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What can empirical utility functions tell us about the value of a statistical life?

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ABSTRACT

This paper explores how utility functions for income and health state can be applied in order to develop closed-form estimates of the value of a statistical life based on an assumption of utility maximisation. For utility functions fitted to the results of studies of life satisfaction in Norway, most estimates of the value of a statistical life are quite low, in the range of 2–30 million NOK. These estimates refer to reducing the risk of a traffic fatality, which currently is about 20 per 1 million inhabitants in Norway. These estimates are lower than nearly all estimates developed in a road safety valuation study made in 2010. By combining utility functions for health impairments and utility functions for income, it is possible to estimate the monetary compensation for a health impairment needed to restore the initial level of utility. These estimates can be extrapolated to obtain estimates of the value of a statistical life.

1. Introduction

Research on the monetary value of human life and limb has a history of almost 100 years, taking the book: "The money value of a man" by Dublin and Lotka (1930) as the starting point. In the period from about 1950 to 1970, studies estimating the cost of road accidents were published in many highly motorised countries, see e.g. Reynolds (1956). These studies were all based on the human capital method. According to this method, the value of a human life is estimated as the present value of lost earnings, i.e. the discounted value of future income from the time of death until retirement.

Around 1970, prominent economists criticised the human capital method as being inconsistent with the basic principles of cost-benefit analysis, more specifically that it did not reflect individual preferences as expressed in terms of willingness to pay for reduction in the risk of death. The argument for basing the valuation of human life on the willingness-to-pay for changes in risk of death was made forcefully by Schelling (1968) and Mishan (1971). However, both of them pointed out that it would be difficult to obtain precise estimates of willingness-to-pay for changes in mortality risk. Thus, Schelling (1968) noted:

> "At the outset, we can conjecture that any estimate based on market evidence will at best let us know to within a factor of 2 or 3 (perhaps only 5 or 10) what the reflective individual would decide after thoughtful, intensive inquiry and good professional advice."

Mishan (1971) did not quantify the likely range of empirical estimates, but noted:

> "One may be forgiven for asserting that there is more to be said for rough estimates of the precise concept than precise estimates of economically irrelevant concepts."

By now, hundreds of valuation studies based on willingness-to-pay have been conducted. Many of these studies have produced several estimates of the value to society of reducing the risk of accidental fatality by an amount corresponding to the prevention of one fatality; a change in risk usually referred to as the value of a statistical life (i.e. the value of a change in risk which is statistically equal to reducing the expected number of fatalities by one). As an example, Veisten (2016) extracted 66 estimates of the value of a statistical life based on a Norwegian valuation study (Veisten et al., 2010). Fig. 1 shows these estimates.

The highest estimate was 362.7 million NOK (1 NOK = 0.088 US Dollars in December 2024), the lowest was 15.8 million NOK. This is a range of almost 23, exceeding the uppermost range of estimates (10) hinted at by Schelling (1968). The range of estimates between studies is even larger than within studies. In a meta-analysis of 856 estimates of the value of a statistical life by Lindhjem et al. (2011), the highest estimate was 197 million US Dollars, the lowest 4450 US Dollars. This is a

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range of 44,270.

The wide range of estimates of the value of saving a human life makes it difficult to extract a single best estimate for use in cost-benefit analysis (Elvik, 2017). Thus, relying on currently available empirical studies of willingness-to-pay for a reduced risk of death provides, at best, a highly imprecise guidance for cost-benefit analysis of safety measures. However, it has been known at least since the 1960s that there is a closed-form solution to the problem of finding a monetary value of saving a life or preventing an injury. The closed-form solution has been presented and discussed by, for example, Fromm (1968), Jones-Lee (1976), Bellavance et al. (2009) and Andersson and Treich (2011), chap. 17. To apply it, all one needs to do is specify a utility function for income or wealth. Once the utility function is known, the rest is a matter of simple calculation. The main question asked in this paper is what empirical utility functions tell us about the value of a statistical life. The next section briefly explains what the value of a statistical life means. The following sections present the closed-form solution to the value of a statistical life, discuss the use of empirical utility functions and the controversy regarding the use of such functions. Following that the divergence between ex ante and ex post valuations of changes in the risk of permanent impairment is discussed. The question is raised whether ex post valuations of impairments whose health-state utility is known can be applied to the valuation of life, not just different health states. It is argued that this is in principle possible.

2. The value of a statistical life

Monetary valuation of life and limb refers to the valuation of changes in the risk of dying or of sustaining an injury. Most valuation studies state the risk of dying as a population mean fatality rate for a specific cause of death, for example that the current mortality rate in road accidents in Norway is close to 20 per 1,000,000 inhabitants per year.

This is the current population average for Norway. Risk varies in the population, by gender, by age groups, by place of residence and according to how much one travels by road. The good being valued in a valuation study is a change in risk, for example a reduction of fatality rate by 2 in 100,000. If this reduction is valued at 500 NOK, the value of a statistical life is estimated as follows:

$$\text{Value of a statistical life (VSL)} = \frac{500}{\left(\frac{2}{100000}\right)} = 25,000,000 \text{ NOK}$$

The value of a statistical life is the value of a risk reduction which statistically corresponds to reduction of the number of fatalities by one. The value of a statistical injury of a given severity is defined analogously.

3. The closed-form estimate of the value of a statistical life

The starting point for developing the closed-form estimate of the value of a statistical life is that expected utility is:

$$\text{Expected utility} = \text{EU(w)} = (1-\text{p})\text{U}_\text{a}(\text{w}) + \text{pU}_\text{d}(\text{w}) \tag{1}$$

Here, p denotes the probability of dying, w is wealth (or income; for the moment the two are treated as interchangeable), subscript a denotes that the individual is alive and subscript d denotes that the individual is dead. It is normally assumed that the individual prefers life to death; hence utility from wealth will be greater when alive than when dead:

$$U_a(w) > U_d(w) \tag{2}$$

Wealth can be assumed to be the same both when alive and when dead, provided the individual can buy insurance that covers all financial losses. It is usually assumed that the marginal utility of wealth is greater when alive than when dead:

$$U_a'(w) \geq U_d'(w) > 0 \tag{3}$$

Here the prime (′) denotes the first derivative. Another property of utility functions commonly assumed in economic theory is risk aversion. Risk aversion means that marginal utility is strictly decreasing both in case of life and in case of death:

$$U_a''(w), U_d''(w) < 0 \tag{4}$$

The double prime (″) denotes the second derivative. A utility function for which the first derivative is positive, and the second derivative is negative, is strictly increasing and concave. In the following, it is assumed that w is the same in life and death. This need not be the case if an individual has life insurance for a different amount than w.

