks a utility-theoretic basis.*

In empirical applications, the time trade-off method and the standard-gamble method frequently lead to different results. On the one hand, individuals may not be risk neutral with respect to length of life. On the other hand, there is a good deal of experimental evidence questioning the validity of expected utility theory [KAHNEMAN AND TVERSKY (1979), POMMERHNE ET AL. (1982)]. The difficulties associated with applying the two methods should therefore not be underestimated.¹⁹

¹⁸ This way of putting the trade-off presupposes that the respondent prefers health state H_h to immediate death. For situations in which the individual would opt for death, a slightly modified lottery can be constructed [see TORRANCE (1986, p. 21)].

¹⁹ BLEICHRODT (2002) shows that if respondents violate the assumptions of the expected utility model in a plausible way, the time trade-off method is likely to lead to a smaller bias than the standard-gamble method.

2.4 Cost-Benefit Analysis

In Cost-Benefit Analysis (CBA), a money value is assigned to an improvement in length or quality of life. To achieve this, two entirely different concepts have been developed, the human-capital approach and the willingness-to-pay approach. In Section 2.4.2 we shall briefly discuss the human-capital approach, which we do not deem appropriate because of its economic and ethical flaws. Our main focus is then on the willingness-to-pay approach in Section 2.4.3. However, there are very fundamental objections against valuing human life in terms of money which need to be addressed first. These are discussed in Section 2.4.1.

2.4.1 Ethical Objections and Counterarguments

Adapting freely Oscar Wilde's definition of a cynic, economists are sometimes said to 'know the price of everything but the value of nothing'. The idea of assigning a money value to human life may therefore meet with widespread disapproval. The objections raised are of two different kinds. One is at a most basic level stating that any attempt to pit life against money is unethical. The other is less fundamental. While accepting the notion that life has a price, it calls into question any other result than that of an infinite value of life. These two arguments will be discussed in turn.

2.4.1.1 Objections Against Weighing Life Against Money

The weighing up of life and freedom of disease on one side and money on the other is considered profane by moral rigorists who are inspired by Christian belief, the Hippocratic oath, or humanistic philosophy of life. Sometimes economic approaches to these valuations are even put on a par with the euthanasia programs of the Third Reich. Does such a valuation not imply that it is acceptable to kill those human beings whose 'value' does not cover their cost of living, such as food and medical treatment?

First, this argument fails to take into consideration the morally relevant difference between actively intervening and letting nature run its course, i.e., between the act of killing people who suffer from an incurable disease and refraining from efforts at prolonging their lives. This distinction plays a major role in the debate about 'dying in dignity'. Of course it can be said that refusing to provide a person with essential medical care or food for free is morally equivalent to killing that person. The greater the efforts required to save a human life, however, the less convincing is this argument. For example, assume that rescuing a group of miners buried in a pit would cost thousands of billions of dollars, causing the rest of the country to survive in misery. Can a refusal to rescue these miners be considered equivalent to killing them in this case?

Second, it is important to keep in mind that most public decisions do not affect ‘identified’ but ‘statistical’ lives. If personally identified individuals are at risk, politicians usually are expected to do everything which is possible to save their lives, probably because the public is aware that even a maximum effort would only consume a very small percentage of the Gross National Product. To see this point, assume it would take €10 million for every miner buried in the pit to be rescued. This does not imply that the public would consent to the government spending the same amount on averting a risk of one in a thousand for one thousand miners of being buried in the pit. ‘Statistical’ lives tend to cause less emotion than ‘identified’ lives.

Third, the issue is not so much weighing life against money but rather remaining life expectancy. When thinking of medical treatment or public safety measures, we usually think of lives actually saved. In reality however, life is prolonged at best (often with some heroic performances of high-tech medicine resulting in a gain of a few months), for in the long run everybody has to die. As long as the time of death is beyond human control, it is even only remaining life expectancy that is increased. Therefore, life expectancy must be weighed against quality of life since ‘more money’ means more consumption possibilities, permitting a higher quality of life. Therefore the moral argument of an inadmissible valuation of life in terms of money is not as convincing as it appears at first sight.

However, the main justification for elaborating and applying an economic approach is based on the simple observation, mentioned in Section 2.1, that political decisions involving such valuations have to be made regularly. The mere fact that some action is undertaken (or refrained from) implicitly means that a weighing up of (prolonged statistical) lives against money has occurred. The economic calculus facilitates awareness of this fact, helping to make policies more consistent.

Conversely, doing without an economic valuation of ‘life’ entails risks of its own. A country may take a measure (such as introducing new medical technology) resulting in costs of €1 million for avoiding premature deaths, failing to take into account alternative measures (for example road works) which could achieve the same for only €50,000. Society as a whole will then be deprived of both a longer life expectancy and consumption.²⁰

Parliaments in many countries decide about public projects only after a thorough valuation of all of their costs and benefits. But when it comes to human lives, there has been a lack of an approved procedure to evaluate them in terms of money. As a substitute, it has become customary to mention such costs and benefits known as ‘intangibles’, which amounts to neglecting them as net benefits in the actual evaluation process. As a consequence, projects with a high risk in terms of human lives are too easily approved, while those with a lower risk tend to be rejected. Ironically, those who are against a valuation of life in terms of money thus jeopardize lives, the exact opposite of what they intend.

²⁰ This reference to society as a whole presupposes that life years won or premature deaths avoided do not depend on who is obtaining them (see Subsection 2.3.2.4).

Finally, public policies in a democracy should not only be consistent in the above-mentioned sense but also reflect the preferences of the citizenry. Since permitting citizens to express their preferences is a prerequisite of democracy, moral condemnation of weighing money against life is at odds with the democratic principle.²¹ By taking the preferences of citizens regarding length and quality of life into account, economic analysis thus also serves to enhance the process of democratic decision-making.

Conclusion 2.7. *Since many public decisions inevitably imply a weighing of prolonging statistical lives against other goods, it is beneficial for society to undertake such a valuation explicitly. Citizens' preferences should be reflected in this valuation.*

2.4.1.2 Arguments Against a Finite Value of Life

The reliance on individual preferences stated at the end of the previous section relates to the second objection against CBA. While not questioning the idea of an economic valuation of life as such, it claims that any resulting value less than infinity is unacceptable. It is argued that there are in principle only two possible approaches to determining the value individuals place on their lives.²² One either has to find

- (a) the amount someone would be willing to pay to avoid certain (and immediate) death, or
- (b) the compensation that would have to be paid to someone as to make him or her accept (immediate) death.

The amount determined according to formulation (a) is not very useful as most people would be willing to give up their entire wealth including most of their future income stream (except a small reserve for subsistence) when facing immediate death. Therefore (a) tells us more about an individual's wealth and ability to obtain credit than about his or her preferences.

On the other hand, question (b) will fail to call forth a limited amount – abstracting from a bequest motive – for the simple reason that money is of no use for the dead. This seems to result in an indeterminate value of life. This indeterminacy, however, can be resolved by noting that formulation (a) implicitly assigns the 'property right' to life to someone else than the individual concerned. Only alternative (b) says that the individual has the right to live and to give it up voluntarily. Given such a right to live, the correct 'value of an identified life' should indeed be infinite.

²¹ The persons affected are not only those having a certain disease, but all people with a positive probability of contracting the disease in the future. For those who cannot be held accountable (young or mentally ill persons), the preferences of suitable agents should be considered.

²² Both formulations can be accommodated within the framework of the expected utility rule. See Subsection 2.3.2 for further details.

This train of thought goes back to JOHN BROOME (1982a,b) who turns against a distinction of identified and statistical lives, as in his view the latter concept is based on incomplete information about who is going to lose his or her life. If statistics were able to tell us that in the course of a construction project one worker, who is not identified yet, is going to be killed, this statistical life is in fact infinitely precious. For as soon as the veil of ignorance is lifted and the name of the victim known, approach (b) would call for an infinite compensation for the loss of this identified life.

The flaw in BROOME's argument is revealed when one takes a closer look at the way he constructs his case. It is very hard to imagine a risk where the number of victims is known in advance with certainty. In most cases, it cannot even be said with certainty that there will be any victims at all. For example, a road bend may have taken an average toll of one human life per year in the past. But this does not mean that exactly one person will die during the next year. To the contrary, observing exactly one death during a given year is a rather unlikely event. To see this, let there be 100,000 users of the road per year, each of whom facing the risk of 1 in 100,000 of being killed in an accident. The statement 'individual i will die but not individuals j, k, \dots ' actually is a very strong one, implying perfect negative correlation across individual risks. Assuming stochastic independence or even a positive correlation – which is far more plausible when speaking of accidents – there is a strictly positive probability that no one will be killed while with a positive albeit very small probability all 100,000 persons will be killed. The total number of casualties thus is unknown, causing the 'statistical life' to be the relevant concept for an economic valuation of safety measures.

In sum, most relevant decisions with regard to life and death seem to involve small risks that can be avoided (or must be accepted). In these situations, we can expect limited amounts of money to be sufficient to compensate an individual for taking a risk. There are numerous examples showing that people are willing to risk their lives for the sake of pleasure, comfort or thrill. Activities such as smoking, driving without seat belts, traveling by car or plane rather than by train, and riding on a roller-coaster demonstrate that avoiding small risks is not infinitely valuable to people.

Since individuals clearly act as if their lives have only a finite value to them, the government should not (implicitly nor explicitly) attribute an infinite value to life when taking decisions in the public domain. Otherwise, inefficiencies due to the discrepancy between the costs of lives saved in the private and public domains would be the result. Such a discrepancy could be justified only if external effects were present.

2.4.2 The Human-Capital Approach

The value of an asset can be determined by measuring the owner's financial loss from losing it. This loss, in turn, is measured by the revenue stream that could have been obtained through careful management of the asset. The application of this simple accounting rule ('productive value principle') to human beings leads to a definition

of the value of life based on the loss of human capital resulting from the death of that human being. The value of life is therefore equal to the discounted sum of the individual's future (marginal) contributions to the social product, which corresponds to future labor income, provided the wage is equal to the value marginal product.

