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CONTINGENT VALUATION

Money for health: the equivalent variation of cardiovascular diseases

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Summary

This paper introduces a new method to calculate the extent to which individuals are willing to trade money for improvements in their health status. An individual welfare function of income (WFI) is applied to calculate the equivalent income variation of health impairments. We believe that this approach avoids various drawbacks of alternative willingness-to-pay methods. The WFI is used to calculate the equivalent variation of cardiovascular diseases. It is found that for a 25 year old male the equivalent variation of a heart disease ranges from €114 000 to €380 000 depending on the welfare level. This is about €10 000–€30 000 for an additional life year. The equivalent variation declines with age and is about the same for men and women. The estimates further vary by discount rate chosen. The estimates of the equivalent variation are generally higher than the money spent on most heart-related medical interventions per QALY. The cost-benefit analysis shows that for most interventions the value of the health benefits exceeds the costs. Heart transplants seem to be too costly and only beneficial if patients are young. Copyright © 2004 John Wiley & Sons, Ltd.

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Introduction

Economic evaluations have become an important tool to allocate (public) money for health care. Most evaluations are based on an assessment of the cost effectiveness or cost utility of health care interventions. The most well-known instruments applied that shed light on the benefits of health care interventions are the quality adjusted life years or QALYs. A QALY measures the amount of healthy years gained by a medical intervention. Dolan [1] distinguishes three methods to generate valuations of health-related quality of life: the visual analogue scale (VAS), the standard gamble (SG) and the time tradeoff (TTO). If these QALYs are combined with the costs of such an intervention, it can be calculated how much money has to be spent on a medical intervention per QALY. This can be used to rank medical interventions by their effectiveness (i.e. the lowest costs necessary to gain one QALY). This information can be useful to achieve a more efficient allocation of (public) health care expenditures.

However, a true economic evaluation of health interventions not only requires knowledge about the cost effectiveness but also on the value individuals attach to the health improvement. Cost effectiveness and cost-utility studies only provide information whether one intervention is more cost effective than another, not whether it contributes to improving welfare. In the words of Mishan [2]: ‘To be rather rude about it, the analysis of cost

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effectiveness can be described as a truncated form of cost benefit analysis.' (p. 110; see also [3]).

The benefits of a program can be determined by calculating the willingness to pay by individuals for the health improvement obtained by the intervention. The willingness to pay reflects the extent to which individuals are willing to trade money for improvements in their health status. Only if the costs of the health improvement are less than the amount individuals are willing to sacrifice for this gain in their quality of life, the intervention constitutes a true welfare improvement. Labelle and Hurley [4] argue that the difficulties of quantifying health-related benefits within a willingness-to-pay methodology explain why cost-effectiveness analysis has received so much more attention and is more approved of in medical sciences than cost-benefit analysis. Indeed, a major reason for the lack of attention to the willingness to pay for health gains is that the methods for calculating the willingness to pay have several limitations and restrictions.

The existing methods to calculate the willingness to pay can be classified by the way in which preferences are measured. Either preferences are deduced from observed behavior (revealed preference), or individuals are asked directly to state their preferences.

The revealed preference method is mostly based on the hedonic wage or compensating wage differentials approach. The basic assumption of this approach is that health risks comprise an aspect of life that one would like to minimize or eliminate. Elimination of health risks and job hazards are costly, and resources spent on reducing health risks and job hazards cannot be spent on other valuable goods. How much will be spent on health measures depends on the value individuals attach to a reduction in health risks. A survey of the hedonic wage approach and of the empirical studies that measure the monetary value of fatal and non-fatal health risks can be found in Kip-Viscusi [5,6]. The hedonic wage approach is not without problems. The most serious one concerns the problem of self-selection and generalization. Individuals who decide for a certain type of behavior or workers who have chosen a specific occupation are not a random sample of the entire population, but rather a selected group for whom the (job or safety) hazards weigh less heavy than for individuals who made a different choice. Although there are several methods to account and correct for self-selection bias, none of them are completely satisfactory and some of them lead to outcomes that are decidedly disputable. Further, inferences about preferences are frequently based on the behavior of a specific group – for example occupational choices by workers, seat belt use by car drivers or expenditures on safety-capped bottles of aspirins by parents with young children – and are then generalized to the population as a whole.

The alternative approach to calculating the willingness to pay is to ask individuals directly how much they are willing to pay for the reduction or elimination of a (fatal) health risk. This approach, also known as the contingent valuation method, has gained considerable attention. Respondents are asked to consider hypothetical contingencies and to place a specific monetary value on a change from one health status to another, or asked what the maximum amount is that he/she is willing to pay for the elimination of a health risk. A survey of the contingent valuation method to calculate willingness to pay is found in [7]. This direct approach has some limitations as well. Respondents are usually confronted with hypothetical situations of which they have no personal experience. Nor might they ever have considered such situation before. Respondents may also find it difficult to fully understand and comprehend the actual risk involved in the situation. It is further frequently found that the subjective evaluations of risks differ from the objective risk [6]. Finally, responses do not have any consequences for the individual involved. Individuals do not have to change their behavior, nor do they have to sacrifice anything as a result of the opinions they state. This may have the effect that individuals are less committed to their answers and makes the reliability of the responses questionable.

In this paper, a new approach is taken to calculate the extent to which individuals are willing to trade money for improvements in their health status. Using a specific utility function, known as the Leyden welfare function of income, we are able to estimate the equivalent income variation needed to make someone with a health impairment as well of as someone without this specific health condition. This approach has the advantage that it is easy to apply and to understand. It uses information on the entire population, thereby avoiding the problems of self-selection and generalization associated with the hedonic wage approach. It further has the advantage that it does not require that respondents evaluate hypothetical situations, nor does it demand that individuals make assessments about the tradeoff between risk evaluations and monetary returns.