The optimal amount to pay for a reduced risk of death is the amount x

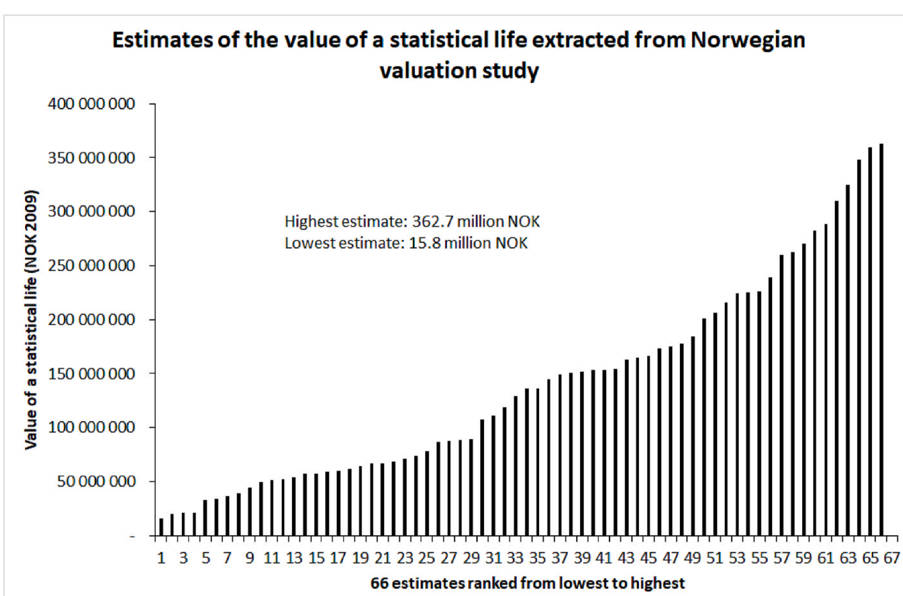

Fig. 1. 66 estimates of the value of a statistical life extracted from Norwegian valuation study (Veisten et al., 2010).

an individual would give up in order to reduce p to p* while keeping expected utility constant. This is the amount x that satisfies the following equality:

$$EU(w) = (1 - p)U_a(w) + pU_d(w) = (1 - p^*)U_a(, w - x) + p^*U_d(w - x) \quad (5)$$

If x is paid, the loss of utility of income resulting from the fact that it is reduced by x is exactly offset by the gain in expected utility from the fact that p is reduced to p*. The optimal amount to pay for a reduction in risk is the marginal rate of substitution between wealth (income) and risk of death. This marginal rate of substitution, which is identical to the value of a statistical life, is found by finding the derivative of the left side of equation (5) (i.e. expected utility in the initial situation) with respect to both w and p, while holding expected utility constant. This yields (Bellavance et al., 2009, p. 446):

$$VSL = \text{marginal rate of substitution} = \frac{dw}{dp} = \frac{U_a(w) - U_d(w)}{(1 - p)U_a'(w) + pU_d'(w)} \quad (6)$$

The numerator represents the difference in the utility of wealth between life and death. If the utility of wealth in death is zero, the numerator becomes identical to the utility of wealth in life. The denominator represents the marginal expected utility of wealth. The prime denotes the first derivative.

The closed-form expression in equation (6) assumes that the individual maximises expected utility. A change in both wealth and the probability of death will therefore only be attractive if it maintains the utility maximum. This condition is fulfilled when the loss of income incurred in paying for a reduction of risk is exactly offset by the gain in expected utility attributable to the fact that death becomes a less likely outcome.

4. Empirical utility functions

The term “empirical utility functions” is used in this paper to refer to any mathematical function fitted to data showing the relationship between income and some indicator of happiness, life-satisfaction or subjective well-being. A large number of such functions can be found in the literature but interpreting them as utility functions is controversial. For the moment, this controversy is ignored. It will be discussed in section 6 of the paper. Suffice it to note that Layard et al. (2008) analysed a sample of such functions in order to determine the marginal utility of income.

Some countries have a long tradition of conducting polls in which a representative sample of the population are asked about how happy they are, all things considered. As an example, the General Social Survey in the United States, contains the question: All things considered, how happy would you say you are these days? Answers can be given as “not too happy” (score 1), “pretty happy” (score 2) and “very happy” (score 3). Fig. 2 shows a function fitted to the results of the survey conducted in 1994–1996 (Frey & Stutzer, 2002).

The term equivalence income is household income divided by the square root of the number of people belonging to a household (an arbitrary rule for adjusting for household size). A logarithmic function describes the relationship very well. A power function also fitted the data very well. Sample size was 5171. The sample was representative of the adult population of the United States. The uncertainty of each data point in Fig. 2 is not known.

In Norway, Hellevik (2008) conducted a survey of happiness. Hellevik scored happiness by taking the difference between the percentage who reported they were very happy and the percentage who reported they were not so happy. This indicator can vary between −100 and + 100. In the data he presented, values between −9 and +36 were reported. To make all values positive, 100 were added them, producing a range from 91 to 136. When these values are plotted against household income, Fig. 3 emerges. Household income was stated as intervals and the midpoint of each interval was used, except the uppermost interval, which was set equal to 1,200,000. The Figure is based on samples studied in 2003–2005 as part of the “Norsk Monitor” continuous survey. Sample size was between 2000 and 4000. The samples were representative of the Norwegian population aged 15 years or above. The uncertainty of each data point in Fig. 3 is not known.

A quadratic function (second degree polynomial) fits the data very well. According to Arrow (1965) fitting utility functions to data by means of second-degree polynomials is very common in economics. He argued against this practice. While the polynomial may be well-behaved in the range of the data it has been fitted to, as the one in Fig. 3, extrapolating a second-degree polynomial will almost always lead to nonsensical results. At some point, the quadratic term becomes dominant, and marginal utility becomes negative.

