Health Economics, Policy and Law (2008), **3:** 277–300
© Cambridge University Press 2008 doi:10.1017/S1744133108004507

Valuing lives and life years: anomalies, implications, and an alternative

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Abstract: Many government interventions seek to reduce the risk of death. The value of preventing a fatality (VPF) is the monetary amount associated with each statistical death that an intervention can be expected to prevent. The VPF has been estimated using a preference-based approach, either by observing market behaviour (revealed preferences) or by asking hypothetical questions that seek to replicate the market (stated preferences). The VPF has been shown to differ across and within these methods. In theory, the VPF should vary according to factors such as baseline and background risk, but, in practice, the estimates vary more by theoretically irrelevant factors, such as the starting point in stated preference studies. This variation makes it difficult to choose one unique VPF. The theoretically irrelevant factors also affect the estimates of the monetary value of a statistical life year and the value of a quality-adjusted life year. In light of such problems, it may be fruitful to focus more research efforts on generating the VPF using an approach based on the subjective well-being associated with different states of the world.

1. Introduction

1.1 Background

In developed countries, regulatory agencies frequently use the monetary value of preventing a fatality (VPF) approach to assess benefits of new environmental, health, and safety regulations (Viscusi and Aldy, 2003). The VPF can be applied in cost–benefit analysis (CBA) to determine the most efficient use of resources. CBA is currently recommended by the government in the United Kingdom (UK) for economic appraisals (HM Treasury, 2005), with the notable exception of healthcare where benefits are expressed in terms of health improvements rather

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than in monetary terms. CBA is based on neoclassical welfare economics and evaluates whether the sum of the benefits to those who gain from a resource allocation decision exceeds the sum of the costs to those who lose from that allocation (Arrow *et al.,* 1996).

Over the last few decades, major developments have occurred in the theory and practice of estimating the VPF. The theoretical approach to value the risk of death, originally developed by Drèze (1962), Jones-Lee (1974), and Weinstein *et al.* (1980), asserts that the trade-off between wealth and the risk of death can be described by the marginal rate of substitution between wealth and risk, which then indicates an individual's willingness to pay for a change in the risk of death. Hammitt (2000) explains the estimation of the VPF according to the following simple one-period model of preferences for wealth and risk of death. Assume that an individual's welfare can be represented by

$$U(p, w) = (1 - p)u_a(w) + pu_d(w), \tag{1}$$

where p is the individual's chance of dying during the current period and $u_{\mathrm{a}}(w)$ and $u_{\mathrm{d}}(w)$ represent his utility as a function of wealth conditional on surviving and dying, respectively. Then the individual's VPF (or marginal rate of substitution between p and w) can be derived by differentiating the equation, while holding utility constant, to obtain

$$VPF = \frac{dw}{dp} = \frac{u_a(w) - u_d(w)}{(1 - p)u'_a(w) + pu'_d(w)}. \tag{2}$$

The numerator is the difference between utility if the individual survives or dies in the current period and the denominator is the expected marginal utility of wealth, that is the utility associated with additional wealth conditional on surviving and dying, weighted by the probabilities of these events. Assuming that life is preferred to death and that greater wealth is preferred to less, both the numerator and denominator are positive, and the VPF will be greater than zero.

1.2 Estimating the VPF

A number of regulatory agencies have adopted this general approach in quantifying the value of preventing deaths from government interventions. In the UK, the Department for Transport has more recently advocated a value of £1.4 million[1] per life saved from safer means of transportation (Department for Transport, 2007). This value has been used by the Home Office, Health and Safety Executive, Environment Agency, Food Standards Agency and other government bodies. However, the VPF varies widely internationally, e.g. the US Environmental Protection Agency (1997) use a value of £4.2 million for air quality regulations, whereas the

1 All estimates reported are converted to 2006 British pounds sterling using averaged annual exchange rates and the all items Retail Price Index

European Union (2001) recommends a value of £0.9 million. Broadly speaking, the VPF has been estimated by one of two preference-based methods.

The first method uses a revealed preferences (RP) approach to value the risk of death by estimating the compensating differentials for on-the-job risk exposure in labour markets (Blomquist, 2004; Kniesner and Viscusi, 2005; Kniesner *et al.,* 2006). Alternatively, the VPF can be based on price–risk trade-offs in product markets, such as for automobiles and fire alarms (Viscusi and Aldy, 2003). A meta-analysis of 197 VPF estimates based on RP reported a mean value of £7.4 million from preventing a fatality internationally, with a standard deviation of £3.8 million (Kochi *et al.,* 2006). These figures vary widely with Kniesner and Leeth (1991), for example, estimating a value of £0.5 million, and Arabsheibani and Marin (2000) report a value of £64.0 million. The wide variation in VPF values is to some extent explained by two fundamental problems relating to the RP methodology. First, the method crucially depends on the ability to disentangle the risk-related wage differentials from the many other factors that determine wage rates. Second, RP is based on the assumption that individuals are well-informed about the risks they face in the workplace and that there is perfect labour mobility.

