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A proposal to solve the comparability problem in cost-utility analysis

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Abstract

In cost-utility analysis it is assumed that health state valuations are directly comparable across individuals. Instead, health state valuations may be relative and related to people's expectations and abilities. Then health state valuations are not fully comparable across people and, consequently, cost utility analysis cannot be applied in full. The present paper analyzes this comparability problem and proposes a method to solve it. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Any social choice rule requires an assumption about the extent to which individual utilities are comparable. In cost-utility analysis, the least that must be assumed is that the units of individual utility functions are comparable (Bleichrodt, 1997). Proposals to adjust cost-utility analysis for equity considerations (Wagstaff, 1991; Williams, 1997; Bleichrodt, 1997; Dolan, 1998) require not only unit comparability but also level comparability of utility. To obtain this degree of comparability, health states are generally evaluated through a common cardinal utility function. This function is typically computed through an algorithm based on a representative sample of the population (Dolan, 1997; Furlong et al., 1998).

The assumption that the function defining the health state utilities can be applied to all individuals in the same way, irrespective of their preferences and characteristics, was

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challenged by Fryback and Lawrence (1997) (Sunstein, 1997; Nord et al., 1999, see also). Fryback and Lawrence argued instead that the valuation of health may be a relative concept related to the expectations and abilities of people. The problem referred to by Fryback and Lawrence is that the set of attainable health states differs across people. If people consider their health relative to the set of attainable health states then their valuation of health varies with this set. The use of a common utility function for health ignores such differences in the set of attainable health states and can lead to a distorted measure of the total benefit that a health care program brings about.

A consequence of treating health state valuations as a relative concept is that it is not generally true that two individuals whose health changes from state a to state b derive an identical benefit from treatment. That is, individual health improvements can no longer be directly compared. This incomparability of individual health improvements is problematic for cost-utility analysis which is based on comparing health improvements across individuals. Theories of partial comparability have been proposed (Sen, 1970; Atkinson and Bourguignon, 1987), but the use of such theories implies that there may exist health care programs that cannot be fully compared. That is, there may exist health care programs x and y that cannot be ranked in terms of cost-effectiveness. This is undesirable for resource allocation decisions. However, if we want to retain full comparability and apply cost-utility analysis in the face of relative health state valuations then a method must be found to make health state valuations comparable across individuals.

The optimal solution to this “comparability problem” is to determine for each individual his set of attainable health states and to elicit his health utility function, scaled such that the utility of death is equal to zero and the utility of his best attainable health state is equal to one. This scaling ensures that a year in the best attainable health state gets the same weight across individuals and avoids the possibility of discrimination due to differences in capacity to benefit.

Unfortunately, the above preferred solution is generally not feasible in practice due to time and/or financial constraints. In most cost-effectiveness analyses, information exists on the actual health states of patients, but not on their own valuations of these health states. Then a different procedure must be found to establish comparability of health state valuations. The purpose of this paper is to propose such a procedure. The primary application of our method is to cases in which objective health state information, the health state description, is available, but subjective health state information, the patient’s health state valuation, is lacking.

The rationale for our approach is that people’s valuation of health depends on their expectations with respect to their health, and that these expectations can be approximated by the distribution of health of a group of comparable individuals. Within groups health states are directly comparable and the common utility function assumed in cost-utility analysis can be applied. Between groups this is not possible. To allow comparisons of health states between groups, we say that individuals who occupy the same position within their groups are in an equivalent health state. Equivalent health states can be compared across individuals and are evaluated through the common utility function assumed in cost-utility analysis. Hence, our procedure amounts to applying the common utility function to equivalent health states instead of absolute health states.

The paper is structured as follows: Section 2 summarizes the structural assumptions made throughout the paper; the comparability problem is analyzed in Section 3; Section 4 explains the procedure of making health state valuations comparable through the notion of equivalent health states; Section 5 concludes.