Since 2020, regular surveys of life satisfaction have been conducted in Norway by Statistics Norway (Støren & Rønning, 2021). A representative sample is asked several questions about their satisfaction with

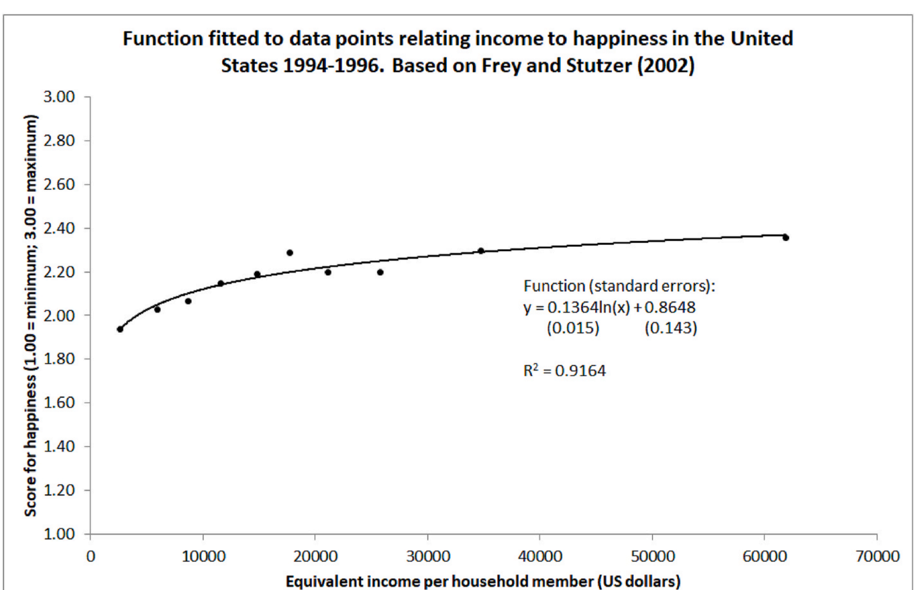

Fig. 2. Function fitted to data points relating happiness to income in the United States 1994–1996

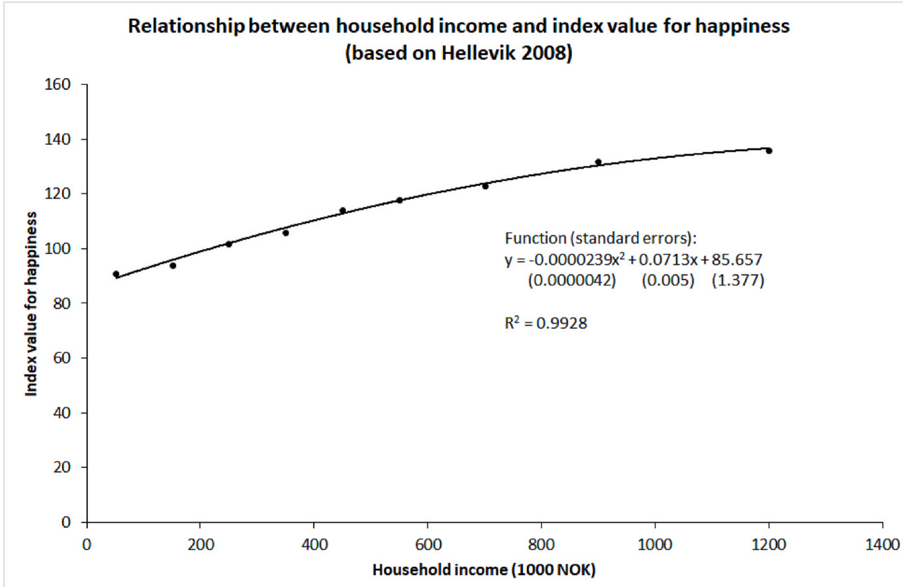

Fig. 3. Relationship between household income and index value for happiness.

different aspects of life, including their overall life-satisfaction. A random sample of 40,000 individuals aged 18 or above is drawn each year. In 2021 the response rate was 44 percent (Støren & Rønning, 2021). A scale spanning from 0 (minimal satisfaction) to 10 (maximum satisfaction) is used. Based on mean values in different income quartiles, as well as the overall mean, Fig. 4 has been developed. The scale was converted to a range from 0 to 1 (i.e. a value of, for example, 6.6 was converted to 0.66). A power function fits the data almost perfectly. Unfortunately, results based on a finer scale for income, e.g. deciles, are not published. The uncertainty of each data point in Fig. 4 is not known.

The functions presented in Figs. 2–4 are all simple bivariate relationships between income and a measure of subjective well-being. Subjective well-being is obviously influenced by many other factors. As an example, Proto and Rustichini (2015) show that the shape of empirical utility functions, like those shown in Figs. 2–4, depend on personality, in particular neuroticism. In an analysis of the Norwegian life satisfaction survey, Støren, Dalen, and Arnesen (2014) show, for example, that the life satisfaction of those with a low income is reduced if, in addition to the low income, they have long-lasting health problems. To account for such interactions, one would need access to the original data underlying the studies presented in Figs. 2–4. This was not feasible. Thus, the functions applied in this paper can be influenced by confounding factors the simple bivariate relationships do not control for. Ideally speaking, a utility function for income should control for all other factors that influence subjective well-being, like age, health state, or employment status. However, utility functions based on health state are discussed later in the paper.

The form of the functions presented in Figs. 2–4 are, respectively, logarithmic, quadratic and power. In the examples shown, these three functional forms all satisfy the two key properties commonly held to characterise a utility function: a positive derivative and a negative second derivative. Hence, the following functions have been defined and estimated for incomes between NOK 200,000 per year and NOK 1,200,000 per year, in steps of 100,000. An annual income of NOK