The second method for estimating the VPF relies on stated preferences (SP). Here, a hypothetical market is constructed and respondents are asked contingent valuation (CV) questions about their willingness to pay (WTP) for a given risk reduction or their willingness to accept (WTA) a given risk increase. The meta-analysis by Kochi *et al.* (2006) report a mean VPF figure from CV studies at around £2.2 million internationally with a standard deviation of £1.0 million (Kochi *et al.,* 2006), which are both lower than the values reported in RP studies.

The advantage of CV questions is the ability to directly infer the relevant trade-off between wealth and risk and to tailor the study design to elicit exactly the information that is required (Chilton *et al.,* 2004). CV has gained credibility with the recommendation from the Blue Ribbon panel of experts and the UK government (Arrow *et al.,* 1993; HM Treasury, 2003). The method is increasingly considered for valuation of health and health care interventions (Smith and Richardson, 2005; Smith 2006), where non-monetary valuation methods so far have prevailed (Dolan, 2000).

The VPF can be used to estimate the value of a life year (VOLY) and the value of a quality-adjusted life year (QALY), the latter a product of a quality of life score (on a scale between 0 for death and 1 for full health) and the number of remaining life years. QALYs are frequently used as a measure of benefit in cost-effectiveness analyses (CEA) in healthcare (Dickie and List, 2006), and the National Institute for Health and Clinical Excellence (NICE) in the UK prioritize health care resources on the basis of cost per QALY gained estimates. Although no explicit threshold exists for cost-effective technologies, NICE generally recommends funding interventions with a cost per QALY gained less than £30,000. Interestingly, NICE is currently considering ways of attaching an explicit monetary value to a QALY, which, in principle, will allow

an 'exchange rate' to be established between the benefits from interventions in health care and interventions elsewhere in the public sector.

1.3 Aims of the paper

This paper considers the factors that affect the VPF, theoretically and empirically, and considers their implications for the VOLY and QALY. It also provides an alternative methodology to elicit the VPF. Indeed, the validity and policy legitimacy of the VPF crucially hinge upon the type of factors that influence the values estimated. The VPF should differ according to a number of factors that theoretically matter for lives saved and it should not differ by theoretically irrelevant factors. To provide an account of the evidence in this regard, we conducted a literature review in EconLit and EconPapers using search terms of 'value of a statistical life' and 'value of a prevented fatality'. This generated around 90 papers. We also reviewed papers from the grey literature, which were identified by searching websites of key researchers in the area. Finally, we use this summary of the literature to reflect on the use of the VPF in policy decision making, including health care resource allocation. For example, much discussion relating to NICE in recent years has focused on the appropriateness of the thresholds applied, yet no study has so far seriously examined the empirical basis for such a threshold.

The paper is organized as follows. In section 2, we consider the evidence on the factors that theoretically should affect the VPF, namely baseline and background risk,[2] wealth, age, and latency of the risk. In section 3, we consider theoretically irrelevant factors. In particular, economic theory predicts that, for marginal changes in risk of death or injury, WTP and WTA should produce broadly similar results, the VPF should not vary to any great extent by the precise magnitude of risk change, and the VPF should not differ according to the specific type of death. In addition, individual preferences should be insensitive to changes in question framing, and responses to CV questions should be unaffected by such factors as the elicitation method. In section 4, we then consider the ways in which monetary values can be established for life years and the extent to which current evidence supports the current unofficial thresholds applied in healthcare decision making. Finally, in section 5, we consider the general robustness of VPF estimates and suggest that monetary values estimated from subjective well-being equations might offer an alternative way forward.

2. Four theoretically relevant factors

The literature identifies four important factors that affect the VPF: baseline and background risk, wealth, age, and latency of the risk. We consider each of these factors in turn, and the evidence relating to them.

2 Baseline risk refers to the risk of the specific adverse event that is being valued and background risk refers to the risk of adverse events generally (i.e. mortality risk).