2. Structural assumptions

Consider a set of health states $\mathbb{S}$. For example, $\mathbb{S}$ may consist of the 243 EuroQol health states (Brooks, 1996). We assume that there exists a social preference relation $\succcurlyeq$ over the set $\mathbb{S}$, where $x \succcurlyeq y$ means that "health state x is at least as good as health state y". The relation $x \succ y$ means that "health state x is strictly better than health state y" and $x \sim y$ means that "health state x is equivalent to health state y". We assume that $\succcurlyeq$ is *complete*, i.e. all health states can be compared through $\succcurlyeq$, and *transitive*, i.e. if $x \succcurlyeq y$, and $y \succcurlyeq z$, then $x \succcurlyeq z$. For convenience, we assume throughout that each individual in society agrees with $\succcurlyeq$. Note that $\succcurlyeq$ is an *ordinal* relation. It only expresses how different health states are ordered and it conveys no information about the difference in strength of preference between health states. Hence, $\succcurlyeq$ contains no cardinal information. For cost-utility analysis, however, comparisons of cardinal utility are required (Bleichrodt, 1997). That is, differences in health state utilities must be comparable across individuals. For example, it must be possible to say whether a change in patient a's health from state x to state x' leads to a larger utility gain than a change in patient b's health from state y to state y'.

We further assume that there are two health states, $w, b \in \mathbb{S}$, which are *worst* and *best*, respectively. That is, there is no health state x in $\mathbb{S}$ such that $w \succ x$. Similarly, there is no health state x in $\mathbb{S}$ such that $x \succ b$. In cost-utility analysis, death is commonly taken as the worst health state and full health as the best health state. We adopt this convention in what follows.

3. The comparability problem

A way of obtaining a cardinal valuation of health is by means of the QALY measure. If health is treated as a relative concept, i.e. related to people's abilities and expectations, then a QALY can be defined as "the value of a year in the best attainable health state". Consider a particular health state $x \in \mathbb{S}$. In cost-utility analysis it is generally assumed that each individual can reach any health state. The QALY valuation of x is then the fraction of a year $u(x)$ in the best health state, b, which is equivalent to a year in state x. As mentioned before, the values of $u(x)$, $x \in \mathbb{S}$, are usually computed through an algorithm based on a representative sample of the population (Dolan, 1997; Furlong et al., 1998). Note that u is a cardinal function representing the social weak order $\succcurlyeq$ on the set of health states $\mathbb{S}$, with $u(w) = 0$ and $u(b) = 1$.

Consider now the case of a disabled individual. Because of his chronic impairment, this patient cannot reach state b. In other words, the set of attainable health states for the disabled individual is not $\mathbb{S}$, but a smaller set $\mathbb{S}' \subset \mathbb{S}$. Let b' be the best element in $\mathbb{S}'$ and let $b \succ b' \succ w$. Then $1 > u(b') > 0$. Let $x \in \mathbb{S}'$. Denote by $v(x)$ the fraction of a year in state b' which for the disabled individual is equivalent to a year in state x. A QALY for this individual is then the value of a year in state b'. Given this concept of a "personalized"

QALY, the function v defines the valuation of the health states that the disabled individual can attain. The function v is a cardinal function representing $\succcurlyeq$ on the set of attainable health states $\mathbb{S}' \subset \mathbb{S}$, with $v(w) = 0$ and $v(b') = 1$.

Because v and u differ, evaluating the disabled individual's health through the function u may lead to a distorted measure of the benefits he derives from treatment. The extent to which this is problematic for cost-utility analysis depends on the relationship between v and u.