The Leyden welfare function is developed and corroborated in a large body of research and has been used to calculate the compensating variation of changes in household size, climate, and schooling and intelligence [8–17]. However, to the best of our knowledge, the Leyden method has never been used to estimate the equivalent variation of a health change. In particular we apply the method to calculate the equivalent variation of a serious coronary heart disease. We use information on differences in mortality rates between individuals with and without a serious heart problem to determine the willingness to pay for a medical intervention. The reason to focus on heart diseases is twofold. First, coronary heart diseases are the most important mortality risk. Based on death rates observed in 1995 in the Netherlands, the lifetime probability of dying from a CVD is 40% for both men and women, although the mean age at which they die is higher from men than for women. In 1995 the CVD mortality rate is 150 per 100 000 for men and 110 per 100 000 for women, and increases with age [18]. Secondly, the costs of medical interventions for heart diseases are often high, which makes it relevant to ask how these costs compare to the value of the health benefits that are obtained by it.

The outline of this paper is as follows. In the following section we present the model. In the next section, we give a brief introduction to the Leyden welfare function of income, describe the data we use, and present our empirical results. In the penultimate section, these empirical findings will be used to calculate the equivalent variation of a cardiovascular disease. The final section concludes.

The model

In this paper, we will monetarise health impairments using the idea of equivalent income variation. To do so we require a utility function that describes the relationship between an individual's utility, income and health at time t. Suppose that we can write this utility function as

$$U = U_t(y_t, h_t) \tag{1}$$

where y is income and h is health, and where utility is increasing in both arguments y and h. With this function the equivalent income variation of a health change is calculated by solving equation

$$U_t(y_{0t}, h_{0t}) = U_t(y_{1t}, h_{1t}) = u_1 \tag{2}$$

If an individual's health deteriorates and falls from h_0 to h_1, then it follows that $y_{1t}(u_1) - y_{0t}(u_1)$ equals the amount of money we can take away from a healthy individual to make him or her as worse off as he or she is after the health change. We take an unhealthy individual as our point of reference represented by utility level u_1. Another way of measuring the monetary impact of a health change is to ask how much money we have to give an unhealthy individual to leave him or her as well off as he or she would be before the health change. This is known as the compensating income variation. Equality between equivalent and compensating income variation exists if calculated amounts do not depend on the utility base we take as our reference. In this paper this is not the case, and we choose to continue with equivalent variations.

A deteriorating health might also lead to utility losses because of a falling life expectancy. If we want to quantify the magnitude of this effect, we have to refine our equivalent income variation measure.

Again, we start with an individual aged a whose health deteriorates and falls from h_0 to h_1. We further assume that this patient receives treatment and recovers after k periods, but that life expectancy is reduced and he or she has only $m - a$ remaining years to live. To keep the model simple and traceable, we present a life utility function that is additive and separable in annual utilities. Income is health dependent and we start assuming no time discounting. Lifetime utility now equals the sum of annual utilities which can be described as

$$U_1 = \sum_{i=a}^{a+k} U_i(y_{1i}, h_{1i}) + \sum_{i=a+k+1}^{m} U_i(y_{1i}, h_{0i}) \tag{3}$$

For an individual with perfect health, with perfect foresight, and with n additional years to live, the sum over all the annual utilities equals

$$U_0 = \sum_{i=a}^{m+n} U_i(y_{0i}, h_{0i1}) \tag{4}$$

In analogy with the exercise we performed in (2), we compare the lifetime utilities in the two states, and calculate the equivalent income variation amount by setting a value $\bar{y}_0$ such that

$$\sum_{i=a}^{m+n} U_i(\bar{y}_0, h_{0i}) = \sum_{i=a}^{a+k} U_i(y_{1i}, h_{1i}) + \sum_{i=a+k+1}^{m} U_i(y_{1i}, h_{0i}) \quad (5)$$

In this analysis where lifetime utility functions are assumed additive over years and cardinal, equivalent income variation equals

$$\sum_{i=a}^{m+n} (y_{0i} - \bar{y}_0) \quad (6)$$

where $\sum_{i=a}^{m+n} y_{0i}$ stands for the income flow an healthy individual can earn over his or her remaining life. We use a fully deterministic model to handle changes in life expectancy. As one of the referees pointed out, a probabilistic model could be enlightening but is left for future research.

This model forms the essence for our empirical application where we will estimate the equivalent income variation (EIV) for having a cardiovascular disease (CVD). In what follows, we estimate a utility function $U(y, h; x)$ where y is annual income, h is dummy which equals one if the individual is a heart patient and zero otherwise, and x is a vector of intervening variables like age. This function enables us to calculate the annual equivalent variations. Making use of Dutch health statistics, we are then able to calculate the equivalent variations needed to compensate for the reduction in years to live.

For the interpretation of the findings in the health care evaluation literature it is important to note that both the compensating income variation (CV) and the equivalent income variation (EV) can be interpreted in terms of willingness to pay (WTP) and willingness to accept (WTA). This is relevant if we compare our calculated EV with the costs of a medical intervention later on. O'Brien and Gafni [19] provide a conceptual framework for health care cost-benefit analysis. Interpreted in their framework the EIV calculated in this paper can be interpreted as the willingness to accept, i.e. the minimum amount that must be paid to potential gainers of the intervention to forgo the gain and make utility equal to what it would have been after the intervention.

Estimating an extended Leyden welfare function

We will use the Leyden welfare function as the method of welfare measurement to calculate the equivalent income variation. The following description of this approach is partly taken from [17].

Leyden welfare

The notion that nearly all individuals are able to evaluate their situation in relative terms by positioning it somewhere between a 'worst' situation and a 'best' situation has been adopted by the Leyden school and applied to welfare measurement. The empirical literature around the Leyden welfare function (WFI) is based on the income evaluation question or IEQ [8]. This question runs as follows:

> Which monthly household after tax income would you in your circumstances consider to be very bad? Bad? Insufficient? Sufficient? Good? Very good?
>
> About €.......very bad.
> About €.......bad.
> About €.......insufficient.
> About €.......sufficient.
> About €.......good.
> About €.......very good.