2.1 Baseline and background risk

In theory, the VPF should increase with higher baseline risk (the risk of a specific adverse event), as the opportunity cost of spending money decreases the higher the risk of death, i.e. when the risk of dying now is high for some specific reason, the opportunity cost of spending money is low as the individual may not be able to spend his wealth later. Due to the low opportunity costs of spending money, an individual is willing to spend money on an intervention that reduces this risk. However, the exact relationship between baseline risk and VPF has not been yet established (Jones-Lee, 1974; Weinstein *et al.,* 1980; Pratt and Zeckhauser, 1996; Hammit, 2000; Pearce, 2000). The VPF may also be affected by the existing background risks (the risks of adverse events more generally) (Eeckhoudt and Hammitt, 2001). When the background risk of death is substantial, the WTP for an intervention that reduces this risk may be lower given the overall poor chances of survival. However, the effect of an increase in both baseline risks and background risks is uncertain.

Alberini and Chiabai (2007b) suggest that the WTP actually decreases with higher baseline risk, although the study did not disentangle the effect of background risks. Krupnick *et al.* (2002) showed that individuals' WTP does not vary considerably with physical health, yet they find individuals diagnosed with cancer to have a WTP of £410 for a 5 in 1,000 risk reduction compared with £280 for the same risk reduction among individuals without a diagnosis of cancer.

2.2 Wealth

An individual's WTP is strongly related to her ability to pay, so poorer people inevitably have a lower VPF than higher income individuals (Viscusi and Aldy, 2003; Ho and Nielsen, 2007). The evidence from compensating-wage-differential studies suggests an income elasticity around 0.5–0.6 (Lui *et al*., 1997; Mrozek and Taylor, 2002; Viscusi and Aldy 2003). This implies that WTP increases with greater wealth, yet at less than a proportional rate. CV studies on the income elasticity of WTP for a reduction in the risk of dying report fairly comparable results (Jones-Lee *et al.,* 1995; Mitchell and Carson, 1986; Miller, 2000; Corso *et al.*; 2001), although some studies suggest a lower elasticity of around 0.25 (Persson *et al.,* 2001; Carlsson *et al.,* 2004), and in two studies an elasticity greater than 1.0 (Hammitt *et al.,* 2003; Hammitt and Zhou, 2006). However, difficulties in isolating a pure wealth effect from other confounding effects, such as the availability of healthcare, mean that these various estimates should be treated with caution (Hammitt and Zhou, 2006).

Additionally, recent work by Kaplow (2005) points to an inconsistency between relative risk aversion exhibited by individuals in financial markets and the income elasticity of VPF typically studied in labour and product markets. The relative risk aversion is directly linked to individuals' income elasticity of VPF, and Kaplow illustrates how the estimates of income elasticity of VPF should

be approximately the same size (or higher) as the coefficients of relative risk aversion. Estimates of the coefficients of relative risk aversion in financial markets suggests values in the range of 2–10, which is substantially higher than the income elasticities of 0.5 to 0.6 identified by Viscusi and Aldy (2003) in their latest review of the literature.

2.3 Age

There is no unequivocal theoretical argument for the effect of age on the VPF (Evans and Smith, 2006). On the one hand, the VPF may decrease with higher age since there are fewer years to benefit from any reduction in the risk of death. On the other hand, the VPF may also increase with higher age, as the opportunity cost of spending money decreases over time given this risk reduction (Pearce *et al.,* 2006). Life-cycle models, such as those by Shepard and Zeckhauser (1982) and Rosen (1988), showed that the age effect is in fact highly complex across the entire life span and that theory does not necessarily support the assumption currently used by the European Union (2001) of a declining VPF with age.

Most evidence suggests that there is an 'inverted U' shaped relationship between WTP and age (Rosen, 1988; Jones-Lee, 1989; Miller and Guria, 1991; Cropper *et al.,* 1994; Kidholm, 1995; Persson *et al.,* 1995; Desaigues and Rabl, 1995; Dillingham *et al.,* 1996; Carthy *et al.,* 1999; Hammitt and Graham, 1999; Aldy and Viscusi, 2004; Chilton *et al.,* 2004). For example, Krupnick *et al.* (2002) find that the WTP for a 5 in 1,000 risk reduction is £280 among 40–60 year-olds, £320 among 60–70 year-olds, and £200 among individuals over the age of 70 (also see Alberini *et al.,* 2004; Smith *et al.,* 2004). It should be noted, however, that Persson and Cedervall (1991), Johannesson and Johansson (1996) and Pearce *et al.* (1999) reported no age effect at all.

2.4 Latency

The effect of latency in the risk of death on the VPF is a relatively new research area stimulated by the many public policies proposing investments with long-term effects. Hammitt and Liu (2004) argue that the effect of latency on the WTP should depend on how the rate of substitution between investment in preventive health measures and the risk of death changes over time, i.e. investments in interventions that reduce the risk of death in the future. If the substitution rate increases over time, the WTP to reduce a latent risk will exceed the WTP for an equally large reduction in current risk. They also suggest that an individual's WTP to reduce a latent risk depends on the individual's future WTP to reduce future risk.