When applied to the situation of a human being that falls victim to an accident at work, this definition seems a reasonable way to ascertain the claims for compensation of surviving relatives. The summation of foregone earnings is called 'gross human capital'. By deducting the deceased's future consumption from his earnings, 'net human capital' can be estimated. This quantity corresponds to the material loss that others suffer because of an individual's death.

The human-capital approach is based on two implicit postulates.

- (1) An individual's value depends on the contribution that he or she makes to the welfare of fellow citizens.
- (2) The appropriate measure of society's welfare is the Gross National Product (GNP).

Postulate (1) is more appropriate to a slave holder society than to a liberal democracy of the 21st century. It makes no essential difference between a person and a machine. Moreover, reliance on the 'net human-capital' approach implies that the individuals themselves do not even count as members of society, because their own loss (of future consumption) is not included in the calculation of the value of their lives.

The main advantage of the human-capital approach is that it can be made operational rather easily.²³ For this reason, it has often been applied in cost-benefit analyses in the past. However, it is completely foreign to microeconomic theory, which focuses on individual valuation. In addition, its ethical underpinnings are very much open to attack. For one, the result of such a human-capital calculation is considered unacceptable by many. Indeed, the value of the life of pensioners and others who are unable to work is always zero (even negative according to the net human-capital approach)! Second, and even more fundamentally, the GNP measure entirely ignores the pleasure of living as such. According to the opinion of most students of the field, this objection has served to discredit the human-capital approach despite its advantages of application.

Conclusion 2.8. *According to the human-capital approach, the value of life is determined by the contribution the individual could make to the social product. Its relatively easy application is outweighed by serious economic and ethical shortcomings.*

²³ However, there remain the well-known problems of estimating the contribution of housewives (and housemen) to the national product and possible discrepancies between wage and marginal productivity of labor owing to imperfect labor markets.

2.4.3 The Willingness-To-Pay Approach

The standard approach to measure the benefits in CBA is willingness to pay (WTP). This method is based on the concept of subjective utility which is assumed to depend both on disposable income and on length and quality of life. As a more detailed specification of the factors influencing length and quality of life is not needed, we can summarize these variables in the vector θ_i , while y_i denotes disposable income. Thus, the utility of person i is given by

$$U_i = U_i(\theta_i, y_i). \quad (2.22)$$

In the reference situation, length and quality of life are denoted by the vector θ_i^1 . Suppose that an intervention which costs K Euros can cause situation θ_i^2 . The willingness to pay WTP_i of person i for this measure can then be defined by the following equation

$$U_i[\theta_i^1, y_i] = U_i[\theta_i^2, y_i - WTP_i]. \quad (2.23)$$

Thus WTP_i measures the maximum amount of money which the person i would be prepared to pay in order to obtain the intervention.²⁴ The decision-making rule in Cost-Benefit Analysis states that an intervention is worthwhile if and only if

$$\sum_i WTP_i > K, \quad (2.24)$$

i.e., if total WTP exceeds the cost of the intervention, denoted by K .

Conclusion 2.9. *In contrast to the human-capital approach, the willingness-to-pay approach is based on the concept of subjective utility.*

If the health effects of an intervention can be measured in a continuous variable, the *marginal willingness to pay* of person i ($MWTP_i$) can be determined. In this case, θ_i is a scalar and we obtain

$$MWTP_i = - \frac{dy_i}{d\theta_i} \bigg|_{dU_i=0} = \frac{\frac{\partial U_i}{\partial \theta_i}}{\frac{\partial U_i}{\partial y_i}}. \quad (2.25)$$

Of particular interest is the $MWTP$ for an increased chance of survival which corresponds to the *value of a statistical life* (VSL) [see, e.g., ROSEN (1988) and HAMMITT AND TREICH (2007)]. For preferences that satisfy the axioms of expected

²⁴ This definition of willingness to pay is also called ‘compensating variation’. An alternative concept is the ‘equivalent variation’ EV_i . It is defined by $U_i[\theta_i^1, y_i + EV_i] = U_i[\theta_i^2, y_i]$ and measures the minimum amount of money which the individual would be willing to accept in order to forgo the intervention [see BOADWAY AND BRUCE (1984, Chapter 7)].

utility theory, this MWTP can be determined more accurately. Consider a one-period model and let σ_i denote the probability of survival.²⁵ Following DRÈZE (1962) and JONES-LEE (1974) suppose that the utility function is state dependent and given by $u(L, y_i)$ in the case of survival and by $u(D, y_i)$ in the case of death, both functions being concave in y_i . Assuming, for simplicity, that disposable income is the same in both states, the expected utility of person i is

$$U_i = E[u(y_i)] = \sigma_i u(L, y_i) + (1 - \sigma_i) u(D, y_i). \quad (2.26)$$

As a reduction of the mortality risk is equivalent to an increase in the probability of survival σ_i , we get for the marginal willingness to pay for the reduction of the mortality risk and therefore for the value of a statistical life

$$\text{VSL} = \text{MWTP}_i = - \left. \frac{dy_i}{d\sigma_i} \right|_{dU_i=0} = \frac{\frac{\partial U_i}{\partial \sigma_i}}{\frac{\partial U_i}{\partial y_i}} = \frac{u(L, y_i) - u(D, y_i)}{E[u'(y_i)]}. \quad (2.27)$$

It is therefore higher, the more strongly the individual prefers life over death and the smaller is the expected marginal utility of money $E[u'(y_i)]$. Note that equation (2.27) implies that the VSL depends on the initial level of σ_i , on the individual's wealth, as well as other factors which affect the shape of the utility function. Furthermore, the access to markets for annuities and life insurance has an impact on the VSL [see BREYER AND FELDER (2005)].

To see why the marginal willingness to pay for the reduction of the mortality risk measures the value of a statistical life, consider a small change in population risk. For example, a health care intervention may increase the survival probability σ by $\Delta\sigma = 0.1$ percent for each member of a population of 20,000 individuals. Assume the VSL for a representative individual to be given by €300,000. If the intervention is undertaken, it can be expected that $20,000 \times \Delta\sigma = 20$ lives are saved. On average, individual willingness to pay is approximated by $\text{VSL} \times \Delta\sigma = €300$. Total willingness to pay is therefore given by $20,000 \times €300$. Thus, for each of the 20 statistical lives saved, the population is willing to pay

$$\frac{\text{WTP}}{\text{Statistical lives}} = \frac{20,000 \times \text{VSL} \times \Delta\sigma}{20,000 \times \Delta\sigma} = \text{VSL} = €300,000.$$

For small risk changes in a population, the VSL therefore provides an approximation to the total willingness to pay for a statistical life.

²⁵ See SHEPARD AND ZECKHAUSER (1982, 1984) and ROSEN (1988) for models which determine the VSL in life-cycle models.

2.4.4 Aggregating Willingness To Pay and Principles of Collective Decision-Making

Cost Benefit Analysis (CBA) supports a measure if total WTP exceeds the cost of this measure. This rule is based on two value judgments.

1. Subjective WTP is the only criterion to be used in assessing the benefits of a measure.
2. The distribution of benefits among individuals is irrelevant (in inequality (2.24), only the sum of individual WTP values enters).

The first value judgment reflects the fundamental difference between CBA and Cost-Utility Analysis (CUA). It states that WTP, derived from subjective utility theory, measures the benefits of health-improving interventions. By relying on WTP as the only source of information, CBA represents a welfarist approach. Extra-welfarists would argue that the improvement of health by itself must be taken into account, replacing (or at least complementing) WTP.

As to the second value judgment, it seems attractive at first sight because WTP values have the same weight across individuals. Whether a person benefits from the measure, however, depends also on his or her *contribution to its financing*. A person's *net benefit*, is defined as follows,

$$NB_i = WTP_i - \alpha_i K \quad (2.28)$$

where α_i denotes person i 's share in financing and $\sum_i \alpha_i = 1$.

From the CBA condition,

$$\sum_i WTP_i > K \quad \Leftrightarrow \quad \sum_i NB_i > 0, \quad (2.29)$$

one cannot conclude that all affected individuals will have a positive net benefit. Therefore CBA cannot be justified by the Pareto criterion. Figure 2.6 illustrates this result for the case two individuals A and B . The shaded area contains all combinations of net advantages for which CBA supports a measure. However, only area II represents a Pareto improvement. In area I, person A is better off at the expense of person B , while in area III it is the other way around.

How can we still justify CBA? In the following, we discuss two arguments in its favor. On the one hand, the potential Pareto criterion can be invoked. On the other hand, it is claimed that applying CBA to a whole set of interventions leads to a Pareto improvement. Finally, the consistency of CBA with Social Welfare Analysis is examined.

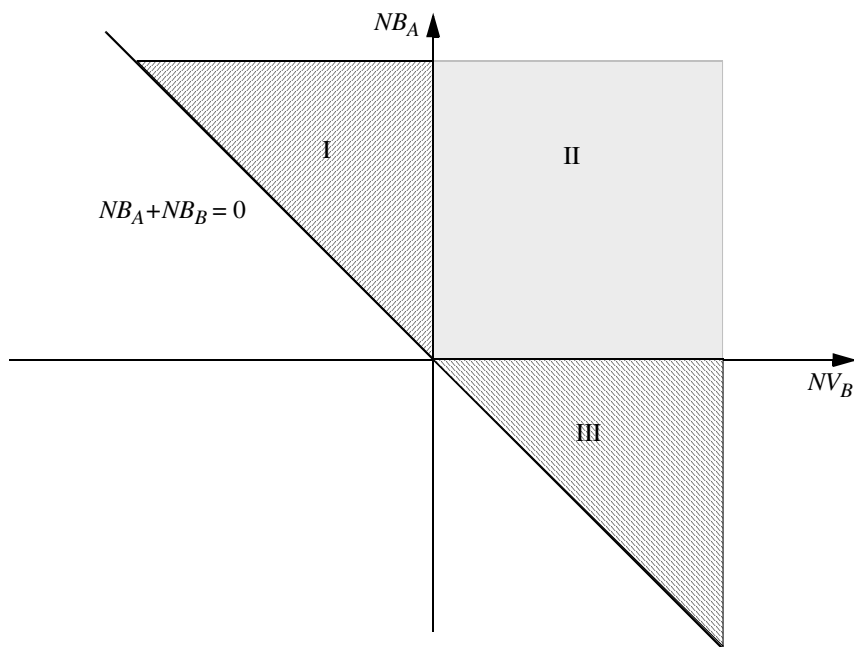


Fig. 2.6. Cost-Benefit Analysis and Net Benefits

2.4.4.1 Cost-Benefit Analysis and the Potential Pareto Criterion

The potential Pareto criterion, also known as Kaldor-Hicks criterion, is frequently used in welfare economics. According to it, an action should be undertaken if it either causes a Pareto improvement or if potential losers could be compensated by the beneficiaries of the action so that there would be a Pareto improvement. It is irrelevant whether the compensation actually takes place. CBA can be justified using this criterion. Suppose $NB_A < 0$, while $NB_A + NB_B > 0$. Then individual B could transfer $T = -NB_A$ to individual A , whose welfare would thus be unaffected by the project. Individual B would still be better off because $NB_B - T = NB_B + NB_A > 0$ by assumption.