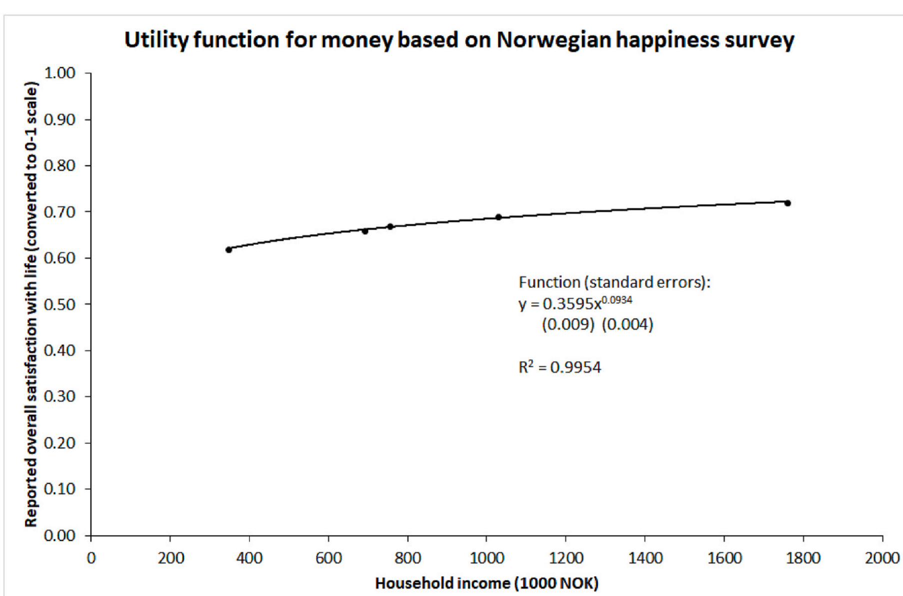

Fig. 4. Utility function for money based on Norwegian happiness survey.

700,000 is close to the current mean income in Norway (income is stated as thousands: 300,000 = 300):

Power function : $0.35 \cdot Income^{0.1}$

Logarithmic function: $0.12 \bullet \ln(Income)$

Quadratic: $(-0.0000001 \bullet Income^2) + (0.0003 \bullet Income) + 0.6$

These functions are plotted in Fig. 5, with utility on a scale ranging from 0 to 1.

The functions increase monotonically throughout their range, but at a gradually slower rate. The power function and the logarithmic function have constant relative risk aversion. The quadratic function has increasing relative risk aversion.

Inserting, for example, 700 into the power function produces a utility value of 0.67387268. This applies assuming certainty. The current risk of a fatal traffic injury in Norway implies that expected utility is:

Expected utility = 0.99998 • 0.67387268 = 0.67285920

The risk of a fatal traffic injury is so small that it only reduces utility by 20 parts in one million. What would a rational utility maximiser be willing to pay to reduce or eliminate this risk?

5. Ex-ante estimates of the value of a statistical life

The answer to the question asked above is given in this section. Table 1 shows estimates of willingness-to-pay (WTP) to reduce the current risk of traffic fatality in Norway by 25 %, 50 % or 100 %. When making these estimates, the utility of income when dead was assumed to be zero. It follows that the terms $U_d(w)$ and $pU'_d(w)$ in equation (6) are zero. It is seen that WTP increases as the risk reduction increases, but only marginally. This lack of sensitivity to the size of the risk reduction is attributable to the fact that even eliminating the risk hardly makes any difference to utility: it has a very low value, so to speak. The amounts estimated reflect this. WTP ranges from a trivial amount like 18 NOK to 272 NOK. The answer to the question about how much a rational utility maximiser ought to pay to reduce the risk of a traffic fatality in Norway is: almost nothing. At most perhaps a couple of hundred NOK.

WTP increases with income. The income elasticity of WTP is 1 for the power function. For the logarithmic function, it is 1.25 when going from an income of 200,000 NOK per year to 300,000 NOK per year and declines to 1.15 when going from an income of 1,100,000 to 1,200,000 NOK per year. For the quadratic function, income elasticity increases from 0.21 at low end of incomes to 3.96 at high end of incomes. Viscusi and Masterman (2017) report an income elasticity of the value of a statistical life of between 0.5 and 0.7 in the United States and just above 1.0 for other countries. These estimates are consistent with the power function and the logarithmic function but not the quadratic function. However, as noted above, the quadratic function is rather implausible despite its wide use.

Table 1
Willingness-to-pay (NOK) for reduced risk of traffic fatality according to three utility functions.

Utility function	Annual income (NOK)	Willingness-to-pay (NOK) for reduction of risk of traffic fatality (current risk = 20/1,000,000)		
		25 % reduction	50 % reduction	100 % reduction
Power	200,000	37.0	38.0	40.0
	700,000	129.5	133.0	140.0
	1 200 000	222.0	228.0	240.0
Logarithmic	200,000	18.2	19.2	21.2
	700,000	81.2	84.7	91.7
	1 200 000	152.0	158.0	170.1
Quadratic	200,000	47.5	48.5	50.5
	700,000	84.6	88.1	95.1
	1 200 000	254.0	260.0	271.8

Values of a statistical life, based on the WTP-values in Table 1 are shown in Table 2. The values range from less than 2 million NOK to more than 50 million NOK. The current recommended value of a statistical life for use in cost-benefit analyses in Norway is 32.2 million NOK (Statens vegvesen, 2021). This is based on a valuation study in 2010 (Veisten et al., 2010), which recommended a value of 30 million NOK for a statistical life. Most values presented in Table 2 are considerably lower than this value.

However, all estimates are uncertain. Based on the standard error of the slope coefficients for the utility functions (i.e. the exponent of the power function, the coefficients for the logarithmic term and the quadratic term), 95 % confidence intervals for the value of a statistical life at an income of 700,000 and a risk reduction of 50 % are: 12.16 to 14.44 (best estimate 13.30) for the power function, 6.61 to 10.33 (best estimate 8.47) for the logarithmic function, and 5.70 to 11.92 (best estimate 8.81) for the logarithmic function. These simple estimates are

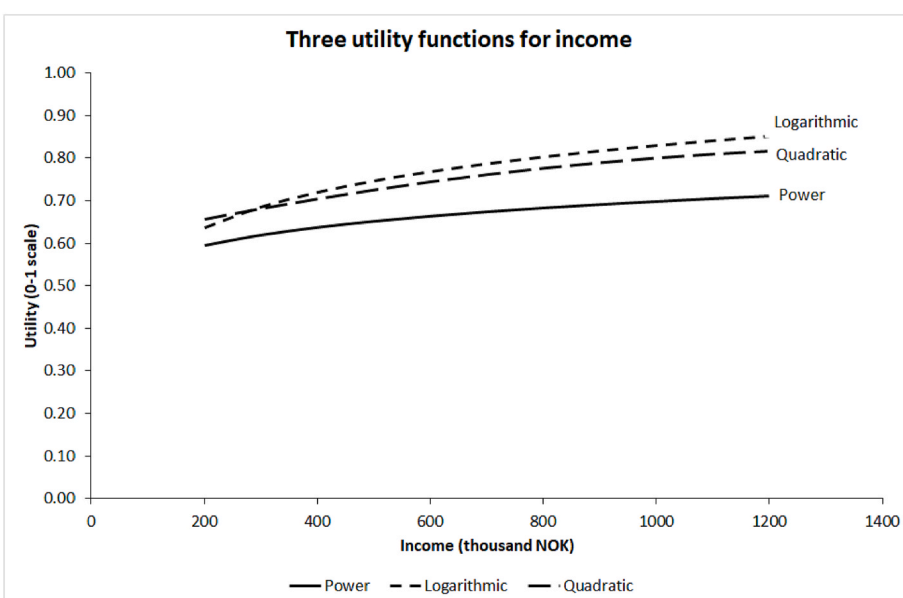

Fig. 5. Three utility functions for income.