Krupnick *et al.* (2002), Alberini *et al.* (2004; 2006b), and Itaoka *et al.* (2005) asked individuals to state their annual WTP over a ten-year period for a change in risk that would occur when they were between 70 and 80 years old. These studies suggest that time would have a negative effect on the VPF, reducing

its value by as much as 40% to 75%. This finding may result from the fact that people to some extent discount the future. Hammitt and Liu (2004) illustrated this effect in their study of cancer patients, where they found the VPF for the immediate risk of lung and liver cancer to be £1.69 million and £0.80 million, respectively, compared with £1.27 million and £0.56 million for latent lung and liver cancer.

Recently, there has been increased research in the importance of discount rates, which examine people's choices between money and future risk reductions. It has been argued that if society is not impartial with respect to current and future generations, then some discounting will clearly be called for, even with future safety effects valued in terms of the current value of statistical life (Jones-Lee and Loomes, 1995). When combining older and newer estimates, the estimated discount rate ranges between 0.3% and 14% (Horowitz and Carson, 1990; Moore and Viscusi, 1990; Johannesson and Johansson, 1996; Hammitt and Liu, 2004; Alberini *et al.,* 2006a; Itaoka *et al.,* 2005; Alberini and Chiabai, 2007a). Alberini and Chiabai (2007a) argue that this range is generally lower than the discount rates people usually require in 'money now versus money later' tradeoffs.

3. Four theoretically irrelevant factors

In theory, the VPF should be unaffected by the way in which the value is elicited. In particular, the VPF should not differ according to the method of elicitation (WTP or WTA setting), the precise magnitude of the marginal change in risk, the specific type of death, or the way the question is framed and presented.

3.1 WTP versus WTA

The change in welfare from an intervention can be measured by estimating the compensating variation or the equivalent variation. The compensating variation measures the amount of money that would return the respondent to the original level of utility should the intervention take place. The equivalent variation measures the amount of money that will change the utility of the respondent to the level that would be achieved by the intervention without the intervention actually taking place. The direction of payment (i.e. WTP versus WTA) depends on whether a welfare gain or loss has occurred. These two values can diverge given wealth effects but for marginal changes in the risk of death wealth effects are not large, so, in line with economic theory, these values should not diverge significantly from one another (Guria *et al.,* 2005).

Evidence, however, shows that WTA values are typically two to eight times higher than WTP values (Knetsch and Sinden, 1984; Brookshire and Coursey, 1987; Coursey *et al.,* 1987; Duboug *et al.,* 1997; Horowitz and McConnell, 2002). In a direct comparison of WTP and WTA within the same VPF study,

Guria *et al.* (1999) presented results on the WTP for a 20% lower risk of death or injury on the roads and a WTA a 20% increase in the same risk in an attempt to reduce any biases from cognitive difficulties in valuing a small relative risk change. They found a median WTP estimate of £90 and a median WTA estimate of £730. In a meta-analysis, Kochi *et al.* (2006) demonstrated that wage-risk values are more than three times larger than the values from CV studies, and part of this difference could be explained by the former being largely WTA-based estimates, whilst CV studies, following the NOAA guidelines (Arrow *et al.,* 1993), are usually WTP-based.

There are two main reasons for the WTP–WTA discrepancy. The first is substitution effects that predict a greater discrepancy make it harder to substitute the good being valued (Hanemann, 1991). However, even when there are many substitution possibilities (e.g. chocolate bars in Kahneman *et al.,* 1990), the WTA is significantly higher than WTP values, suggesting other reasons for this discrepancy. The second reason is endowment effects, which state that individuals are generally loss averse and tend to value goods more highly once they own them (Tversky and Kahneman, 1991). Whilst this is clearly a plausible and psychologically meaningful reason for the disparity, it plays no part in standard economic theory.

3.2 The size of the risk change

For marginal changes in risk, economic theory suggests that the relationship between WTP and risk change should be roughly proportional. This means that the VPF will remain generally invariant to the precise magnitude of marginal changes in the risk of death, yet sensitive to absolute changes in the risk. However, evidence from CV studies suggests that responses are highly insensitive to the absolute change in the level of risk (Jones-Lee *et al.,* 1995; Dubourg *et al.,* 1997; Beattie *et al.,* 1998; Carthy *et al.,* 1999; Hammitt and Zhou, 2006). Eom (1994), Lin and Milon (1995), and Kochi *et al.* (2006), for instance, all found the underlying WTP values to be the same regardless of changes in the magnitude of risk. Beattie *et al.* (1998) demonstrated that the VPF for five road traffic accidents was £8.4 million, while the VPF for 15 road traffic accidents was £3.45 million. Interestingly, Corso *et al.* (2001) have shown that visual aids within the elicitation procedure can reduce this insensitivity to the magnitude of risk, and Bateman and Brouwer (2006) believe that using dichotomous choice elicitation formats will reduce this insensitivity.