A famous proverb says ‘Actions speak louder than words’. It implies a rather strong criticism of the potential Pareto criterion, which suggests that the mere possibility of doing something good already counts, no matter whether it materializes or not. Indeed, in a situation in which some people are made better off at the expense of others, it is not a comforting argument to state that basically everybody could be made better off. A more persuasive justification is necessary.²⁶

²⁶ If equilibrium effects are taken into account, the relationship between CBA and the potential Pareto criterion becomes ambiguous. CBA may support a project although a potential Pareto improvement is not possible [see BLACKORBY AND DONALDSON (1990)].

2.4.4.2 Cost-Benefit Analysis with Many Interventions

In the presence of a whole set of interventions, the cases in which a person is made better off at the expense of others and the cases, in which he or she suffers a loss may neutralize each other. Overall, this would make CBA satisfy the Pareto criterion. In Figure 2.6, this means that person A's utility lies in area I at least as often as in area III, leaving those cases of area II only, where both individuals are better off.

To be valid, this justification requires that the amount of net benefits does not *systematically* vary among affected individuals. If, e.g., WTP for health-improving interventions does not depend on income whereas the financial contribution does, net benefits are negatively correlated with income. As a result, CBA would systematically support interventions improving the situation of people with low income at the expense of people with high income. Suppose person A of Figure 2.6 has low income, then more outcomes would fall in area I than in area III. This may be judged desirable by some but undesirable by others. At any rate, the Pareto criterion cannot be invoked anymore to justify CBA in this case.

2.4.4.3 Cost-Benefit Analysis and Social Welfare Analysis

The difficulties encountered in the preceding two subsections motivate a more general investigation into the nature of the relationship between CBA and social welfare. For this endeavor, welfare economics provides the useful concept of a social welfare function. Its aim is to express value judgments of an observer on the 'welfare of society' by using a real-valued function W . Assume that W satisfies the following two requirements.

- (1) *Welfarism*: W does not depend on the process of allocation but only on the utilities reached by an allocation;
- (2) *Individualism*: the only benchmark for welfare is the utility U_i of the individual.

A function W satisfying these conditions permits social welfare to be expressed in a *Bergson-Samuelson welfare function*,

$$W = W(U_1, \dots, U_n) \quad \text{with} \quad \frac{\partial W}{\partial U_i} \geq 0. \quad (2.30)$$

This function can have different functional forms, depending on the degree of inequality aversion prevalent in society. A well-known example is the utilitarian social welfare function

$$W = \sum_{i=1}^n U_i \quad (2.31)$$

which attributes the same weight to all members of society. The utilitarian welfare function satisfies the *strong Pareto principle* which states that welfare W must rise, if utility U_i of any individual i increases, with the utilities of all other individuals held constant.

By way of contrast, the maximin social welfare function

$$W = \min\{U_1, \dots, U_n\} \quad (2.32)$$

makes social welfare equal the utility of the worst-off person. Thus, increasing a person's utility raises social welfare only if this person is worst-off. Therefore the maximin welfare function violates the strong Pareto principle. However, it satisfies the *weak Pareto principle* according to which welfare rises if the utility of each person increases [see BOADWAY AND BRUCE (1984, p. 146)].

These are just two out of a great many formulations, which differ not only with regard to their equity concept but also to their information demands.²⁷ Here, we only assume that a function as in (2.30) exists. To keep things simple, we limit our analysis to the case of two individuals $i = A, B$. Vector θ_i^1 describes a person's health-related characteristics in the initial situation. Social welfare is then given by

$$W^1 = W(U_A(\theta_A^1, y_A), U_B(\theta_B^1, y_B)). \quad (2.33)$$

Let there be an intervention costing K that results in the characteristics θ_i^2 . Individuals' WTP for it, denoted by WTP_i , is defined by

$$U_i(\theta_i^2, y_i - WTP_i) = U_i(\theta_i^1, y_i). \quad (2.34)$$

Individuals contribute α_i to the cost, where $\alpha_A + \alpha_B = 1$. Then, social welfare after the intervention can be written as

$$W^2 = W(U_A(\theta_A^2, y_A - \alpha_A K), U_B(\theta_B^2, y_B - \alpha_B K)). \quad (2.35)$$

The change in social welfare is defined as

$$W^2 - W^1 = \Delta W \approx \frac{\partial W}{\partial U_A} \Delta U_A + \frac{\partial W}{\partial U_B} \Delta U_B. \quad (2.36)$$

Using equation (2.34), one obtains for a change in utility

$$\begin{aligned} \Delta U_i &= U_i(\theta_i^2, y_i - \alpha_i K) - U_i(\theta_i^1, y_i) \\ &= U_i(\theta_i^2, y_i - \alpha_i K) - U_i(\theta_i^2, y_i - WTP_i). \end{aligned} \quad (2.37)$$

Define $\hat{y}_i^2 \equiv y_i - \alpha_i K$ and $\hat{y}_i^1 \equiv y_i - WTP_i$. Then, it is approximately true that

$$U_i(\theta_i^2, \hat{y}_i^2) - U_i(\theta_i^2, \hat{y}_i^1) \approx \frac{\partial U_i}{\partial y_i} (\hat{y}_i^2 - \hat{y}_i^1). \quad (2.38)$$

Note that in view of (2.28), the difference $(\hat{y}_i^2 - \hat{y}_i^1)$ is nothing but the individual net benefit NB_i . Therefore (2.37) can be rewritten to become

$$\Delta U_i \approx \frac{\partial U_i}{\partial y_i} NB_i. \quad (2.39)$$

²⁷ See, e.g., ROEMER (1996).

Inserting this into (2.36) finally yields

$$\Delta W \approx MU_A NB_A + MU_B NB_B, \quad \text{with} \quad MU_i \equiv \frac{\partial W}{\partial U_i} \frac{\partial U_i}{\partial y_i}. \quad (2.40)$$

That is, the change in welfare approximately corresponds to the sum of net benefits of the measure, weighted by the social marginal utility of income MU_i . Now this expression can be compared with the CBA criterion defined in (2.29), which calls for summing up the individual net benefits NB_i . Therefore, an intervention satisfying the CBA criterion improves social welfare *with certainty* if – as judged by the observer – both individuals have the same social marginal utility of income. Assuming this equality, one indeed obtains

$$\Delta W \approx MU_i (NB_A + NB_B), \quad i = A, B \quad (2.41)$$

and consequently

$$\Delta W > 0 \Leftrightarrow NB_A + NB_B > 0 \quad \Leftrightarrow \quad WTP_A + WTP_B > K. \quad (2.42)$$

Of course, this development gives rise to the question as to the conditions under which equality of social marginal utility holds. Maximizing social welfare subject to an aggregate income constraint,

$$\max_{y_A, y_B} W = W(U_A(\theta_A, y_A), U_B(\theta_B, y_B)) \quad \text{s.t.} \quad y_A + y_B = \bar{y}, \quad (2.43)$$

and assuming the social welfare function to be concave in utilities and the utility functions to be strictly concave in income, the optimal income distribution is characterized by

$$MU_A = \frac{\partial W}{\partial U_A} \frac{\partial U_A}{\partial y_A} = \frac{\partial W}{\partial U_B} \frac{\partial U_B}{\partial y_B} = MU_B. \quad (2.44)$$

Thus, when the observer judges the income distribution to be optimal, social marginal utilities of income are equal. This guarantees that a decision based on CBA always causes an increase in social welfare.

If income is not optimally distributed, however, an intervention supported by CBA may diminish social welfare as soon as for some individual i , WTP_i falls short of the cost share $\alpha_i K$ and therefore $NB_i < 0$. According to equation (2.40), this is the case if a net loss accrues to individuals who have a particularly high social marginal utility of income. Analogously, CBA may reject an intervention even though it increases social welfare, provided that positive net benefits are received by individuals with a high social marginal utility of income.

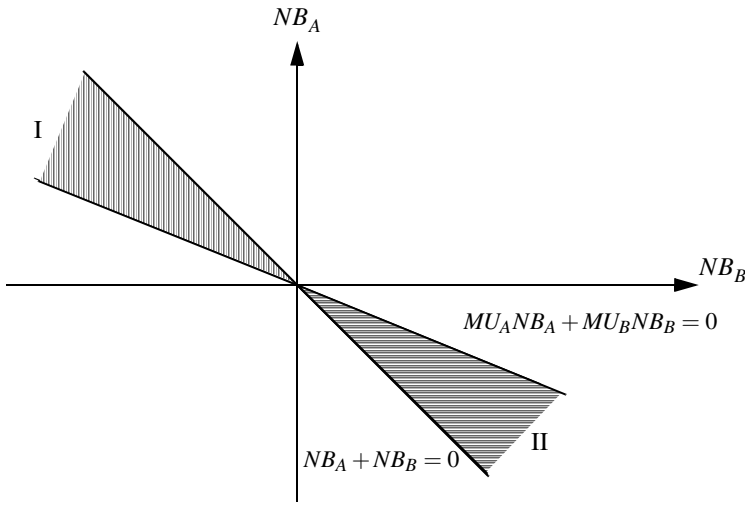


Fig. 2.7. Cost-Benefit Analysis and Social Welfare Analysis

Figure 2.7 illustrates. In addition to $NB_A + NB_B = 0$, it also contains the locus $\Delta W = 0$ from equation (2.40) assuming $MU_A > MU_B$, i.e., person A's social marginal utility exceeds the one of person B. Thus,

$$-\left. \frac{dNB_A}{dNB_B} \right|_{\Delta W=0} = \frac{MU_B}{MU_A} < 1, \quad (2.45)$$

causing the graph of the CBA condition to be (absolutely) steeper than that of social welfare improvement.