Table 2
Value of a statistical life (million NOK) based on willingness-to-pay shown in Table 1.

Utility function	Annual income (NOK)	Values of a statistical life (million NOK) for different reduction of risk of traffic fatality in Norway (current risk = 20/1,000,000)		
		25 % reduction	50 % reduction	100 % reduction
Power	200,000	7.40	3.80	2.00
	700,000	25.90	13.30	7.00
	1 200 000	44.40	22.80	12.00
Logarithmic	200,000	3.64	1.92	1.06
	700,000	16.24	8.47	4.59
	1 200 000	30.40	15.80	8.51
Quadratic	200,000	9.50	4.85	2.53
	700,000	16.92	8.81	4.76
	1 200 000	50.80	26.00	13.59

most likely too narrow. A 95 % confidence interval for recommended value of 32.2 million NOK, based on Veisten et al. (2013) is 26.0–39.6 million NOK.

The value of a statistical life declines as the size of the risk reduction increases. This occurs because WTP does not increase in proportion to the size of the risk reduction, but at a much slower rate. This is due to: (1) the very small impact a reduction in risk has on overall utility, and (2) the flatness of the utility functions. This can be seen by, for example, applying the following utility function:

$$\text{Utility} = 0.0015 \cdot \mathit{Income}^{0.9}$$

This function increases in value from 0.177 for an income of 200,000 (entered as 200) to 0.886 for an income of 1,200,000. Now, suppose that there is a risk of 10 % of a fatality, and that this can be reduced to 8 %, 5 % or 2 %. At the mean income of 700,000, WTP is about NOK 16,900 for the smallest risk reduction, NOK 40,700 for the medium risk reduction, and NOK 63,100 for the largest risk reduction. While not fully proportional to the size of the risk reduction, these numbers are close to being so.

6. The discussion about utility functions

As noted in section 4, interpreting functions relating income to some indicator of happiness or life satisfaction as utility functions is controversial. Viscusi (2013) rejects this interpretation:

> "Although happiness scores elicited in surveys are not tantamount to utility levels, many researchers have advocated them as measures of well-being. However, unlike the VSL formulation, well-being measures have no explicit economic content and no cardinal significance. A representative well-being survey question asks the respondent to rate his or her happiness or satisfaction with life on a numerical scale such as 0 to 10, 1 to 10, or 1 to 7. At a most fundamental level, how should a person even think about such a question? What is the reference point for such an assessment? … If you have a permanent disability, then you may nevertheless feel pretty good about how your life is going on a particular day, but you might be much happier if you were not disabled – and you would give a different happiness score if the no-disability state were in the reference set."

He goes on to remark that happiness scores share the inherent inadequacies of ordinal measures. He adds that for the scales to have meaning, the intervals for different respondents (e.g. going from 7 to 8, or from 8 to 10 on a 10-point scale) must represent identical welfare effects across people. This is unlikely to be the case. Different people will, for example, interpret a score of 7 on a scale from 0 to 10 differently. One person might regard this as a very high level of happiness, another might rate a score of 7 as signifying a population average level of happiness (nearly all studies find that average scores are in the upper half of a scale). By contrast, Frey and Stutzer (2002) defend a utility interpretation:

> "Happiness is not identical to the traditional concept of utility in economics. It is, however, closely related. … Subjective well-being can be considered a useful approximation to utility, which economists have avoided measuring explicitly. This allows us to empirically study problems that previously were analysed only on an abstract theoretical level."

An important issue is whether answers to happiness surveys can be interpreted as a cardinal scale. Van Praag and Ferrer-i-Carbonell (2008) discuss this issue in some detail. Using the German scale, which ranges from 0 to 10 as the starting point, they note that this scale is ordinal. However, using an ordered probit analysis, they argue that the scale can be treated as approximately cardinal, and show that the results obtained when treating the scale as cardinal are almost identical to those obtained when treating it as ordinal.

Clark et al. (2008) argue that utility, as normally defined in economics, is expected utility from a choice, i.e. decision utility. Happiness, on the other hand, is an evaluation of what has occurred, an evaluation of experienced utility that may not be identical to decision utility. This point is discussed at greater length by Loewenstein and Ubel (2008). They argue that experienced utility may not be suitable as a guideline for public policy due to the emotional adaptation to adverse events. They state (page 1799):

> "If we based public policy on experienced utility, we might avoid spending scarce public resources on measures to prevent adversities like leg amputations, spinal cord injuries, and kidney failure which most people would be very adverse to experiencing, but which lead, for most people, to significant emotional adaptation. … Not only do such policy implications conflict with common intuitions and values, but, despite reporting levels of mood and well-being that are similar to healthy persons, people experiencing these conditions report a willingness-to-pay large sums of money or make other major sacrifices to restore their lost function. In our own research examining different measures of utility for different medical conditions, we have repeatedly found striking divergences between measures based on experienced utility and those based on decision utility."

The divergence Loewenstein and Ubel mention is actually not surprising and is no paradox, as will be shown in the next section. Loewenstein and Ubel think that an ideal measure of utility for public policy should reflect both decision utility and experienced utility.

7. State-dependent utility functions: ex post valuation based on a multiplicative function

There is a divergence between decision utility and experienced utility which arises when the decision concerns a risky prospect, which it does in the case of monetary valuation of life and limb. This divergence was first identified by Blackorby and Donaldson (1986), but their result has been ignored in studies of the value of a statistical life, since an ex ante approach, based on decision utility, has been regarded as the only meaningful approach to the valuation of fatality risks.