Suppose first that v and u are cardinally equivalent. That is, for all $x \in \mathbb{S}'$, v and u are related by a positive linear transformation: $v(x) = ku(x) + m$, $k > 0$ and m real. Because $v(b') = 1$, $v(w) = u(w) = 0$, we obtain that $m = 0$, and $k = 1/u(b')$. Consequently, for all $x \in \mathbb{S}'$,

$$v(x) = \frac{u(x)}{u(b')}$$

Because $u(b') < 1$, we derive that for any attainable health state $x \in \mathbb{S}'$, $v(x) > u(x)$. Because v can be obtained from u through a simple rescaling, utilities can be made comparable and cost-utility analysis can be applied. This approach is similar to the proposal put forward by Johannesson (2001). The rescaling factor $k = 1/u(b') = u(b)/u(b') > 1$, which is the relative value of b and b' in terms of u, may be interpreted as an equity weight that should be assigned to the disabled individual to take into account that his set of attainable health states, i.e. his capacity to benefit from treatment, is smaller than that of the representative individual.

Cardinal equivalence of v and u is plausible if all health states worse than b' are attainable for the disabled individual. In general, however, this is not the case and even if we consider only health states that lie in preference between w and b', $\mathbb{S}'$ will be a smaller set than $\mathbb{S}$. Loosely speaking, there will be some "gaps" in $\mathbb{S}'$ as compared to $\mathbb{S}$ on the preference interval between w and b'. The disability of the individual may prevent him, for example, from reaching any health state $y \prec b'$ in which mobility is at the optimal level. Because of the impossibility of achieving some intermediate health states, it is likely that u and v are not cardinally equivalent. If v and u are not cardinally equivalent, units of measurement can no longer be made directly comparable through a simple rescaling and a different solution must be found to make utilities comparable across individuals. Such a solution is the topic of the next section.

4. Interpersonal comparability through equivalent health states

Consider a particular population N. Each individual in the population has a given health state, which we express formally by saying that there exists a *health function h* defined from N into $\mathbb{S}$, the set of health states. For each individual a in N, $h(a)$ denotes his health state.

Suppose that the health states of individuals a and a' are both equal to x. That is, $h(a) = h(a') = x$. Cost-utility analysis then assumes that these individuals have identical health state valuations. As we argued before, this assumption is not plausible if the individuals have different sets of attainable health states.

Consider a group of agents $M \subset N$ whose set of attainable health states is $\mathbb{S}' \subset \mathbb{S}$. Let $w \in \mathbb{S}'$, and let b' be the best element in $\mathbb{S}'$. Our task is to approximate the function $v : \mathbb{S}' \to [0, 1]$, where, as before, for all $x \in \mathbb{S}'$, $v(x)$ stands for the fraction of a year in state b', which, for people in M, is equivalent to a year in state x.

For group M, we define two new functions F_M and G_M. The function value $F_M(x)$ measures the number of individuals in M whose health state is not strictly better than health state x. That is, F_M is a function from the set of health states $\mathbb{S}'$ into the set of natural numbers $\mathbb{N}$ defined by:

$$F_M(x) = \#\{a \in M | x \succcurlyeq h(a)\} \tag{1}$$

where the symbol # denotes "the number of". F_M is increasing in health status, the better the health state the higher the function value, and is bounded above by $F_M(b')$, which is equal to the total number of individuals in M. This follows because there is no health state strictly better than b' in $\mathbb{S}'$. Consequently, all individuals in M must be in a health state that is not strictly preferred to b' and $F_M(b') = \#M$. Assume for convenience that no individual in the population is in a state equivalent to the worst health state, death. Then $F_M(w) = 0$.

The function G_M measures the proportion of individuals in M whose health state is not strictly better than x. That is, G_M is a function from the set of health states $\mathbb{S}'$ into the interval [0,1] defined as

$$G_M(x) = \frac{F_M(x)}{\#M} \tag{2}$$

note that F_M and G_M both represent $\succcurlyeq$ on $\mathbb{S}'$.

Two functions F and G can similarly be defined for the population at large. For any $x \in \mathbb{S}$, let

$$F(x) = \#\{a \in N | x \succcurlyeq h(a)\} \tag{3}$$

and

$$G(x) = \frac{F(x)}{\#N} \tag{4}$$

Hence, $F(x)$ measures the number of individuals whose health state is not strictly better than x in the population at large. Similarly, $G(x)$ measures the proportion of individuals whose health state is not strictly better than x in the population at large.