In Figure 2.7, the shaded areas represent cases in which CBA and Social Welfare Analysis differ in their recommendations. In area I, Social Welfare Analysis supports a measure while CBA does not because A's net benefit is more strongly weighted than person B's net loss. In area II, Social Welfare Analysis rejects a measure that is supported by CBA because it weighs the net loss suffered by A more strongly than the net benefit accruing to B.

In the light of Social Welfare Analysis, the crucial issue for applying CBA is whether – from the point of view of the observer – income is optimally distributed. If this is not the case, Social Welfare Analysis requires

$$\Delta W \approx MU_A NB_A + MU_B NB_B > 0 \quad (2.46)$$

for an intervention to be recommended, i.e., the sum of individual net benefits weighted by their social marginal utility of income must be positive.²⁸ This decision criterion was first proposed by WEISBROD (1968). Using the definition of net

²⁸ Alternatively, one may use the weights $w_i = \frac{MU_i}{\sum_i MU_i}$ which add up to one.

benefits $NB_i \equiv WTP_i - \alpha_i K$, the social welfare rule can alternatively be expressed as

$$SB \equiv \underbrace{MU_A WTP_A + MU_B WTP_B}_{\text{social benefit}} > \underbrace{MU_A \alpha_A K + MU_B \alpha_B K}_{\text{social cost}} \equiv SC, \quad (2.47)$$

where the social benefit corresponds to the sum of individual WTP weighted by the social marginal utility of income. Likewise, social cost is the weighted sum of individual contributions.²⁹

Notice that the information requirements of Social Welfare Analysis exceed those of CBA. First, not only willingness to pay, but also the financial contributions $\alpha_i K$ need to be determined. Secondly, society must agree on a social welfare function from which to derive social marginal utilities MU_i . Opinions about the relative merits of members of a society will differ, and it is not clear whether a consensus can be achieved. However, this is not a problem of Social Welfare Analysis but arises from the fact that evaluation typically involves value judgments. CBA only appears to circumvent this problem by implicitly assuming an optimal income distribution.

Conclusion 2.10. *Cost-Benefit Analysis can be justified by the potential Pareto criterion. However, the problem with this standard is that Pareto improvements may only be hypothetical. When a whole set of interventions is to be evaluated, overall Pareto improvement can be achieved, provided that the net benefits do not differ systematically among the affected persons. From the point of view of Social Welfare Analysis, CBA can only be applied if the income distribution is deemed optimal. Otherwise, net benefits must be weighted by social marginal utility of income.*

The difference between Cost-Benefit and Social Welfare Analysis may suggest a division of labor between income taxation and economic evaluation, the former being concerned with an optimal income distribution, the latter applying the cost-benefit rule to health-improving interventions. In the light of our model which assumed exogenous incomes this seems to be the adequate response. However, this assumption was only made for ease of exposition. In practice, income is determined to a great extent by labor supply. This puts a limit on the ability of income taxation to redistribute, a problem analyzed by the theory of optimal income taxation which studies the trade-off between distortions in labor supply and redistribution from high to low-ability individuals.³⁰ A solution which equalizes the social marginal utilities of income is usually not optimal as it would imply excessively high marginal tax rates.

²⁹ Defining the 'net social benefit' as the difference between social benefit and social cost, social welfare analysis can be used to evaluate mutually exclusive interventions. If there are a number of mutually exclusive interventions with a positive net social benefit, the one with the highest net social benefit should be adopted.

³⁰ At the heart of this problems is the fact that individuals have private information about their ability. The classic contribution is MIRRLEES (1971); an introduction to the theory of optimal income taxation can be found in MYLES (1995, Chapter 5) and SALANIÉ (2003, Chapter 4).

2.4.5 Measuring Willingness To Pay: Using Surveys

Both Social Welfare Analysis and CBA have WTP – as defined by equation (2.23) – as their point of departure. Therefore, it is crucial to be able to measure WTP. In general, economists prefer to infer WTP from actual behavior. The market price provides a lower bound for WTP because consumers buy a product only if their WTP exceeds or equals the price paid. Markets for medical care are both influenced by health insurance and heavily regulated, however, causing observed price to be too low and estimated WTP too high as a rule. Still, there is the possibility of indirectly inferring WTP from other, less regulated markets in the spirit of revealed preferences. Recently, health economists have increasingly resorted to the direct alternative of interviewing people, thus relying on stated preferences. Both methods have their specific pros and cons which will be discussed in the following. The current subsection is devoted to stated preferences whereas subsection 2.4.6 will deal with revealed preferences.

There are two approaches to measuring WTP directly. The *Contingent Valuation Method* confronts participants with one hypothetical scenario which involves the health care measure to be evaluated. The only attribute that varies is price. By way of contrast *Discrete Choice Experiments* present participants with a series of yes/no choices between the status quo and an alternative that differs with regard to several attributes, not only price. Before describing the two methods in detail, however, a few general problems associated with the use of interviews for WTP measurement need to be discussed.

2.4.5.1 General Problems of Surveys

The interview is not only the most direct but also the most transparent method to find out preferences. However, participants may not understand the questions, fail to take them seriously enough – as the situations are only hypothetical – or even hide their real preferences. Specifically, the following problems occur in the context of health.

- (1) *Dealing with small probabilities.* If the scenarios described in the questionnaire are to roughly reflect reality, it is essential to consider very small probabilities and probability differences as soon as the intervention considered changes the chances of survival. Small probabilities, however, have little meaning to most people, who often fail to distinguish between probabilities that differ by powers of ten.³¹ Answers therefore will not be very reliable, and by asking similar questions involving different probabilities, it is easy to obtain results which contradict the transitivity of preferences or the axioms of expected utility maximization. In this case, the theoretical framework of Subsection 2.4.3 is no longer applicable.

³¹ In another context this was already observed by KAHNEMAN AND TVERSKY (1979).

- (2) *Emotional rejection of questions.* Another problem is getting participants to answer delicate questions involving the trade-off between life and wealth. Refusal to answer such questions is likely to bias results if it occurs predominantly among people who place a very high value on their own life. Emotional rejection of questions could also result in a conscious or unconscious distortion of revealed preferences.
- (3) *Insufficient motivation of the interviewed.* Even if there is a basic willingness to answer the questions, there is no motivation to seriously think about one's preferences in a real rather than hypothetical situation. Respondents could be tempted to express what they think the interviewer wants to hear or what will help their personal image.
- (4) *Strategic behavior.* If the interviewed know that the decision for a specific project will be based on their responses, they have an incentive to behave strategically. Persons anticipating benefits from the project will overstate their WTP in order to increase the probability of the project being accepted. In the opposite case, they will understate their WTP to help prevent the project.

2.4.5.2 The Contingent Valuation Method

The predominant approach to WTP measurement has been the Contingent Valuation (CV) Method, developed in environmental economics for evaluating public goods.³² Since the mid-1970s, CV has also been applied to health care.³³

In CV studies, two procedures can be distinguished.

- (1) When applying the *open-ended technique*, individuals are directly asked for the maximum amount they would pay for the hypothetical project. As this may be too demanding, tools such as the *bidding game* have been developed. Respondents are asked whether they would pay a certain price and in case they agree, the price is raised until they finally reject. If the initial price is rejected, it is reduced until the respondent accepts the project. The resulting price represents the maximum willingness to pay.
- (2) The *closed-ended technique* attempts to create a situation familiar to respondents by asking just yes-or-no questions. Therefore, participants merely have to decide whether or not they are willing to pay the suggested price, which varies between them. This technique can be used to calculate the share of yes-votes as a function of the price. Multiplying this share with the total number of participants yields a function which can be interpreted as the aggregate demand function for the

³² For an overview of more than one hundred CV studies, see CUMMINGS ET AL. (1986) and MITCHELL AND CARSON (1989).

³³ KLOSE (1999) presents an overview of the Contingent Valuation reports with respect to health economics.

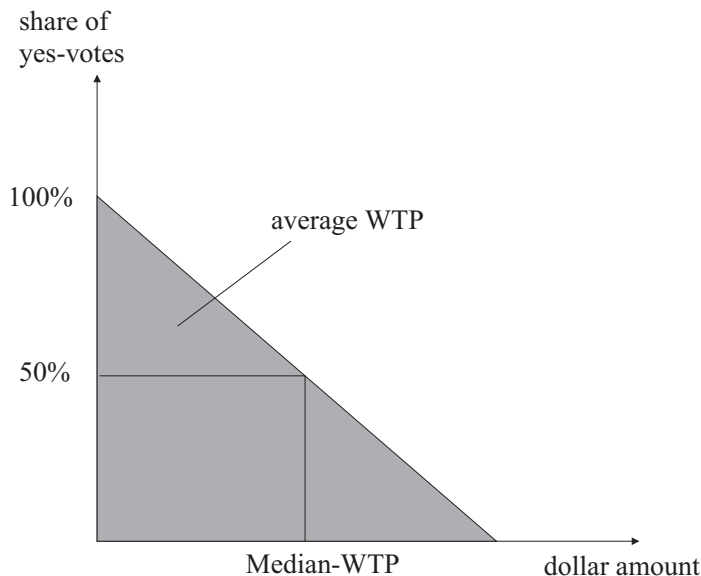


Fig. 2.8. Calculating the Willingness to Pay Using the Survival Function

good. Figure 2.8 shows aggregate WTP as the area of this demand function, which is specified as a survival function.³⁴ Median WTP can be read off the price fifty percent of the respondents are just about to accept. Average WTP can be higher or lower than the median value, depending on the distribution of WTP. If this distribution is skewed towards low WTP values, it falls short of the median. In the case of a linear survival function (which is nothing but a cumulative distribution function), the two values coincide.