The answers of the IEQ are denoted as c_1, c_2, c_3, c_4, c_5, and c_6. If we accept that the answers linked to the verbal qualifiers 'very bad, bad, insufficient, sufficient, good' and 'very good' are evaluations of welfare derived from these various income levels, the IEQ gives us six points on an individual welfare function [14]. These verbal qualifications are translated on a numerical scale

$$U(c_k) = \frac{2k-1}{12}, \quad \text{for } k = 1, \ldots, 6 \quad (7)$$

This cardinalization depends on the number of levels distinguished, in this case 6. The labels are placed equidistant from one another. This is known as the Equal Interval Assumption. In [14,20] the equal interval assumption is tested and both studies do not reject it. It is interesting to note that in the experimental psychology literature the same assumption is also advocated [21]. On theoretical and empirical grounds the relationship between the six answers and welfare values is approximated by a lognormal distribution function [22,23]. Utility is written as

$$U(y) = \Lambda(y; \mu, \sigma) = N\left(\frac{\ln y - \mu}{\sigma}; 0, 1\right) \tag{8}$$

where Λ stands for the lognormal distribution function, N stands for the standard normal distribution function. The welfare parameter μ is estimated by

$$\mu = \frac{1}{6}\sum_{k=1}^{6} \ln c_k \tag{9}$$

The parameter σ^2 is estimated analogously by

$$\sigma^2 = \frac{1}{5}\sum_{k=1}^{6} (\ln c_k - \mu)^2 \tag{10}$$

Since the IEQ clearly states that answers have to be given 'in your circumstances' the welfare function is measured conditional on these circumstances. The two welfare parameters are also conditionally measured and we therefore assume μ and σ to vary over individuals and households.

The traditional explanation for differences in μ is that families with different net family incomes y and family sizes fs will respond differently to the income evaluation question. Family size is included because children within the household create costs and therefore influence perceived welfare. That is, a family of six will need a higher income to obtain a certain welfare level than a family of four, other things being equal. Income is included to reflect the way people adapt their income judgment to changes in their current income. This is referred to as preference drift [8]. The following relationship has been shown to hold:

$$\mu = \beta_0 + \beta_1 \ln fs + \beta_2 \ln y \tag{11}$$

This method has yielded stable and consistent results covering two decades, many countries and many populations. Our results presented in Table 2 again confirm this.

With respect to the parameter σ, the literature indicates that σ is not so easy to explain [8,9,24]. In this paper we will treat σ as a random variable, and set it equal to the sample average, thus conforming the literature.

The data

For our analysis we use the 1995 wave of the Supplementary Provision Survey (SPS, Aanvullend Voorzieningengebruik Onderzoek 1995) of the Dutch Social and Cultural Planningbureau (SCP). The SPS is a random national cross-sectional survey consisting of over 14 000 observations at the individual level. The main purpose of the survey is to monitor the use of publicly subsidized goods and services. It also contains information about individual characteristics. The SPS is conducted every 4 years. For each new wave a new cross-section of the population is interviewed. From this data set we have selected individuals aged 18 and older.

In the 1995 edition the questionnaire included the income evaluation question. Eight thousand and thirty welfare functions could be identified when we restricted ourselves to fully answered IEQs where the answers are strictly increasing in order. Missing observations on household income reduces the sample further to 7131 individuals. If we correct for extreme IEQ-response behavior by assuming that 'normal' response behavior satisfies

$$0.01 \leq N\left(\frac{\ln y - \mu}{\sigma}\right) \leq 0.99$$

we have 6727 observations that remain in the sample. In other words, 'normal' respondents evaluate their own after tax income y with utility in the range of 0.01 and 0.99 on a [0,1]-scale. This mechanism simultaneously corrects for possible measurement errors in income or IEQ answers. Missing values on variables concerning schooling, gender, household composition and health status are excluded. Schooling is measured in years of schooling, gender is a dummy variable that equals one for females, household composition is represented by the number of household members and health status is a dummy variable that equals one when the respondent experienced a cardiovascular disease recently. We end up with a sample consisting of 6382 observations. Descriptive statistics appear in Table 1.

Estimating CVD effects on welfare and family income

Health affects the Leyden welfare function in two ways. The first effect arises because the perception

Table 1. Descriptive statistics of selected variables in SPS sample

	Mean	Standard deviation	Minimum	Maximum
Female	0.513	0.499	0.000	1.000
Age	45.009	15.575	18.000	94.000
Years of schooling	10.840	3.942	6.000	17.000
Household size	2.651	1.298	1.000	11.000
Monthly household income	1570.056	748.067	544.536	3970.557
Cardiovascular disease (CVD)	0.024	0.153	0.000	1.000
μ	7.827	0.347	6.288	9.309
σ	0.410	0.182	0.052	2.410
N	6382			

Household income is calculated in Euros (€).