The functions G_M and G play a central role in making the health state valuations of individuals in group M comparable with the health state valuations of the population at large. Consider an individual $a \in M$, whose health state is $x \in \mathbb{S}'$, i.e. $h(a) = x$. The function $G_M(x)$ indicates the relative position of individual a within M. That is, it indicates how well off individual a is, relative to individuals who are in the same group. Let there be a health state $y \in \mathbb{S}$, such that $G_M(x) = G(y)$. This equality implies that the proportion of individuals in M who are in a health state not strictly better than x is equal to the proportion of individuals in the population at large who are in a health state not strictly better than y. Because G_M and G are cumulative distribution functions, the equality $G_M(x) = G(y)$ can also be expressed by saying that health state x for group M and health state y for the population at large correspond to the same percentile in their respective cumulative distributions. That is, the *relative position* of individual a in his group M is equal to the relative position he would have in the population at large if his health state were y.

As an example, let M be the group of blind people, and let x be the health state "*blind and living in a wheelchair*". For the population at large, state x is worse than it is within group M. Then, state y is a better health state than state x. This follows, because the proportion of individuals who are in a health state worse than the state "*blind and living in a wheelchair*" is higher in group M than in the population at large.

The health state y, defined above, can be interpreted as individual a's *equivalent health state*. We then apply the common utility function assumed in cost-utility analysis to the equivalent health state y to obtain the valuation of health state x for individuals in M. To conclude this section, we formalize the above discussion.

Definition 1. The *equivalent health state* y of individual $a \in M$ is defined as $G_M[h(a)] = G(y)$.

Let E_M be a function which is group-dependent and which assigns to each health state x in $\mathbb{S}'$, its equivalent health state y in $\mathbb{S}$. Formally E_M is a function from $\mathbb{S}'$ into $\mathbb{S}$ such that $E_M(x) = G^{-1}[G_M(x)]$, where G^{-1} denotes the inverse of G. To obtain the function v, we set $v(x) = u(E_M(x))$, for all x in $\mathbb{S}'$.

5. Final remarks

The aim of this paper was two-fold: first to argue that there is a comparability problem in cost-utility analysis, and, second, to propose a solution for this comparability problem. The cause of the comparability problem is that the set of attainable health states differs across individuals. This makes that the benefits from treatment cannot be directly compared across individuals and therefore that cost-utility analysis can only be applied in cases where the set of attainable health states is the same for all individuals involved.

Our proposal aims to make health states comparable through the concept of equivalent health states. It is a proxy-method and should only be applied in case individual-specific utilities, defined on the set of attainable health states, cannot be obtained. As noted in the introduction, our proposal assumes that people's health state valuations are closely related to the distribution of health of a group of individuals with whom they consider themselves comparable. We believe that this assumption is reasonable. For example, it is a well-known finding that people suffering from some chronic disease, e.g. diabetes, when asked to rate their health often claim that they are in full health (EuroQol state 11111). Such a response only makes sense if people take into account their set of attainable health states and consider their health relative to a group of comparable individuals.

Our method intends to solve the comparability problem in cost-utility analysis and, thereby, to measure more accurately the benefits people derive from treatment. Even though its focus is therefore more on efficiency than on equity, the method has some equity implications. For each group, our method gives the same weight to a year in the best attainable health state. Therefore, our method can avoid discrimination due to differences in capacity to benefit from treatment. Several authors have raised concerns about the possibility of discrimination due to differences in capacity to benefit from treatment, which is inherent in cost-utility analysis (Harris, 1988; Hadorn, 1992; Nord et al., 1999; Johannesson, 2001). Proposals have been put forward to avoid such discrimination through the application of equity weights although little guidance was given how such weights might be obtained. Application of our method eliminates the need to use such equity weights. Note, however, that our method does not eliminate the need to impose equity weights for other reasons than differences in capacity to benefit. For example, it may still be necessary to impose equity weights to reflect concerns about the final distribution of "personalized" QALYs.

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