It is still an open question whether the open-ended or the closed-ended technique should be preferred in CV studies. The main advantage of the latter is that the decision resembles a familiar market situation. A general disadvantage of CV, however, is its liability to bias, in particular of the following types.³⁵

- (a) *Bias caused by reference values and the order of questions.* CV is prone to so-called ‘anchoring’ effects. Respondents indicate their WTP relative to a reference value rather than their value. For example, in bidding games, stated WTP frequently depends on the starting point (starting-point bias). When several projects are presented at a time, the answer to the first question can influence all the following ones (question-order bias).

³⁴ For an overview of the different methods to estimate a survival function, see NOCERA ET AL. (2003).

³⁵ See MITCHELL AND CARSON (1989, Chapter 11) for a detailed description of possible sources of bias when using CV.

- (b) *Sensitivity to wording of questions.* The results of CV studies are very sensitive to the wording of the questions. For instance, the definition of property rights or the means of payment used can bias WTP values. At an even more basic level, there is the risk that respondents perceive the presented good or program quite differently from what the investigator intended.
- (c) *Attitude towards the object of investigation.* When applying the closed-ended technique, there is the danger of 'yea-saying'. To express their general agreement with the object of investigation, respondents accept prices in excess of their true WTP [see BLAMEY ET AL. (1999)].

Considering in addition the general problems associated with interview studies mentioned in the preceding subsection, it seems doubtful that reliable WTP measurement can be obtained from a CV study. Nevertheless, this method has yielded theoretically plausible results, when applied to health care [see KLOSE (1999)]. Specifically, individuals with high incomes have been found to have a higher WTP than others. Moreover, measured WTP increases with the quantity of health services offered by a program. It could not yet be established, however, that stated WTP is consistent with actual buying decisions (constituting so-called criterion validity). Also, with regard to the reliability of the method, there is evidence of only a limited degree of reproducibility of results obtained using the CV method.

Conclusion 2.11. *Contingent Valuation calls on respondents to evaluate a hypothetical program or good whose attributes are held constant across scenarios except for price. While theoretically plausible results can be obtained with this method, it is very sensitive to several types of bias. Furthermore, there is still no firm evidence that the stated willingness to pay matches actual decisions.*

Frequently, surveys are used to determine the *value of a statistical life* (VSL) (see Section 2.4.3). VISCUSI (1993) and more recently HAMMITT AND GRAHAM (1999) report on nearly two dozen survey studies investigating the value of a statistical life. These studies were mainly performed in the United States and in Great Britain. Sample sizes differ considerably (from 30 up to more than 1,000). In some cases, respondents were students attending classes taught by the authors; in other cases, they constituted representative samples of the country's population. All questionnaires defined realistic scenarios stating plausible reasons for changes in the risk of dying such as additional safety measures in road traffic, nuclear power plants, or the removal of toxic waste. The intent was to make respondents take the questions seriously.

The results show considerable *variation* in the calculated value of life. This is because of the fact that average stated WTP values for large risk reductions of about $1:10^3$ are not substantially larger than for risk reductions in the order of $1:10^5$ to $1:10^6$. Studies using large risk reductions thus lead to estimates of the VSL that are

lower by several orders of magnitude. For example, FRANKEL (1979) found values of a statistical life ranging from US\$57,000 to US\$3.37 million in the *same study*, depending on the size of the assumed risk reduction.

These results confirm the presumption mentioned above that most respondents have difficulties in dealing with very small probabilities. Indeed, hypothetical probabilities below a certain level (which could be around 1:1,000) are ‘mentally adjusted’ to a higher value.

However, JONES-LEE ET AL. (1985) report that their (arithmetic) mean was strongly influenced by some outliers on the high side. Using the median instead of the mean yielded a value of a statistical life of only £800,000 rather than £1.5 million. While the potential Pareto criterion has to be based on the arithmetic mean, using the median can be justified by the principle of majority rule, which applies when risk-reducing measures proposed by the government are voted upon in a poll. There are some further considerations which suggest that the results presented may fail to mirror ‘true’ willingness to pay.

- A considerable percentage of respondents indicate *the same* WTP for risk reductions of *different* sizes, starting from the same initial risk level.
- Some respondents even indicate *smaller* amounts for *higher* risk reductions [see JONES-LEE ET AL. (1985), SMITH AND DESVOUSGES (1987)].
- Considerable differences between WTP for a small decrease in risk and compensation demanded for small increases in risk are found in the same study.

Finally, the type of death described in the scenarios (for example dying of cancer vs. dying in a car accident) affects the stated WTP as well. This is relevant because, e.g., in the case of cancer, being able to avoid a long period of suffering may call forth substantial WTP.

Conclusion 2.12. *Considerable variation and widespread inconsistencies in results suggest that ‘stated preferences’ – at least in the guise of Contingent Valuation – lack reliability when applied to WTP for risk reduction.*

2.4.5.3 Discrete Choice Experiments

Discrete Choice Experiments (DCE) are a variant of *conjoint analysis*, which was developed in psychology in the late 1960s [see LUCE AND TUKEY (1964)]. This method attempts to explain and predict consumers’ behavior on the basis of their preferences for the attributes of a good. It is based on the New Demand Theory [see LANCASTER (1966)] which defines preferences in terms of attributes rather than quantities of goods. Since decisions typically are to buy or not to buy one unit of the good, they are of the discrete type. In contradistinction to the CV approach, the status quo and the hypothetical alternative differ with regard to several or all attributes rather than price only.

Since the beginning of the 1980s, DCEs have been applied in transport economics and more recently to environmental economics [see for example HENSHER (1997), BENNETT AND BLAMEY (2001)]. In the mid-1990s, the method was implemented in health economics as well [RYAN (1995), RYAN AND HUGHES (1997)], and in the meantime quite a few DCE studies have been conducted.³⁶

Before starting a DCE, the attributes characterizing both the status quo and the alternative need to be defined. In the case of knee surgery, e.g., this could be the following:

- desired effects;
- possible complications;
- length of wait for surgery;
- length of hospital stay;
- out-of-pocket cost as the price attribute.

These attributes can be combined to form various (hypothetical) products. Every product or program is therefore characterized by a vector of parameter values. These hypothetical alternatives are usually juxtaposed against a fixed status quo, and respondents are asked sequentially whether they prefer the status quo or the current alternative. A DCE therefore amounts to tracing out an indifference curve in attribute space, with the status quo defining a reference point. A preferred combination of attributes must lie above the indifference curve (or surface, respectively in the case of more than two attributes), a rejected one, below. Through repeated choices, the indifference locus can be interpolated.

DCEs make the following assumptions on preferences:

- (1) *Existence of a representative consumer.* The aggregated preferences of the study population can be represented by a single utility function. However, group-specific differences in preferences are taken into account by a vector of socio-economic control variables in the utility function.
- (2) *Restrictions imposed on the form of the utility function.* Almost all applications assume linearity, which implies constant marginal utilities of attributes. Since this assumption is too restrictive, especially when price (and with it disposable income) varies over a wide range in the experiment, a quadratic utility function is used alternatively. However, this still implies rather restrictive assumptions.³⁷

³⁶ See, e.g., BRYAN ET AL. (1998), JOHNSON ET AL. (2000), RATCLIFFE AND BUXTON (1999), TELSER AND ZWEIFEL (2002) and VICK AND SCOTT (1998). A preliminary survey of the applications in health care is given by RYAN AND GERARD (2004).

³⁷ A quadratic utility function is used, e.g., by GEGAX AND STANLEY (1997) and PECKEL-MAN AND SEN (1979).

The decision-theoretic model can be presented as follows.³⁸ Each alternative j is characterized by its price p_j and a vector of characteristics $b_j = (b_j^1, \dots, b_j^z)$, while y_i denotes the income of individual i . The indirect utility of alternative j for individual i can thus be written as

$$V_{ij} = v(p_j, b_j, y_i, \varepsilon_{ij}), \quad (2.48)$$

where ε_{ij} denotes a random variable. This is the random utility model developed by MCFADDEN (1974). Note that this model does not imply that individuals choose at random. Rather, ε_{ij} stands for those determinants of choice that are not captured by equation (2.48) but cannot be observed by the experimenter. The individual will choose the alternative j if its utility exceeds the utility of the status quo (more generally, of all alternatives l available), i.e.,

$$v(p_j, b_j, y_i, \varepsilon_{ij}) \geq v(p_l, b_l, y_i, \varepsilon_{il}), \quad \forall l \neq j. \quad (2.49)$$

Since individuals' decisions are random variables, one can only define the probability for choosing alternative j ,

$$P_j = \text{Prob}[v(p_j, b_j, y_i, \varepsilon_{ij}) \geq v(p_l, b_l, y_i, \varepsilon_{il})], \quad \forall l \neq j. \quad (2.50)$$

In order to estimate (2.50), an assumption not only regarding the functional form of $v(\cdot)$ but also the distribution of the error terms ε must be made. For the latter, Probit and Logit models constitute the dominant alternatives.

Using the results of this estimation, one can calculate the marginal rate of substitution (MRS) between any two attributes. The MRS states how much of one attribute someone is willing to give up in order to obtain one more unit of the other attribute. The MRS is defined by the ratio of the two partial derivatives of the indirect utility function with respect to attributes k and m :

$$\text{MRS}_{k,m} = \frac{\frac{\partial v(p_j, b_j, y_i, \varepsilon_{ij})}{\partial b_j^k}}{\frac{\partial v(p_j, b_j, y_i, \varepsilon_{ij})}{\partial b_j^m}}. \quad (2.51)$$

Specifically the MRS between attribute b_j^k and price p_j captures the amount of disposable income (i.e., the negative of price) a person is willing to pay in order to receive one more unit of attribute k . But this is nothing else than WTP for attribute k ,

$$\text{WTP}_k = - \frac{\frac{\partial v(p_j, b_j, y_i, \varepsilon_{ij})}{\partial b_j^k}}{\frac{\partial v(p_j, b_j, y_i, \varepsilon_{ij})}{\partial p_j}}. \quad (2.52)$$

³⁸ A detailed description of the method and the underlying theoretical model can be found in LOUVIERE ET AL. (2000).

Given a linear utility function, WTP values are constant. Therefore, WTP for non-marginal changes is obtained by multiplying (2.52) by the respective changes in the attributes between the status quo and the alternative. In this simple case, WTP for the program as a whole can be estimated by simply adding the WTP values of its attributes.