Table 2. Estimating CVD effects on Leyden welfare and family income using three specifications

(A) Using Leyden welfare measure μ as dependent variable						
Intercept	0.885	*0.336******	0.830	*0.338****	0.901	*0.341******
Log household size	0.067	*0.006******	0.067	*0.006******	0.067	*0.006******
Log household income	0.501	*0.006******	0.501	*0.006******	0.501	*0.006******
Female	−0.014	*0.005****	−0.014	*0.005****	−0.013	*0.005****
Log years of schooling	0.037	*0.008******	0.037	*0.008******	0.037	*0.008******
Log age	1.458	*0.187******	1.489	*0.188******	1.448	*0.190******
Log age squared	−0.190	*0.025******	−0.194	*0.025******	−0.188	*0.025******
Cardiovascular disease (CVD)			0.031	*0.018**	0.680	*0.421*
CVD × log age					*−0.155*	*0.101*
R^2	0.580		0.580		0.581	
N	6382		6382		6382	
(B) Using log family income as dependent variable						
Intercept	−8.372	*0.571******	−8.244	*0.575******	−8.365	*0.581******
Female	−0.049	*0.010******	−0.050	*0.010******	−0.051	*0.010******
Log years of schooling	0.326	*0.015******	0.326	*0.015******	0.325	*0.015******
Log age	8.481	*0.308******	8.407	*0.310******	8.475	*0.313******
Log age squared	−1.136	*0.041******	−1.126	*0.026******	−1.135	*0.042******
Cardiovascular disease (CVD)			−0.072	*0.035****	−1.210	*0.788*
CVD × log age					0.272	*0.188*
R^2	0.199		0.200		0.200	
N	6382		6382		6382	

Standard errors in italics; *, ** and *** implies significance at the 10, 5 and 1% levels, respectively. In column three of panels A and B the CVD parameters are jointly significant. In panel A the F test equals 2.614 (p value is 0.073). In panel B the F test equals 3.144 (p value is 0.043).

of welfare is directly influenced by health. The second effect arises because health affects welfare indirectly through the capacity to earn income. In the empirical implementation of the model we account for this by estimating the effects of having a cardiovascular disease on experienced welfare and on family income.

Table 2 reports these estimates. The structure of Table 2 is as follows. In panel A we regress welfare, measured by the welfare parameter μ

defined in (11), on individual characteristics. In panel B we do a similar exercise but replace the dependent variable by family income. In the first column we start with baseline equations without the health variable. In the second column health enters the equation as a CVD indicator. In the third column we add an interacted CVD $\times$ age effect and allow for age to be a mitigating health factor.

With conventional controls, the first column in panel A in Table 2 reports income, family size, schooling and age effects. The income effect indicates that preferences drift with changes in family income. With increases in family income, there are welfare leakages because part of the additional income increases aspirations as well. A preference drift of 50% and a family size elasticity of 7% are fully in line with the results commonly found. We find that the effect of education is positive and significant. With schooling more income is needed to attain a given welfare level; it is as if schooling raises household needs. The age variables account for life cycle effects. In the beginning of life there is the need to accumulate wealth in order to provide for anticipated expenditures at a later age. We find maximum needs at the age of about 48 years old. We also find that gender matters with respect to welfare evaluations, but that its effect in size is relatively small. In the second column the CVD parameter shows up positively. This correspond with our idea that having a cardiovascular disease creates a fall in experienced welfare. Its effect is statistically significant at the 10% level. We think that this is a cell size effect. Only 154 individuals report that they have experienced a CVD. In the third column the interaction effect is negative which indicates that the welfare loss caused by a CVD is substantially larger for younger patients. This finding is consistent with the idea that a CVD at a younger age is much more of an impediment to a normal life than at an older age. At the end of the life cycle, around the age of 80, we find that welfare losses due to a CVD become negligible. The impact of CVD and its interaction are jointly significant at the 10% level.

In panel B we consider health effects on log family income. In the column we start with our baseline family income equation and find conventional results. We find a significant gender effect. The education elasticity turns out to be close to 35%. Age effects follow the standard experience profile; maximum income is found at the age of 42 years old. In the second column the estimated CVD parameter is negative. Individuals who experienced a cardiovascular disease earn about 7% less. In the third column we allow for age-dependent health effects and find that the impact of having a cardiovascular disease is strongest when people are young. At the age of 85, which corresponds closely to observed life expectancies, the CVD impact on family income has disappeared. The two CVD-related parameters are jointly significant at a 5% level.

We are aware that unobservables may play an important role when estimating the effect of a cardiovascular disease on income and welfare. This has led to a literature on estimating the effect of health with instrumental variables. We do not address this issue in the present paper due to lack of credible instruments.

Calculating equivalent income variation of a cardiovascular disease

We calculate the monetary equivalent of a welfare change caused by a cardiovascular disease by means of the equivalent income variation. This is the amount of money we can take away from a healthy individual to make him or her as worse off as he or she is just after having experienced a cardiovascular disease. This amount consists of two parts. The first part is the amount to compensate for the experienced welfare loss because health deteriorates from h_0 (healthy) to h_1 (unhealthy). The second part is the amount to compensate for the shortened life expectancy. With an empirical representation of welfare function, presented in the previous section, we are able to calculate this first part of the EIV.

Equivalent variations to compensate for losses in welfare

How does a cardiovascular disease affect welfare? With help of our results of Table 2 we are able to shed light on this question. Within the Leyden welfare methodology welfare effects are usually expressed in terms of equivalence scales [8,9,13,15,17]. In this section, we will express the effects of a CVD on welfare in terms of equivalence scales.

Let us assume that income y only depends on health h, and that the welfare parameter μ only depends on income y and health h, and that we can write down the following expressions:

$$\ln y = \alpha_0 + \alpha_1 h \tag{12}$$

and

$$\mu = \beta_0 + \beta_1 h + \beta_2 \ln y \tag{13}$$

If z is the equivalence scale, it is easy to see that two individuals with different health conditions h_0 and h_1 enjoy equal welfare if, and only if,

$$U(y(h_0)) = U(zy(h_1)) \tag{14}$$

Translated into equivalence in terms of Leyden welfare, this means

$$\ln y(h_0) - \mu(y(h_0)) = \ln zy(h_1) - \mu(zy(h_1)) \tag{15}$$

where σ is assumed constant. Keeping everything else constant, substitution of previous equations (12) and (13) in (15) yields

$$(1 - \beta_2)\alpha_1 h_0 - \beta_1 h_0 = (1 - \beta_2)\ln z + (1 - \beta_2)\alpha_1 h_1 - \beta_1 h_1 \tag{16}$$

which gives us the solution

$$\ln z = -\alpha_1(h_1 - h_0) + \frac{\beta_1}{1 - \beta_2}(h_1 - h_0) \tag{17}$$

The first term represents the indirect impact on welfare through income and reflects the fact an individual with a CVD earns on average α_1 less. It is the labour market's punishment to an individual's welfare that needs to be compensated. The second term represents the direct impact on welfare, and reflects the fact that it is more difficult to enjoy income when you are a diagnosed CVD patient. The parameter $\beta_1/(1 - \beta_2)$ measures how much additional income is needed to compensate an individual for having a CVD.