In studies designed to value the prevention of injuries, including the prevention of permanent disability, both decision utility (ex ante) and experienced utility (ex post) are relevant, and they do not give identical results. To see this, assume that utility is a function both of income and health state. Phelps and Lakdawalla (2024) propose a multiplicative function:

$$\text{Utility (I, H)} = \text{U(I)} \bullet \text{U(H)}$$

With this formulation, a permanent loss of health, represented by a certain value for U(H) can be incorporated into the utility function for income as a multiplier. It represents, for any income, the loss of utility attributable to the fact that a permanent impairment reduces well-being.

Consider, as an example, a risk of 1 in 1000 of sustaining an injury that results in a permanent impairment representing a 1 % loss of health-state utility. The effect of this on the expected utility of income is found by multiplying the ex ante utility of income by 1 – (0.001 • 0.99). For an income of 700,000 NOK, a rational utility maximiser would be willing to pay NOK 6900 to eliminate this risk. This is the ex ante value of eliminating the risk. Suppose now that the risk has not been fully eliminated and that an individual earning 700,000 NOK per year sustains the injury. This reduces the utility of income for that individual by 1 %. One might think that adding 1 % to income would compensate for this loss. This is wrong. The loss of utility, for an individual earning 700,000 NOK per year, is equivalent to an income loss of 67,100 NOK. This amount would have to be added to the ex ante income in order to restore ex ante utility. The logic of this is shown in Fig. 6.

In Fig. 6, the power utility function has been applied. The upper function is before a permanent impairment has occurred. The lower function is after the permanent impairment has occurred. The utility function is then shifted down by 10 %. This is indicated by the vertical arrow at an income of NOK 700,000. To restore initial utility, income would have to increase so that the lower function reaches the same height in the diagram as the upper function at the income of NOK 700,000. This is indicated by the horizontal arrow pointing to the right. In this example, to compensate for the loss of utility, income would need to increase by about NOK 1,300,000 from NOK 700,000 to about NOK 2,000,000. Thus, a 10 % loss in health-state utility would need more than a doubling of income to be compensated for. This is the high amount Loewenstein and Ubel (2008) referred to.

To show how this perspective can be applied to value the prevention of permanent impairments and the loss of life, a hypothetical utility function for health state has been developed. Utility functions for health state are poorly known (Phelps & Lakdawalla, 2024). A study by Parimbelli et al. (2017), evaluating utility for paraplegics has been used. Paraplegia is usually a permanent impairment. According to Haagsma et al. (2012) a spinal cord injury has a lifelong disability weight of 0.676, indicating a level of functioning of about 0.30 (on a scale from 0 with no bodily function to 1 with full bodily function). According to Parimbelli et al., health-state utility for paraplegics evaluated by means of a standard gamble is 0.85. The utility of perfect health is set to 1 and the utility of death set to 0. A function like the one shown in Fig. 7 can then be developed.

Applying the power utility function for income, it can be estimated that at an income of NOK 700,000 per year, NOK 2,856,000 would need to be added to income to compensate for the loss of utility, making for a new income of NOK 3,556,000. According to the logarithmic utility function for income, NOK 1,525,000 would have to be added to income to restore initial utility. For the quadratic utility function, compensation was found not to be possible as the function reaches a maximum at an income of about NOK 1,500,000, which is below what would be needed for full compensation. This shows, as noted already, that polynomial utility functions are inappropriate and should be avoided.

One possible interpretation of these estimates is that they are the lower bound of the value of preventing a permanent impairment associated with a health-state utility of 0.85. By eliciting the values ex-post, it is possible to base them on the experiences of those who have actually sustained a permanent impairment. Extrapolating the values to fatal injury is straightforward, at least if health-state utility has been obtained by means of a standard gamble. In such a gamble, the respondent is asked to state the probability of success of a treatment having either: (1) complete recovery or (2) instant death as the possible outcomes that would make him or her indifferent between the treatment and continuing to live with the impairment. Thus, if the value of preventing an impairment associated with a health-state utility value of 0.85 is NOK 2,856,000, the value of preventing a fatality is 1/0.15 •2,856,000 = NOK 19,040,000.

It is relevant to ask whether the study of Parimbelli et al. (2017) is representative. The systematic pattern in its results suggests that it is. It found, for example, a higher utility value for paraplegics than for tetraplegics (tetraplegia affects the functioning of arms and hands in addition to legs). Those who had a normal bladder or bowel function reported a higher level of utility than those with an impaired bladder or bowel function. Married paraplegics reported a higher level of utility than those living alone.

8. Discussion

Hundreds of studies have been made to obtain the monetary value of preventing accidental death or injury. The results of these studies are all over the place. Selecting a single best estimate for the value of a statistical life is challenging. The whole field of research may be viewed as a failure: it set out to find a uniform value of a statistical life but ended up finding a bewildering range of values. Some researchers (Baker et al.,

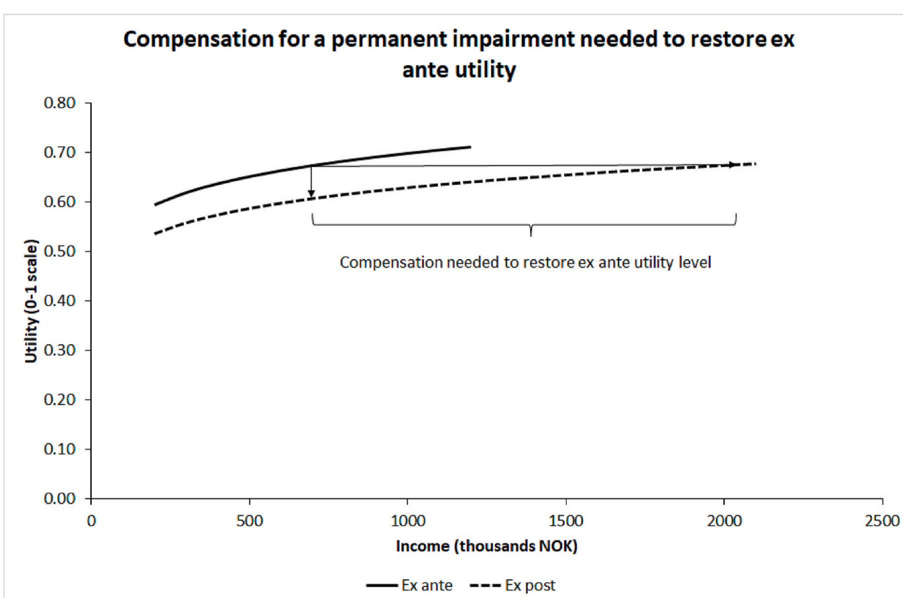

Fig. 6. Compensation for permanent impairment needed to restore initial utility.