An important advantage of DCE over CV follows from the fact that respondents tend to evaluate all attributes of a program rather than focusing on price only. This makes DCE less susceptible to strategic behavior. Moreover, being based on an estimated utility function, the results of a DCE can be used to determine WTP for any program that has the same set of attributes. On the other hand, as in the QALY model of Cost-Utility Analysis, rather restrictive assumptions concerning individuals' preferences have to be made. Therefore, their validity needs to be checked. To this day, few studies have investigated the validity and reliability of DCE. However, first results obtained by BRYAN ET AL. (2000), RYAN ET AL. (1998), TELSER (2002), TELSER AND ZWEIFEL (2002) and ZWEIFEL ET AL. (2006) indicate that DCE may be a valid and reliable approach to WTP measurement in the case of health as well.

Conclusion 2.13. *Discrete Choice Experiments attempt to determine and forecast individuals' preferences for the attributes of a product from their accept/reject decisions. The significant advantages of this method are limited susceptibility to strategic behavior and applicability of its results to projects having the same attributes. However, its restrictive assumptions regarding preferences still need to be tested.*

2.4.6 Measuring Willingness to Pay: Using Market Data

The major advantage of inferring WTP indirectly from market data is that market observations reflect real rather than hypothetical decisions. This holds true also of situations involving risk. Risk preferences can be inferred from actions designed to avoid risks. A well-known example is the choice (or avoidance) of a job that is known for its risks to life and health (examples are race car drivers, truck drivers, stuntmen, miners, or electricians). But everyday decisions like putting on the safety belt also provide information about risk preferences.

Using 'revealed preference' for measuring WTP, however, has its problems as well. Take the example of occupational choice. Here, the basic idea is to estimate the compensation required for accepting a higher risk of death from the difference in wage rates for occupations with and without an increased threat to life. The problems with this approach are the following.

- (1) *Separating risk from other influences.* In contrast to the hypothetical situations described in questionnaires, real life situations have many aspects, making it difficult to isolate a single determining factor. One hardly finds two occupations that are identical except for their risk to life and health. Differences in wage rates also

reflect differences in educational requirements, mental and physical demands, and many other characteristics of occupations. As long as these characteristics cannot be held constant, it is quite daring to identify a wage differential with a risk premium.

- (2) *Discrepancy between subjective probability and relative frequency.* Even if the wage differential were a pure risk premium, the marginal rate of substitution between risk and wealth can only be determined with the help of subjective estimates of relevant probabilities. According to expected utility theory, decisions are based on subjective probabilities. By way of contrast, in the case of occupational hazards (e.g., fatal industrial accidents), only relative frequencies can be observed. As these fatal accidents are relatively rare, it is questionable whether those affected know the frequencies, let alone use them as a basis for their subjective probability estimates. Surveys among drivers indicate that most underestimate their personal risk of causing an accident relative to the frequency observed in the total population. Another question is whether observed behavior actually can be interpreted as the outcome of expected utility maximization as required by theory. Empirical evidence [already by EISNER AND STROTZ (1961)] indicates that when dealing with relatively small risks, individuals systematically violate this rule – as was already noted in Subsection 2.4.5.2 in the context of hypothetical questions.
- (3) *Representativeness of persons in risky occupations.* Finally, it can be called into question whether persons in risky occupations are representative of the total population. The fact that such an occupation and no other was chosen by them implies that – even ignoring objections (1) and (2) for the moment – the wage differential constitutes the *upper limit* of their compensation asked for bearing the increased risk (conversely their WTP for a risk reduction). Simultaneously, it marks the *lower limit* for the rest of the population (assuming that these individuals are in principle suited for the job as well). This consideration, however, is not very helpful in cases in which the measured ‘compensating wage differential’ is extremely small or even negative. In this case, we have to conclude that members of such a profession may have a special preference for risky situations (perhaps for the thrill that comes with them) that is not shared by the rest of the population.³⁹

Conclusion 2.14. *Measuring willingness to pay on the basis of market data has the advantage of relying on real rather than hypothetical decisions. This method, however, has its problems as well. In particular, one needs to make sure that individuals know the relevant risks and that preferences are singled out as a determinant of observed behavior.*

³⁹ It is doubtful, however, that people who take high risks professionally or privately for the sake of ‘thrill’ (stuntmen, hang gliders) feel the same way about a less spectacular risk of equal magnitude (e.g., poisoning due to harmful substances).

The first extensive empirical survey of wage differentials among occupations entailing differing threats to life was conducted by THALER AND ROSEN (1975). Their data refer to 900 workers in 37 *risky occupations*. The authors relate workers' wage incomes to various causes, using multiple regression analysis to isolate occupational risk. Probabilities of death are taken from life insurance statistics. Depending on the specification of the estimated equation, estimated regression coefficients yield values of statistical life between US\$136,000 and 260,000 (referring to 1967).

More recent surveys using data from the United States and Great Britain indicate larger wage differentials in response to comparable risk increments. The value of a statistical life often exceeds US\$1 million while continuing to exhibit variations of up to two powers of ten.

Another approach is to derive the 'value of life' from the observed *behavior of consumers*, using data such as

- the higher price of houses in neighborhoods with better air quality;
- the purchase and installation of smoke detectors in wooden houses;
- the use of safety belts and the choice of speed when driving a car;
- the use of subways to cross streets with heavy traffic.

Surprisingly, the results of these completely different studies bunch more closely than those comparing wage rates. They imply a value of life between US\$200,000 and US\$600,000 in 1983 prices [see JONES-LEE ET AL. (1985)]. In view of the reservations, both against the direct and the indirect method of measuring WTP for changes in the risk of death (see Subsection 2.4.5.1 again), however, it cannot be concluded with certainty that the value of a statistical life lies within this interval.

2.5 Cost-Utility, Cost-Benefit and Social Welfare Analysis

2.5.1 Comparing Cost-Utility and Cost-Benefit Analysis

When comparing Cost-Utility Analysis (CUA) with Cost-Benefit Analysis (CBA), one similarity and two major differences stand out. Neither method considers how the net benefits from an intervention are distributed. This is a weakness for policy makers (and indeed, citizenries) who prefer the net benefits of a measure not to be distributed too unequally among those affected. As demonstrated above, this aspect can be taken into account by using a health-related or social welfare function.

The first principal difference is that CUA as such fails to provide a recommendation whether or not a project should be carried out unless there is a predetermined health care budget. It leaves open the question of how that budget should be set. Second, the two methods differ in how the benefits accruing to the affected persons should be taken into account in the decision-making process. CUA draws upon the

extra-welfarist concept of health while CBA relies on the conventional utility concept of welfare economics. The two methods are therefore based on different value judgments and not just on different technical procedures. By opting for a specific method, a decision is made as to the factors that are taken to be relevant for individual welfare. The analyst can only try to clarify the welfare-economic relationships. Ultimately, the decision for or against an evaluation method can only be made by society.

Conclusion 2.15. *Cost-Utility Analysis and Cost-Benefit Analysis differ not only technically but, above all, in how they incorporate the welfare of those affected. CUA focuses on health, CBA on utility. They are thus based on different value judgments.*

An advocate of CBA may ask an interesting question regarding the compatibility of the two methods, viz. can one use the results of CUA for CBA? In particular, we pose the question whether a unique ‘willingness to pay for a QALY’ exists, which can be compared to the cost per QALY of specific interventions to assess whether the intervention is worth doing. This would be particularly helpful for health care systems that do not use fixed budgets.⁴⁰

For an answer to this question, note first that the assumptions of the QALY model have to be satisfied (see Section 2.3.2.2). As shown in Section 2.3.2.3, QALYs are an argument of an expected utility function which also depends on disposable income y only if a number of assumptions are satisfied. Specifically, expected utility must take the form presented in equation (2.16). Then expected utility of an individual i with income y_i and an initial QALY endowment QALYs_i is given by

$$EU_i = b(y_i)\text{QALYs}_i. \quad (2.53)$$

From this, the marginal WTP for a QALY can be derived,

$$\text{MWTPQ}_i = -\frac{dy_i}{d\text{QALYs}_i} \bigg|_{dEU_i=0} = \frac{\frac{\partial EU_i}{\partial \text{QALYs}_i}}{\frac{\partial EU_i}{\partial y_i}} = \frac{b(y_i)}{b'(y_i)\text{QALYs}_i}. \quad (2.54)$$

Given a positive marginal utility of income, this quantity is positive.

Based on (2.54), one can estimate an individual’s WTP for a health care intervention by multiplying the marginal WTP for a QALY by the number of additional QALYs achieved,

$$\text{WTP}_i \approx \text{MWTPQ}_i \times \Delta\text{QALYs}_i = \frac{b(y_i)}{b'(y_i)\text{QALYs}_i} \Delta\text{QALYs}_i. \quad (2.55)$$

Based on the resulting values, a CBA (or a Social Welfare Analysis, see below) can be performed. This would be easy because evaluation of health states from surveys serve as input to CUA. However, the following aspects have to be considered.

⁴⁰ See also BLEICHRODT AND QUIGGIN (1999).

- (a) Equation (2.16) requires restrictive assumptions which are only partially satisfied in practice (see Section 2.3.2.3).
- (b) Equation (2.54) shows that individuals' marginal WTP for a QALY depends on their disposable income and their initial QALY endowment. This likely causes WTP for a QALY to vary between them. In particular, equation (2.54) implies that marginal WTP for a QALY should increase with disposable income if $b''(y) < 0$, i.e., if the standard assumption holds that marginal utility of income is decreasing ceteris paribus. This hypothesis is supported by empirical studies which find evidence for a positive income effect on WTP per QALY [see BYRNE ET AL. (2005) and KING ET AL. (2005)].

A pragmatic approach would be to use average MWTPQ in a population. If the measure to be evaluated affects groups with different incomes or initial QALYs in different ways, however, this way may result in the wrong choice. Suppose, for example, that mainly people with low incomes benefit while MWTPQ increases with income. In this case, using average MWTPQ would lead to an overestimation of total WTP. This approach can only be justified if there is no systematic relationship between MWTPQ and the additional number of QALYs gained.