Table 3 presents both welfare effects associated with the net earnings and welfare estimates given in the final column of Table 2. The first column shows that a 25 year old individual with a CVD would need about 43% more income to maintain his or her level of welfare. The second column shows that the labour market rewards those who are healthy and punishes those who are sick. For a 25 year old individual we find that a CVD creates a 40% reduction in income. If we combine direct and indirect welfare effects, we find that a CVD at age 25 requires income to increase with a 100% to maintain his or her welfare level. With $h_1 = 1$ and $h_0 = 0$ defining a 25 year old individual with and without a CVD, these equivalence scales are outcomes of the following calculations:

Table 3. CVD equivalence scales for different age groups

	Direct	Indirect	Total
25 years	1.43	1.39	2.00
35 years	1.29	1.27	1.64
45 years	1.19	1.19	1.42
55 years	1.12	1.12	1.26
65 years	1.06	1.07	1.14
75 years	1.02	1.03	1.05

$$\alpha_1 = -1.21 + 0.27\ln(25) = -0.33 \rightarrow \exp(-\alpha_1) = 1.39$$

$$\beta_1 = 0.68 - 0.15\ln(25) = 0.18 \rightarrow \exp(\beta_1/(1 - \beta_2)) = 1.43$$

The same table shows that for each age category individuals with a CVD need more income than healthier individuals. They need to be compensated because a CVD makes them less satisfied with their income for any given income level, but also because a CVD makes them earn less. We also observe that these compensations vary with age and fall with rising age. At the end of the life cycle at the age of 75 these compensations are small but still positive. At age 80 all effects turn out to be negligible.

Equivalence scales identify these compensations in relative terms y_1/y_0. To get an idea of the magnitude in absolute terms, we report the corresponding equivalent income variations per year in Table 4. These amounts $y_1 - y_0$ are calculated for three welfare levels insufficient, sufficient and good. For our reference individual, we take an unhealthy individual with a higher vocational education, registered as being married with no kids. The monetary amounts in Table 4 represent the annual EIV amounts to compensate people for their welfare losses created by having a CVD. The effects we find in Table 4 correspond closely to the effects we observed in Table 3. The first entry of €12 370 stands for the annual amount that can be taken away from a healthy individual to leave him equally worse off as a 25 year old, higher educated, married, and childless man with a CVD who experiences a life of insufficient quality. Note that a life of insufficient quality refers to the level of income satisfaction and not to quality of

Table 4. Equivalent variation to compensate for annual welfare losses due to a CVD for different age, gender and welfare groups

	Males			Females		
	u_1	u_2	u_3	u_1	u_2	u_3
25 years	12 370	17 504	25 667	12 030	17 023	24 962
35 years	8024	11 355	16 650	7804	11 043	16 193
45 years	4972	7035	10 316	4835	6842	10 033
55 years	2886	4083	5988	2806	3971	5823
65 years	1462	2068	3033	1421	2011	2950
75 years	486	687	1008	472	668	980

Equivalent variations are annual amounts and calculated in Euros (€). The three welfare levels correspond to the labels 'insufficient,' 'sufficient' and 'good.'

life as a whole. This latter approach is recently taken up [25,26]. We further see that the equivalent variations for 25 year old patients range from €12 000 up to €25 000, increase with the welfare level, decrease with age, and are somewhat smaller for women.

Equivalent variations to compensate for losses in life expectancy

A diagnosed CVD patient also experiences a loss in lifetime utility because of a lower life expectancy. To calculate the monetary equivalent of this particular utility loss, we require information on the patient's remaining years to live, and the number of years by which his or her life is shortened. In our model m and n correspond to these values. Since our sample does not provide information on m and n, we rely on Dutch health statistics to find suitable values for the remaining life years.

The life expectancies $(m+n)$ we take from [27] and the falling life expectancies (n) we take from [28]. Corresponding values are reported in Table 5. Life expectancies are age dependent and increase when people get older. The expected gains in life years by complete elimination of the health risk because of a CVD fall with rising age. The dependency on age is much smaller for women than for men. We find that the reduction in life expectancy because of a CVD is 13.29 years for a 25 year old male. For an equally old women this amounts to 11.62 years.

We obtain the monetary equivalence to compensate for reduced life expectancy in three steps. First, we find expressions for lifetime utility. With annual utility that is assumed cardinal and additive over years, we add the annual welfare levels up from age a onwards and stop when we reach age m and $m+n$. For any given welfare level u, these lifetime utilities (U_1 and U_0 in (3) and (4)) amount to $(m-a)u$ and $(m+n-a)u$. Second, we obtain equality in lifetime utility. With individuals with $m-a$ remaining years to live as a reference, we equate lifetime utility by lowering all annual welfare levels with a factor $(m-a)/(m+n-a)$ for those individuals who live n years longer. Third, we calculate the annual monetary amounts that correspond to the different welfare levels u and $u(m-a)/(m+n-a)$, and add these amounts up from age a onwards and stop when we reach age $m+n$. Like we do in Equation (6), we interpret the difference between these income flows as equivalent income variations to compensate unhealthy individuals for their reduced life expectancy.

In Table 6 we report these differences. We find that the equivalent variations are much higher than the amounts reported in Table 5. We further see that the EIVs increase with welfare level, decrease with age, and are smaller for women.