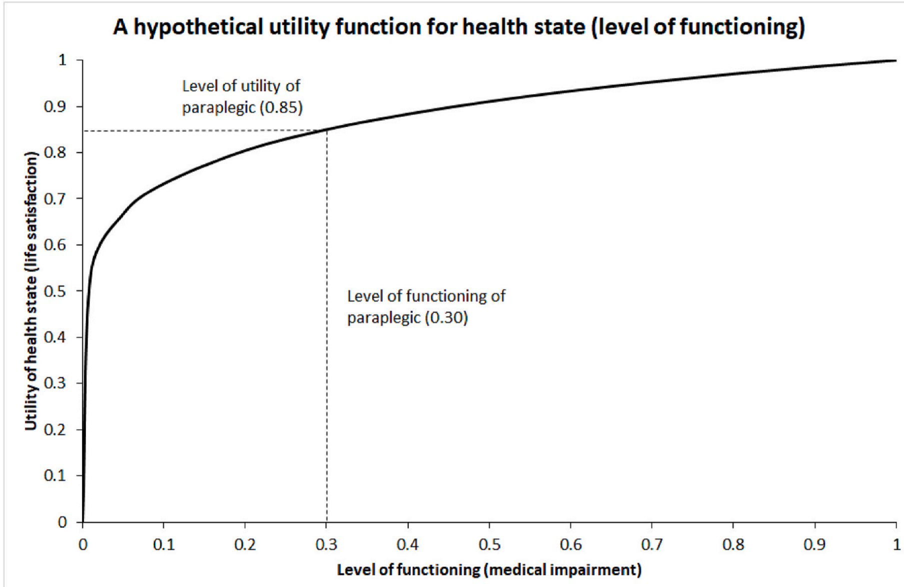

Fig. 7. A hypothetical utility function for health state (level of functioning).

2008, 2009; Viscusi, 2010) now call for using an array of values adapted to characteristics of the context. It has been suggested, for example, that the value of a statistical life ought to vary according to income.

This is a slippery slope. Outside the ranks of economists, it is hard enough to find many people who accept even the idea of putting a monetary value on human life, much less the idea of valuing the lives of rich people more highly than the lives of poor people (as would be the result of varying values according to income).

People have only the vaguest idea, if any at all, about how much their life is worth in monetary terms. They do, on the other hand, have a pretty good notion about how satisfied they are with life. They may not think about their satisfaction with life in numerical terms and certainly not in monetary terms. Extensive experience shows, however, that people give meaningful answers to surveys about subjective well-being. If one interprets mathematical functions fitted to the results of such studies as utility functions, it is possible to obtain estimates of the value of a statistical life (or a statistical injury) by inserting values for risk and willingness-to-pay into these utility functions and work out the values that maximise utility.

The results will not be the same for all types of utility functions. However, given the constraints usually imposed on utility functions – that they are concave an increase monotonically – results based on different mathematical specifications of the utility function cannot vary very much. The estimates made in this paper indicated quite low values of a statistical life – lower than the very conservative value recommended on the basis of a valuation study in Norway in 2010 (Veisten et al., 2010). The low values are not surprising. The current risk of a traffic fatality in Norway is 20 in one million, and such a low risk makes a correspondingly small difference to expected utility. If the estimates presented in Table 2, even the higher ones, were to be applied in cost-benefit analyses of road safety measures in Norway, almost all such measures would be found to have smaller benefits than costs.

One might reply that the potential impacts on policy of a lower monetary valuation of a statistical life are completely irrelevant. The values ought to be preference-based, and the values based on the utility functions are by definition preference-based. But they are based on decision utility, or preferences between lotteries. Once risk is resolved, i.e. once one of the outcomes of a lottery has materialised, the situation changes completely.

While it makes no sense to speak about ex-post utility in the case of death, it makes sense in the case of permanent impairment. To restore utility to the initial level, fairly large compensation will usually be needed, because utility functions tend to be quite flat. If the utility level associated with a certain permanent impairment can be estimated, the utility function for income can be used to estimate the compensation needed to restore initial utility. If saving a life is conceived of as going from a health state utility of 0 to a health state utility of 1, the prevention of one case of permanent impairment with a health state utility of 0.85 is equivalent to saving 1-0.85 = 0.15 lives, implying that the value of saving one life ought to 6.67 times the value of the ex-post compensation needed to restore the initial utility for a permanent impairment with a health-state utility of 0.85.

The problem with this approach is that it gives only the lower bound of value. Surveys of willingness-to-pay, on the other hand, give estimates of maximum willingness-to-pay. A basis for an upward adjustment of the values estimated according to ex-post utility functions can perhaps be found by relying on the degree of risk aversion in the utility function for income. As an example, the utility of a 50-50 lottery on the incomes of NOK 200,000 and NOK 1,200,000 corresponds to a certainty equivalent of NOK 510,000, which is less than the expected income from the lottery (NOK 700,000). If income is NOK 700,000, one could scale up ex-post monetary valuations by the ratio 700/510 = 1.37.

9. Conclusions

It has been known for about 60 years that there is a closed-form solution to the problem of obtaining the value of a statistical life consistent with an assumption of utility maximisation. Yet, this solution has never been applied. Applying it is straightforward and can rely on information which is nowadays widely available. Utility functions for income permit an ex-ante valuation of changes in risk, i.e., willingness-to-pay for changes in the probability of an adverse outcome of a lottery. Utility functions for health state allow the ex-post utility of permanent impairments to be assessed. By combining utility functions for health with utility functions for income, the ex-post compensation that must be paid to someone with a permanent impairment in order to restore ex-ante utility level can be estimated. This compensation can be extrapolated to obtain the value of a statistical life. Examples of the use of utility functions for income and health to estimate ex ante and ex post values of preventing death or permanent impairment are given in the paper.

By applying the approach used in this paper, estimates of the value of a statistical life that can be applied to any policy affecting the risk of death or permanent injury can be developed. These values are likely to vary less than those hitherto obtained from surveys designed to elicit willingness-to-pay for changes in the risk of death or health impairments.