In general, it is necessary to differentiate MWTPQ according to income and initial health (and possibly further factors). For this reason, there exists no unique marginal willingness to pay for a QALY which can be used in CBA. Furthermore, group-specific estimates of the numbers of QALYs gained are needed. However, these are frequently not available from Cost-Utility Studies.

These considerations also show that it is highly unlikely for CUA and CBA to yield the same result. This would require not only that the assumptions of the QALY model are satisfied and preferences are given by equation (2.53) but also that WTP for a QALY must be the same for everyone so that CBA weights the changes in QALYs equally. In addition, the budget defining the scope of CUA would have to correspond to the optimum expenditure resulting from CBA. Nevertheless, the analysis shows that QALYs can in principle be used in CBA, provided that differences in MWTPQ and the numbers of QALYs gained are adequately captured.

Conclusion 2.16. *Individuals' marginal willingness to pay for a QALY depends on their disposable income and their initial QALY endowment. The use of QALYs in CBA therefore requires group-specific values of marginal willingness to pay for a QALY and of the numbers of QALYs gained. In general, Cost-Benefit Analysis leads to a different result than Cost-Utility Analysis.*

Thus, not only do the two methods differ in their value judgments, but it is also difficult to use the results of CUA for CBA. We can conclude that these two are basically different concepts for evaluating health-related measures. The major practical advantage of CBA is that it answers the question of whether or not an intervention should be carried out at all. By contrast, CUA takes the budget devoted to health care as given, failing to provide guidance as to how this budget should be set.

2.5.2 Social Welfare and QALYs

In Section 2.4.4.3, we discussed how Social Welfare Analysis can be used to evaluate health care interventions. This method is based on the concept of a *Bergson-Samuelson welfare function*,

$$W = W(U_1, \dots, U_n).$$

It was shown that Social Welfare Analysis generally differs from Cost-Benefit Analysis.⁴¹ Whereas CBA simply sums up WTP, Social Welfare Analysis requires to consider separately each person's WTP and her or his contribution to financing a health-improving measure. To obtain the change in social welfare, these have to be weighted by social marginal utility of income, MU_i . Generalizing equation (2.47) to a population with n individuals, the social welfare rule for the adoption of a medical intervention is

$$SB \equiv \underbrace{\sum_{i=1}^n MU_i WTP_i}_{\text{social benefit}} > \underbrace{\sum_{i=1}^n MU_i \alpha_i K}_{\text{social cost}} \equiv SC, \quad (2.56)$$

where α_i denotes person i 's share in financing the cost K of the intervention. In the following, we analyze how Social Welfare Analysis can be performed using QALYs. In particular, we examine how changes in QALYs and contributions to financing should be weighted.

Assume that QALYs are an argument of an expected utility function independent of consumption. Preferences are therefore given by equation (2.53). Then social marginal utility of income reads as

$$MU_i \equiv \frac{\partial W}{\partial U_i} \frac{\partial U_i}{\partial y_i} = \frac{\partial W}{\partial U_i} b'(y_i) \text{QALYs}_i, \quad (2.57)$$

with U_i being equal to EU_i in the present context. Using the individual's WTP for a health care intervention derived in (2.55), one therefore obtains the following approximation for social benefit

$$SB = \sum_{i=1}^n \frac{\partial W}{\partial U_i} b'(y_i) \text{QALYs}_i \times WTP_i \approx \sum_{i=1}^n \frac{\partial W}{\partial U_i} b(y_i) \Delta \text{QALYs}_i.$$

Likewise, (2.57) implies that social cost is given by

$$SC = \sum_{i=1}^n \frac{\partial W}{\partial U_i} b'(y_i) \text{QALYs}_i \alpha_i K.$$

⁴¹ An exception was the unlikely case that income is optimally distributed according to chosen social welfare function.

Thus, the social welfare rule becomes

$$\sum_{i=1}^n \frac{\partial W}{\partial U_i} b(y_i) \Delta QALY_{s_i} > \sum_{i=1}^n \frac{\partial W}{\partial U_i} b'(y_i) QALY_{s_i} \alpha_i K. \quad (2.58)$$

To obtain further results, it is necessary to specify the social welfare function. Let us first consider the utilitarian social welfare function $W = \sum_i U_i$ which implies $\partial W / \partial U_i = 1$. The rule for financing a health-care measure is then given by

$$\sum_{i=1}^n b(y_i) \Delta QALY_{s_i} > \sum_{i=1}^n b'(y_i) QALY_{s_i} \alpha_i K. \quad (2.59)$$

Imposing the standard assumption of diminishing marginal utility of income, $b''(y) < 0$, one finds that

- (a) health improvements should be valued more highly for high-income individuals (because of $b'(y) > 0$). This follows from the utility function (2.53) which implies that health and consumption are complements. Furthermore, it does not matter whether a person is initially healthy or not as measured by the initial QALY endowment. This follows from the linearity of the utility function (2.53) in QALYs.
- (b) the financial contribution $\alpha_i K$ has a higher impact on social cost if individuals have low income. Due to diminishing marginal utility, the loss of utility for these individuals is larger. The contributions of those with a high QALY endowment, i.e., high initial health, also receive more weight in social cost. Again, this is a consequence of the complementarity of health and consumption.

The judgment that health improvements are more valuable for those with high income while those with better health should be given more weight in social cost will not be shared by most people. This can mean that utilitarianism, which is more widely accepted in matters of pure income distribution, does not express people's value judgments in a wider context. Alternatively, the problem may lie in the particular shape of the utility function (2.53), which expresses linearity in QALYs and complementarity of QALYs and consumption.

Instead of giving up the utility function (2.53), we now look at different aggregation rules which express aversion to inequalities not only in income but also in utility. Consider the social welfare function

$$W = \frac{1}{1-\rho} \sum_{i=1}^n U_i^{1-\rho}, \quad \rho \geq 0, \rho \neq 1.^{42} \quad (2.60)$$

The parameter ρ can be interpreted as a measure for the aversion to inequality in utilities. For $\rho = 0$, inequalities in utilities do not matter and one obtains the utilitarian social welfare function. With positive values of ρ , social welfare becomes averse to utility inequalities.⁴³ As ρ goes to infinity, the social welfare function approaches the maximin case $W = \min\{U_1, \dots, U_n\}$.

⁴² For $\rho = 1$, social welfare can be defined as $W = \sum_i \ln U_i$.

⁴³ In the two-person case, welfare indifference curves in the utility space become convex.

From the social welfare function (2.60), one obtains that marginal social utility $\partial W / \partial U_i = U_i^{-\rho}$ is isoelastic in U_i : a one percent increase in U_i leads to ρ percent decrease in marginal social utility. Thus, individuals with low total utility are given more weight. This increases the weight of individuals with low income and a low QALY endowment in social benefit and cost. Using (2.53) yields

$$\frac{\partial W}{\partial U_i} = U_i^{-\rho} = b(y_i)^{-\rho} \text{QALYs}_i^{-\rho}.$$

Inserting in (2.58) leads to the social welfare rule

$$\sum_{i=1}^n b(y_i)^{1-\rho} \text{QALYs}_i^{-\rho} \Delta \text{QALYs}_i > \sum_{i=1}^n b'(y_i) b(y_i)^{-\rho} \text{QALYs}_i^{1-\rho} \alpha_i K. \quad (2.61)$$

With the utilitarian rule as a reference case ($\rho = 0$), we find with regard to social benefit (left-hand side)

- for $\rho > 0$, individuals with low health are given more weight.
- for $\rho > 1$, health improvements for those with low income are valued higher.

Concerning social cost (right-hand side), we observe

- a reinforced emphasis on low-income individuals if $\rho > 0$. The factor $b(y_i)^{-\rho}$ gives their contribution a higher weight apart from diminishing marginal utility.
- for $\rho > 1$, a higher weight for individuals with low initial health.

With aversion to inequalities in utility, the results therefore seem to conform much better to widely held value judgments. If this aversion is high ($\rho > 1$), then low-income and low-health individuals receive more weight in social benefit as well as social cost.

From a practical point of view, Social Welfare Analysis calls for considering the distribution of income and health in economic evaluation. This makes the analysis more difficult. A pragmatic approach would be to identify particular groups who show significant differences with respect to health and income. Furthermore, note that social cost is also influenced by the way health care is financed, here the share of cost α_i which is financed by individual i . These shares are also policy variables which can be optimized.

Conclusion 2.17. *Social Welfare Analysis based on QALYs can be employed if these are an argument of an expected utility function independent of consumption. How changes in QALYs and contributions to financing should be weighted according to income and initial health depends on the particular social welfare function assumed. If aversion to inequality in utilities is sufficiently high, low-income and low-health individuals should be given more weight in both respects.*

2.6 Summary

- (1) Cost-Effectiveness Analysis (CEA) only serves for a comparison of measures with uni-dimensional effects. Cost-Utility Analysis (CUA) also allows comparisons among measures with several heterogeneous effects. To indicate whether a measure is desirable, both methods require a fixed budget for health care. By contrast, Cost-Benefit Analysis (CBA) provides an evaluation of life and health in terms of money and thus permits to assess every project separately.
- (2) The concept of 'quality-adjusted life years' (QALYs) allows to make changes in the quality of life and changes of the length of life comparable. A decision-theoretic analysis based on expected utility theory shows that the concept of QALYs requires several assumptions, viz. preferences for health states must be stable over the whole life cycle, there must be risk neutrality with respect to length of life, and preferences must obey the 'zero-condition'. To some extent, it is possible to relax these assumptions. Taking into account that utility depends not only on health but also on consumption, further assumptions are necessary to ascertain that QALYs capture all health-related benefits in a scalar index.
- (3) Cost-Utility Analysis is not compatible with a welfarist position, which claims that collective decisions should be based on total utility of the affected persons. The use of QALYs can, however, be justified with an extra-welfarist position, according to which only health – as measured by QALYs – is relevant for particular collective decisions. The principle of maximization of QALYs can be criticized on the grounds that the distribution of QALYs should also play a role.
- (4) If preferences of respondents satisfy the assumptions of the QALY model, with utility linear in length of life, the time trade-off and the standard-gamble methods lead to an analogous result in that they measure the utility weights of respective health states on a scale ranging from 0 (death) to 1 (perfect health). The standard-gamble method, however, is more general because it does not require utility to be linear in remaining length of life. By contrast, the rating scale method is less suitable since it lacks a utility-theoretic basis.
- (5) In Cost-Benefit Analysis (CBA), a money value is assigned to an improvement in length or quality of life. To achieve this, two entirely different concepts have been developed, the human-capital approach and the willingness-to-pay approach. According to the human-capital approach, the value of life is determined by the contribution the individual could make to the social product. Its relatively easy application is outweighed by serious economic and ethical shortcomings. In contrast to the human-capital approach, the willingness-to-pay approach is based on the concept of subjective utility.
- (6) Cost-Benefit Analysis can be justified by the potential Pareto criterion. However, the problem with this standard is that Pareto improvements may only be hypothetical. When a whole set of measures is to be evaluated, overall Pareto improvement can be achieved, provided that the net benefits do not differ systematically among the affected persons. From the point of view of Social Welfare

Analysis, CBA can only be applied if the income distribution is deemed optimal. Otherwise, net benefits must be weighted by social marginal utility of income.