Equivalent variations to compensate for cardiovascular diseases

Now that we have all the ingredients we can calculate the equivalent income variations for having a cardiovascular disease. The amounts to compensate for the welfare loss induced by having a CVD are tabulated in Table 5. The amounts to

Table 5. Descriptive statistics on life expectancies for different age and gender groups

	Males			Females		
	$m+n$	n	$(m-a)/(m+n-a)$	$m+n$	n	$(m-a)/(m+n-a)$
25 years	75.15	13.29	0.73	80.80	11.62	0.79
35 years	75.65	13.22	0.67	81.05	11.56	0.74
45 years	76.30	12.93	0.59	81.55	11.45	0.68
55 years	77.40	12.12	0.46	82.35	11.15	0.59
65 years	79.75	10.57	0.28	83.90	10.50	0.44
75 years	83.90	8.31	0.07	86.70	9.02	0.23

Life expectancies in absence of a CVD are denoted by $m+n$. Absolute and relative losses in life expectancies because of a CVD are denoted by n and $m-a/m+n-a$, where a stands for age. These numbers come from CBS (1995).

Table 6. Equivalent variation to compensate for life expectancy losses due to a CVD for different age, gender and welfare groups

	Males			Females		
	u_1	u_2	u_3	u_1	u_2	u_3
25 years	101 923	183 370	355 143	91 901	167 776	332 597
35 years	101 584	179 630	338 928	91 610	164 770	318 985
45 years	99 104	170 295	308 553	82 573	146 871	279 546
55 years	88 396	147 066	255 485	79 538	137 114	249 526
65 years	78 155	124 296	204 700	69 224	115 716	202 226
75 years	56 355	86 127	135 879	59 686	94 545	155 008

Equivalent variations are annual amounts and calculated in Euros (€). The three welfare levels correspond to the labels 'insufficient,' 'sufficient' and 'good.'

compensate for the loss in additional years to live due to a CVD are tabulated in Table 6. Together they form the equivalent income variations for diagnosed CVD patients in different age groups and at different welfare levels. In Table 7 we operationalize these EIVs.

The first entry shows that the monetary equivalent for a healthy male aged 25 is about €114 000 to be as equally worse off as a diagnosed 25 year old male CVD patient who is living a life of insufficient quality. To reach higher welfare levels, the same individual has to be compensated more in order to avoid a CVD. Compared to insufficient, the equivalent variation increases to almost €380 000 to maintain a welfare level that is good. When he is 65 years old, the hazards and troubles of a CVD require smaller compensating amounts varying between €80 000 and €210 000. We find in general that all EIVs fall with age, and that the EIV amounts for female patients are almost always lower than the amounts for equivalent male patients. This makes sense given the argument that women almost always face smaller losses in their life expectancy when diagnosed as a CVD patient. When we translate these EIV numbers into compensating values for each additional year lost, we find that the annual EIV amounts continuously fall with rising age, but this time the gender gap has disappeared. The estimated amounts vary between about €7000 and €30 000.

These final EIV estimates are relevant for cost-benefit analysis of medical interventions, particularly for heart-related interventions. QALYs measure the amount of healthy years gained by a medical intervention and, when combined with the costs of such an intervention, can be used to calculate how much money has to be spent on a medical intervention per QALY. These amounts can be used to rank medical interventions by their effectiveness. Although this procedure allows us to determine which intervention provides more value for money, it does not provide information on which intervention should be funded and which interventions are no longer cost effective. To determine which kind of interventions is efficient, we need information on how much an intervention is worth to the patient him or herself.

Table 7. Equivalent variations to compensate diagnosed CVD patients for different age, gender and welfare groups

	Males			Females		
	u_1	u_2	u_3	u_1	u_2	u_3
	Total compensations					
25 years	114 293	200 874	380 810	103 931	184 799	357 559
35 years	109 609	190 985	355 579	99 414	175 813	335 178
45 years	104 075	177 330	318 869	87 408	153 713	289 579
55 years	91 282	151 149	261 473	82 344	141 085	255 349
65 years	79 617	126 365	207 733	70 646	117 728	205 176
75 years	56 841	86 814	136 886	60 158	95 213	155 988
	Compensations per year lost					
25 years	8792	15 452	29 293	8661	15 400	29 797
35 years	8431	14 691	27 352	8284	14 651	27 931
45 years	8006	13 641	24 528	7946	13 974	26 325
55 years	7607	12 596	21 789	7486	12 826	23 214
65 years	7238	11 488	18 885	7065	11 773	20 518
75 years	7105	10 852	17 111	6684	10 579	17 332

Equivalent variations are annual amounts and calculated in Euros (€). The three welfare levels correspond to the labels 'insufficient,' 'sufficient' and 'good.'

Around 1995 – when collection of the SPS data started – heart transplantations in the Netherlands cost on average €32 000 but vary from €26 000 to €42 000 per quality adjusted life years [29]. Dutch estimates for the costs for open heart surgery vary from €10 000 to €30 000 for each additional healthy year lived while estimates for bypass treatments range from €2500 to €20 000 [30]. If we consider the welfare levels sufficient and higher, the confrontation between our treatment calculations and the cost effectiveness seems to justify most bypass and open heart surgery treatments. Heart transplants seem to be too costly and only efficient if patients are young. For definite answers; however, more research with more detailed information on the type of cardiovascular diseases is necessary.

Sensitivity analysis

We should be careful when interpreting these results. The estimates we presented are based on a number of assumptions. Changing these assumptions will directly affect our estimates. We consider two potential limitations of our approach and test how sensitive our EIV estimates are if we use alternative and maybe more realistic assumptions. First, we assumed that individuals did not discount their future life and estimated our variations in absence of positive time discounting. If we would allow for personal discounting we end up with lower compensations because the importance of the future for today's lifetime utility has decreased. Second, we hypothesized that patients who suffered from a cardiovascular disease fully recovered the year after the incident and faced shortened life expectancies. But if we would accept that diagnosed people face higher probabilities of being diagnosed again, we end up with higher compensations because consecutive CVD events would lead to higher losses in welfare that need to be compensated as well. In Table 8 we operationalize the EIVs and do a sensitivity analysis regarding these two limitations.