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Data availability

Data will be made available on request.

References

Andersson, H., & Treich, N. (2011). The value of a statistical life. In A. de Palma, R. Lindsey, E. Quinet, & R. Vickerman (Eds.), *A handbook of transport economics* (pp. 396–424). Cheltenham UK: Edward Elgar (Chapter 17).

Arrow, K. J. (1965). *Aspects of the theory of risk bearing*. Helsinki: The Yrjö Jahnsson Foundation.

Baker, R., Chilton, S., Jones-Lee, M., & Metcalf, H. (2008). Valuing lives equally: Defensible premise or unwarranted compromise? *Journal of Risk and Uncertainty, 36*, 125–138.

Baker, R., Chilton, S. M., Jones-Lee, M. W., & Metcalf, H. R. T. (2009). Valuing lives equally in a benefit cost analysis of safety projects: A method to reconcile theory and practice. *Safety Science, 47*, 813–816.

Bellavance, F., Dionne, G., & Lebeau, M. (2009). The value of a statistical life: A meta-analysis with a mixed effects regression model. *Journal of Health Economics, 28*, 444–464.

Blackorby, C., & Donaldson, D. (1986). Can risk-benefit analysis provide consistent policy evaluations of projects involving loss of life? *Economic Journal, 96*, 758–773.

Clark, A. E., Frijters, P., & Shields, M. A. (2008). Relative income, happiness, and utility: An explanation for the Easterlin paradox and other puzzles. *Journal of Economic Literature, 46*, 95–144.

Dublin, L. A., & Lotka, A. J. (1930). *The money value of a man*. New York: Ronald Press Company.

Elvik, R. (2017). Does valuation research provide a credible basis for cost-benefit analysis of safety measures? *International Journal of Business Continuity and Risk Management, 7*, 192–203.

Frey, B., & Stutzer, A. (2002). What can economists learn from happiness research? *Journal of Economic Literature, XL*, 402–435.

Fromm, G. (1968). Comment to "The life you save may be your own". In S. B. Chase (Ed.), *Problems in public expenditure analysis* (pp. 166–176). Washington D. C.: the Brookings Institution.

Haagsma, J. A., Polinder, S., Lyons, R. A., Lund, J., Ditsuwan, V., Prinsloo, M., Veerman, J. L., & Beeck, E. F. van (2012). Improved and standardized method for assessing years liced with disability after injury. *Bulletin of the World Health Organization, 90*, 513–521.

Hellevik, O. (2008). Jakten på den norske lykken. *Norsk monitor 1985-2005*. Oslo: Universitetsforlaget.

Jones-Lee, M. W. (1976). *The value of life: An economic analysis*. London: Martin Robertson.

Layard, R., Mayraz, G., & Nickell, S. (2008). The marginal utility of income. *Journal of Public Economics, 92*, 1846–1857.

Lindhjem, H., Navrud, S., Braathen, N. A., & Biausque, V. (2011). Valuing mortality risk reductions from environmental, transport and health policies: A global meta-analysis of stated preference studies. *Risk Analysis, 31*, 1381–1407.

Loewenstein, G., & Ubel, P. A. (2008). Hedonic adaptation and the role of decision and experience utility in public policy. *Journal of Public Economics, 92*, 1795–1810.

Mishan, E. J. (1971). Evaluation of life and limb: A theoretical approach. *Journal of Political Economy, 79*, 687–705.

Parimbelli, E., Pistarini, C., Fizzotti, G., Rognoni, C., Olivieri, G., & Quaglini, S. (2017). Computer-assessed preference-based quality of life in patients with spinal cord injury. *BioMed Research International*, Article 4543610.

Phelps, C. E., & Lakdawalla, D. N. (2024). *Valuing health. The generalized and risk-adjusted cost-effectiveness (GRACE) model*. New York: Oxford University Press.

Proto, E., & Rustichini, A. (2015). Life satisfaction, income and personality. *IZA DP No 8837*. Bonn: Institute for the Study of Labor.

Reynolds, D. J. (1956). The cost of road accidents. *Journal of the Royal Statistical Society: Series A, 119*, 393–408.

Schelling, T. C. (1968). The life you save may be your own. In S. B. Chase (Ed.), *Problems in public expenditure analysis* (pp. 127–176). Washington D. C.: The Brookings Institution.

Statens vegvesen. (2021). *Håndbok 712. Konsekvensanalyser*. Oslo: Statens vegvesen. Vegdirektoratet.

Støren, K. S., Dalen, H. B., & Arnesen, H. S. (2014). Sosial ulikhet i livskvalitet. *Analyser av livskvalitetsundersøkelsen 2022 og 2023. Rapport 2024/22. Oslo, Statistisk sentralbyrå*.

Støren, K. S., & Rønning, E. (2021). *Livskvalitet i norge 2021. Rapport 2021/27*. Oslo: Statistisk sentralbyrå.

Van Praag, B. M. S., & Ferrer-i-Carbonell, A. (2008). *Happiness quantified. A satisfaction calculus approach* (Revised edition). Oxford: Oxford University Press.

Veisten, K. (2016). Et konkret forslag til en liten nedjustering av ex-ante verdsetting av "lettere skade" basert på Verdsettingsstudien. *Arbeidsdokument*, 51015. Oslo, Transportøkonomisk institutt.

Veisten, K., Flügel, S., & Elvik, R. (2010). Den norske verdsettingsstudien. Ulykker – verdien av statistiske liv og beregning av ulykkenes samfunnskostnader. *Rapport 1053C. Oslo, transportøkonomisk institutt*.

Veisten, K., Flügel, S., Rizzi, L. I., Ortuzar, J., & Elvik, R. (2013). Valuing casualty risk reductions from estimated baseline risk. *Research in Transportation Economics, 41*, 50–61.

Viscusi, W. K. (2010). Policy challenges of the heterogeneity of the value of statistical life. *Foundations and Trends® in Microeconomics, 6*, 99–172.

Viscusi, W. K. (2013). The benefits of mortality risk reduction: Happiness surveys versus the value of a statistical life. *Duke Law Journal, 62*, 1734–1745.

Viscusi, W. K., & Masterman, C. J. (2017). Income elasticities and global values of a statistical life. *Journal of Benefit-Cost Analysis, 8*, 226–250.