- (7) There are two alternative approaches to WTP measurement. According to the stated-preference method, surveys are used to determine respondents' WTP. The method of 'revealed preference' infers willingness to pay from the individuals' market behavior.
- (8) To determine WTP using stated preferences, there are again two alternatives. The Contingent Valuation Method uses questionnaires or personal interviews to ask participants directly for their WTP for a good or program. Discrete Choice Experiments, by contrast, attempts to interpolate an indifference curve by confronting respondents with a series of choices between the status quo and an alternative with changed attributes. Considerable variation and widespread inconsistencies in results suggest that the Contingent Valuation Method lacks reliability when applied to WTP for risk reduction. Discrete Choice Experiments impose restrictive assumptions regarding preferences which still need to be tested.
- (9) Measuring WTP on the basis of market data has the advantage of relying on real rather than hypothetical decisions. This method, however, has its problems as well. In particular, one needs to make sure that individuals know the relevant risks and to single out preferences as a determinant of observed behavior.
- (10) Cost-Utility Analysis and Cost-Benefit Analysis differ not only technically but, above all, in how they incorporate the welfare of those affected. CUA focuses on health, CBA on utility. They are therefore based on different value judgments.
- (11) Individuals' marginal willingness to pay for a QALY depends on their disposable income and their initial QALY endowment. Unless there is no systematic relationship between the marginal willingness to pay for a QALY and the additional number of QALYs gained, group-specific values of willingness to pay for a QALY and of the numbers of QALYs gained must be determined. In general, Cost-Benefit Analysis leads to different recommendations than Cost-Utility Analysis.
- (12) Social Welfare Analysis based on QALYs can be employed if these are an argument of an expected utility function independent of consumption. How changes in QALYs and contributions to financing should be weighted according to income and initial health depends on the particular social welfare function. If aversion to inequality in utilities is sufficiently high, low-income and low-health individuals should be given more weight in both respects.

2.7 Further Reading

For a detailed description of evaluation methods in health economics, we recommend DRUMMOND ET AL. (2005) and JOHANNESSON (1996). In the HANDBOOK OF HEALTH ECONOMICS, articles by HURLEY (2000), GARBER (2000), DOLAN (2000) and WILLIAMS AND COOKSON (2000) deal with the issues of this chapter.

2.E Exercises

2.1. What do the approaches to economic evaluation presented in Section 2.2 have in common? What are the differences?

2.2. Discuss possible equity concerns in economic evaluation. How can they be addressed?

2.3. What are the strengths and weaknesses of the QALY concept?

2.4. Discuss the pros and cons of the different approaches to measure willingness to pay.

2.5. Consider the following independent health care interventions *A* to *E*:

Intervention	Cost in €000	Gain in QALYs
<i>A</i>	300	10
<i>B</i>	380	20
<i>C</i>	600	25
<i>D</i>	720	40
<i>E</i>	500	10

- (a) Assume that the budget for health care interventions is €2 million.
- (i) Rank the interventions according to the ACURs.
 - (ii) Use your result from (i) to determine which interventions should be implemented to maximize the total gain in QALYs.
 - (iii) Consider a new intervention *F* which is mutually exclusive with intervention *B*. It generates 28 QALYs at a cost of €700,000. Calculate the ACUR and the ICUR of intervention *F*. Show that it is optimal not to adopt *F* even though its ACUR is lower than the ACUR of another intervention which should be used. Explain your result.
- (b) Consider again interventions *A* to *E* and suppose that the budget is €1.4 million.
- (i) Assume that all interventions can be scaled down proportionally without any restrictions. Use the ACUR-ranking to determine which interventions should be implemented to maximize the total gain in QALYs.
 - (ii) Which interventions should be implemented if *C* is indivisible? Explain your result and comment on the limitation of using a ranking according to cost-utility ratios.

2.6. Consider the following mutually exclusive health care interventions A to E :

Intervention	Cost in €000	Gain in QALYs
A	300	20
B	460	22
C	600	30
D	780	32
E	1,000	40

All interventions can be scaled down proportionally without any restrictions. Show that a combination of other interventions always dominates interventions B and D . Relate your result to the ICURs of interventions B and D .

2.7. Consider again the mutually exclusive health care interventions A to E given in Exercise 2.6 and assume a unique willingness to pay for a QALY. Determine the optimal intervention according to Cost-Benefit Analysis for a willingness to pay of (i) €20,000, (ii) €37,500 and (iii) €50,000 per QALY using

- (a) the net benefit method;
- (b) incremental cost-benefit ratios.

Comment on your result.

2.8. Suppose an individual has an expected utility function compatible with the QALY model. There are three possible health states $H_h; h = 1, 2, 3$ with probabilities π_h . Health state h yields constant utility $u(H_h)$ until death, which occurs after T_h periods. The following table describes the initial situation,

h	$u(H_h)$	π_h	T_h
1	0.2	0.1	3
2	0.5	0.2	5
3	0.8	0.7	7

- (a) Determine the number of QALYs and life expectancy in the initial situation.
- (b) Determine the change in QALYs due to measures A , B and C with the following effects.
 - A : a reduction of life expectancy in state 1 by 2 periods and in state 2 by 1 period, respectively, combined with an increase in life expectancy in state 3 by 2 periods.

- B*: a reduction in the probabilities of states 1 and 3 by 0.05 each, combined with an increase by 0.1, for state 2.
- C*: a reduction in life expectancy in state 1 by 2 periods, an increase in life expectancy in state 3 by 1 period, reductions in the probability of state 1 by 0.05 and of state 3 by 0.15 respectively, and an increase in the probability of state 2 by 0.2.

2.9. Suppose expected utility of an individual can be expressed by the function

$$\sum_{t=1}^2 \sum_{h=1}^2 \pi_{h,t} y_t^{0.5} u(H_h)$$

and assume that $y_1 = 25$, $y_2 = 4$, $u(H_1) = 0.4$ and $u(H_2) = 0.6$.

- (a) For the values $\pi_{1,1} = \pi_{1,2} = \pi_{2,1} = \pi_{2,2} = 0.5$, determine expected utility and number QALYs of the individual.
- (b) Now assume $\pi_{1,1} = 0.6$, $\pi_{2,1} = 0.4$, $\pi_{1,2} = 0.3$ and $\pi_{2,2} = 0.7$. Again determine expected utility and QALYs of the individual. Compare your result with part (a) and explain the difference.

2.10. Suppose expected utility of individual i with survival probability σ_i and income y_i is given by

$$EU_i = \sigma_i (y_i)^{0.5},$$

i.e., utility in case of death is zero. There are two individuals A and B , who differ only in their incomes, with $y_A = 1000$, and $y_B = 500$. In the initial situation, probability of survival is 90 percent for both. An intervention which costs $K = 64$ raises survival probability to 92 percent.

- (a) Is this intervention supported by an unweighted CUA?
- (b) How must the intervention be financed in order to achieve a Pareto improvement?
- (c) Suppose social welfare is defined by $W = EU_A + EU_B$. Each individual has to bear one-half of the cost.
- (i) Determine social welfare with and without the intervention.
- (ii) Determine the approximate weights for a CBA that correctly indicate an increase in social welfare.

2.11. Suppose there are two individuals $i = A, B$ with income y_i and initial QALY endowment QALYs_i . Expected utility of individual i is given by

$$EU_i = \ln(y_i)\text{QALYs}_i.$$

A health care intervention with cost $K = 50$ leads to an increase in QALYs_i by ΔQALYs_i . Individual A has income $y_A = 200$, a QALY endowment $\text{QALYs}_A = 100$ and benefits by $\Delta\text{QALYs}_A = 1$. For individual B consider the following three scenarios (i) to (iii):

	(i)	(ii)	(iii)
y_B	200	200	100
QALYs_B	50	50	100
ΔQALYs_B	2	1	6

For each scenario, determine the result of CBA

- (a) based on individual willingness to pay as given by equation (2.55).
- (b) based on average marginal willingness to pay, i.e., calculate total willingness to pay using the formula

$$(\text{MWTPQ}_A + \text{MWTPQ}_B)/2 \times (\Delta\text{QALYs}_A + \Delta\text{QALYs}_B).$$

Discuss your results.

2.12. Suppose there are two individuals $i = A, B$ with income y_i and initial QALY endowment QALYs_i . Expected utility of individual i is given by

$$EU_i = \ln(y_i)\text{QALYs}_i.$$

A health care intervention increases QALYs_i by ΔQALYs_i . Each person finances half of the cost K of the intervention. Consider the following four scenarios (i) to (iv):

	(i)	(ii)	(iii)	(iv)
y_A	100	100	50	100
QALYs_A	50	50	100	120
ΔQALYs_A	1	1	5	1
y_B	100	200	200	200
QALYs_B	100	100	100	100
ΔQALYs_B	1	2	1	1
K	13	30	20	12

For each scenario, determine the result of CBA, a Social Welfare Analysis based on a utilitarian welfare function, and a Social Welfare Analysis using the function (2.60) with $\rho = 0.5$. Discuss your results.

Health Economics

Zweifel, P.; Breyer, F.; Kifmann, M.

2009, XX, 529 p., Hardcover

ISBN: 978-3-540-27804-7