In Table 8 we calculate the EIVs for three different personal discount rates set at 0, 5, and 25%. These discount rates are taken from Warner and Pleeter [31] who estimate personal discount rates that range from 0 to 30%. The first three columns represent the EIVs for patients who do not discount their future life which means that we end up with the amounts expressed earlier in Table 7. The columns four to six represent the EIVs for patients with discount rates of 5% and columns seven to nine represent the EIVs for patients with discount rates of 25%. We find that, with recovery periods of one year, the estimated amounts fall with increasing discount rates. We also find that especially for young patients the

Table 8. Sensitivity analysis

Males	No discounting			Discounting at 5%			Discounting at 25%		
	u_1	u_2	u_3	u_1	u_2	u_3	u_1	u_2	u_3
	Recovery within 1 year								
25 years	8792	15 452	29 293	3453	6140	12 333	952	1348	1978
35 years	8431	14 691	27 352	4019	7263	14 582	626	890	1319
45 years	8006	13 641	24 528	4962	8824	16 972	493	761	1299
55 years	7607	12 596	21 789	5848	10 008	18 096	1061	1929	3999
65 years	7238	11 488	18 885	6477	10 469	17 576	3259	5733	10 783
75 years	7105	10 852	17 111	6861	10 549	16 751	5698	9059	14 918
	Recovery within 2 years								
25 years	9705	16 744	31 188	4326	7356	14 059	1678	2302	3215
35 years	9021	15 526	28 576	4583	8048	15 696	1094	1506	2118
45 years	8369	14 155	25 283	5309	9308	17 659	782	1140	1791
55 years	7833	12 916	22 259	6064	10 309	18 524	1241	2165	4305
65 years	7360	11 661	19 139	6594	10 632	17 807	3357	5860	10 948
75 years	7156	10 924	17 216	6909	10 617	16 847	5739	9112	14 987
	No recovery								
25 years	26 314	40 246	65 651	14 491	20 255	30 179	5420	6676	8205
35 years	18 402	28 800	48 041	10 594	15 715	25 332	3406	4214	5214
45 years	13 168	20 946	35 240	8570	13 499	22 970	2118	2711	3592
55 years	10 101	16 125	26 965	7718	12 457	21 281	1982	3042	5317
65 years	8159	12 790	20 795	7223	11 460	18 890	3675	6241	11 392
75 years	7264	11 077	17 441	7005	10 747	17 023	5800	9188	15 078
Females									
	Recovery within 1 year								
25 years	8661	15 400	29 797	2910	5117	10 253	1 003	1419	2081
35 years	8284	14 651	27 931	3369	6110	12 483	652	924	1357
45 years	7946	13 974	26 325	3956	7223	14 637	454	651	980
55 years	7486	12 826	23 214	4895	8726	16 785	444	733	1382
65 years	7065	11 773	20 518	5582	9583	17 376	1176	2188	4615
75 years	6684	10 579	17 332	6145	9864	16 424	3723	6409	11 656
	Recovery within 2 years								
25 years	9623	16 762	31 793	3831	6398	12 071	1768	2424	3384
35 years	8906	15 530	29 220	3963	6937	13 657	1146	1573	2199
45 years	8364	14 565	27 192	4356	7779	15 426	786	1088	1546
55 years	7726	13 166	23 712	5125	9046	17 239	635	984	1707
65 years	7196	11 958	20 789	5708	9757	17 623	1280	2325	4793
75 years	6728	10 641	17 423	6187	9923	16 507	3758	6455	11716
	No recovery								
25 years	27 267	41 728	68 403	14 577	20 029	29 100	5712	7035	8645
35 years	18 895	29 665	49 948	10 327	15 051	23 850	3584	4429	5464
45 years	13 999	22 539	38 886	8148	12 648	21 590	2327	2899	3622
55 years	10 216	16 689	28 878	6918	11 372	20 218	1428	1921	2788
65 years	8058	13 179	22 580	6386	10 651	18 790	1622	2734	5269
75 years	6762	10 689	17 494	6229	9984	16 596	3797	6505	11 777

Equivalent variations are annual amounts and calculated in Euros (€). The three welfare levels correspond to the labels 'insufficient,' 'sufficient' and 'good.'

introduction of discounting has an impact on the EIVs. At the age of 25, patients are not so much concerned about whether they die 40 or 50 years from now. Therefore, the corresponding EIVs are very low and range from €1000 to €12 000. On the basis of these results, we would conclude that heart transplants can no longer be justified, but that bypass treatments and open heart surgery for older patients could still be beneficial in terms of efficiency.

In Table 8, we also calculate the EIVs for alternative CVD histories and experiment with patients who recover completely in 1 year, in 2 years and with patients who do not recover at all. As expected, we find that the estimated amounts increase with increasing recovery periods. Hence, most bypass and open heart surgery treatments are still possible, but that heart transplants seem only efficient when patients are young.

Conclusion

Cost-effectiveness and cost-utility estimates play an increasingly important role in decisions about the adoption of new medical technology. Limitations on financial resources and the increasing costs of new medical technologies force governments and health care insurance companies to make more 'rational' decisions about which treatments are reimbursed and which are not. The rising costs of health care raises the question whether we are spending too much on health care. In order to answer this question we need to know how much value individuals put on their health. This paper contributes to answering this question by introducing a new method to calculate the equivalent variation belonging to the elimination of the health impairments associated with heart diseases: the Leyden income evaluation approach.

It is found that for a 25 year old male the compensating variation of a heart disease ranges from €114 000–€380 000 depending on the welfare level. This is about €10 000–€30 000 for an additional life year, again depending on the quality of life. The equivalent variation declines with age. The estimates further vary by the discount rate chosen. The estimates of the compensating variation are generally higher than the money spend on most heart-related medical interventions per QALY. Compared to the money spend on medical interventions per QALY the estimated benefits of the elimination of heart problems seem to justify these medical treatments.

The Leyden income evaluation method avoids some of the drawbacks and pitfalls of other methods. It also has the advantage that it can be applied at low costs to many different situations. In particular we think that a fruitful topic for further research would be to calculate the WFI before and after a medical intervention in order to determine the monetary value of the gain in welfare because of medical treatment.

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References

1. Dolan P. The measurement of health-related quality of life for use in resource allocation decisions in health care. In *Handbook of Health Economics*, Culyer A, Newhouse J (eds). Elsevier: Amsterdam, 2000; 1723–1760.
2. Mishan E. *Cost-Benefit Analysis: an Informal Introduction*. Unwin Heyman: London, 1998.
3. Kenkel D. On valuing morbidity, cost-effectiveness analysis, and being rude. *J Health Econ* 1997; **16**: 749–757.
4. Labelle R, Hurley J. Implications of basing health-care resource allocations on cost-utility analysis in the presence of externalities. *J Health Econ* 1992; **11**: 259–277.
5. Kip-Viscusi W. The value of risks to life and health. *J Econ Lit* 1993; **31**: 1912–1946.
6. Kip-Viscusi W. *Rational Risk Policy*. Oxford Economic Press: Oxford, 1997.
7. Diener A, O'Brien B, Gafni A. Health care contingent valuation studies: a review and classification of the literature. *Health Econ* 1998; **7**: 313–326.
8. Van Praag BMS. The welfare function of income in Belgium: an empirical investigation. *Eur Econ Rev* 1971; **2**: 337–369.
9. Van Praag BMS, Kapteyn A. Further evidence on the individual welfare function of income: an empirical study in the Netherlands. *Eur Econ Rev* 1973; **4**: 33–62.

10. Van Praag BMS, Goedhart Th, Kapteyn A. The poverty line: a pilot survey in Europe. *Rev Econ Stat* 1980; **62**: 461–465.
11. Hagenaars AJM, Van Praag BMS. A synthesis of poverty line definitions. *Rev Income Wealth* 1985; **31**: 139–153.
12. Van de Stadt H, Kapteyn A, Van de Geer S. The relativity of utility: evidence from panel data. *Rev Econ Stat* 1985; **67**: 179–187.
13. Van Praag BMS. Climate equivalence scales: an application of a general method. *Eur Econ Rev* 1988; **32**: 1019–1024.
14. Van Praag BMS. Ordinal and cardinal utility: an integration of the two dimensions of the welfare concept. *J Econometrics* 1991; **50**: 69–89.
15. Plug EJS, Van Praag BMS. Family equivalence scales within a narrow and broad welfare context. *J Income Distribution* 1995; **4**: 171–186.
16. Plug EJS, Van Praag BMS. Similarity in response behavior between household members: an application to income evaluation. *J Econ Psychol* 1998; **19**: 497–513.
17. Plug EJS, Van Praag BMS, Hartog J. If we knew ability, how would we tax individuals? *J Publ Econ* 1999; **72**: 183–211.
18. Reitsma JB, Dalstra JAA, Bonsel GJ, Van der Meulen JHP, Koster RW, Gunning-Schepers LJ, Tijssen JGP. Cardiovascular disease in the Netherlands, 1975 to 1995: decline in mortality, but increasing numbers of patients with chronic conditions. *Heart* 1999; **82**: 52–56.
19. O'Brien B, Gafni A. When do the 'dollars' make sense? Toward a conceptual framework for contingent valuation studies in health care. *Med Decis Making* 1996; **16**: 288–299.
20. Buyze J. The estimation of welfare levels of a cardinal utility function. *Eur Econ Rev* 1982; **17**: 325–332.
21. Parducci A. *Happiness, Pleasure and Judgment*. Lawrence Erblaum Associates Publishers: New Jersey, 1995.
22. Van Praag BMS. *Individual Welfare Functions and Consumer Behavior*. North-Holland: Amsterdam, 1968.
23. Van Herwaarden FG, Kapteyn A. Empirical comparison of the shape of welfare functions. *Eur Econ Rev* 1981; **15**: 261–286.
24. Hagenaars AJM. *The Perception of Poverty*. North-Holland: Amsterdam, 1986.
25. Ferrer-i-Carbonell A, Van Praag BMS. The subjective costs of health losses due to chronic diseases. An alternative model for monetary appraisal. *Health Econ* 2002; **11**: 709–722.
26. Groot W, Maassen van den Brink H. A direct method for estimating the compensating income variation for severe headache and migraine. *Soc Sci Med* 2004; **58**: 305–314.
27. CBS. *Vijfennegentig jaren statistiek in tijdreeksen 1899–1994*. (Historical series of the Netherlands 1899–1994). SDU: The Hague, 1995.
28. Van Ginneken JKS, Bannenberg AFI, Dissevelt AG. *Gezondheidsverlies ten gevolge van een aantal belangrijke ziektecategorieen in 1981–1985*. (Loss in health due to a number of important illnesses). Dutch Central Bureau of Statistics: Voorburg, 1989.
29. Van Hout B, Bonsel G, Habbema D, Van der Maas P, De Charro F. Heart transplantation in the Netherlands; Costs, effects and scenarios. *J Health Econ* 1993; **12**: 73–93.
30. Adang E. *Medical technology assessment in surgery*. PhD thesis, University of Maastricht, 1998.
31. Warner JT, Pleeter S. The personal discount rate: evidence from military downsizing programs. *Amer Econ Rev* 2001; **91**: 33–53.