These results indicate a very serious problem in estimating the VPF, as they suggest it is possible to generate almost any value based on the size of risk reduction presented to respondents. They also suggest that respondents are not reporting properties of pre-existing preference ordering but rather arrive at responses by some form of mental processing that does not properly take into account the trade-off between risk and compensation.

3.3 Type of death

In principle, a death is a death and it should not matter whether the risk of death relates to a car accident or to cancer. There may, of course, be differences in the process of dying but these should be captured by differences in the morbidity loss and not the mortality loss. This additional premium for fear etc. is distributed across the population differently to how the risk of death itself is distributed and the losses associated with these different outcomes should be kept separate from one another (Adler, 2003). In other words, the VPF itself remains independent of context but the overall loss in welfare can depend on context.

However, Sunstein (1997) has argued that people are willing to pay a premium to avoid 'bad deaths', such as those which are dreaded (e.g. cancer), uncontrollable, involuntarily incurred and inequitably distributed (see also the seminal work in this area by Slovic, 1987). In particular, individuals appear willing to tolerate higher risks from activities perceived as being beneficial to the individual, while factors such as lack of control and catastrophic potential can significantly increase individuals' perceived risk and willingness to pay (Slovic *et al.,* 1980). For example, Carlsson *et al.* (2004) found that air transportation safety is valued more highly than safety on the road, in that the VPF from air traffic accidents is larger than the VPF relating to road traffic accidents. They argue that even if income is controlled for, there is still a discrepancy between the two which is likely to be caused by the mental suffering of imagining an airplane disaster.

Chilton *et al.* (2006) empirically showed that the VPF is affected not only by the baseline risk but also dread risk. They use the term 'dread' to refer to a number of factors besides the risk of death, such as the degree of voluntariness and control over the cause of death, anticipation of the degree of pain and the suffering preceding death. They find dread risks constitute a significant proportion of the VPF. For example, the VPF from road accidents is estimated at £1.49 million with £0.26 million relating to dread risks, while the VPF relating to railway accidents is £1.45 million with £1.42 million constituting dread risks.

3.4 Irrelevant cues

According to Sugden (2005), irrelevant cues exist when respondents are unduly influenced by the elicitation procedure in reporting pre-existing, context-independent preferences. There has been much discussion in the literature about the potential sources of bias in CV studies (Arrow *et al.,* 1993; Carson, 1997; Carson *et al.,* 2001), and one of them is the *elicitation method*. Bateman and Jones (2003) have argued that the actual payment mechanisms in CV studies eliciting an individual's WTP, such as open-ended, iterative bidding, dichotomous choice, and payment card mechanisms, reveal regular differences in estimated VPFs. For example, studies by Kealy and Turner (1993), Kriström (1993), Boyle *et al.* (1996), and Ryan *et al.* (2004) indicate that these methods elicit highly varying WTP estimates.

Consequently, the appropriate elicitation method is a regular source of debate (Smith, 2003). While there is agreement that the open-ended method is not appropriate (Arrow *et al.*, 1993; Donaldson *et al.,* 1997), the dichotomous choice and payment card methods have both proved popular (Bateman *et al.,* 2002; Smith, 2003, 2006). Dichotomous choice methods have been widely used in environmental and health economics and were recommended by the NOAA panel (Arrow *et al.,* 1993), and the payment card method appears to have increased in prominence in over the last ten years or so (Bateman *et al.*, 2002; Smith, 2006).

Other potential biases include *start-point bias,* which occurs when the starting point of a question, such as the initial bid applied within an iterative bidding exercise, influences the stated monetary values (Herriges and Shogren, 1996). *Order effects* can occur when individuals' responses are affected by the order of the questions in a CV study (Stewart *et al.,* 2002). *Range bias* can occur when respondents are sensitive to the choice and the positioning of values within a given payment scale (Whynes *et al.,* 2004). Both Dubourg *et al.* (1997) and Bateman *et al.* (2005) have demonstrated that the higher the range provided by the payment card and random card sorting, the higher the WTP for the risk reduction, and hence the higher the VPF.

4. Estimating the value of a life year or a quality-adjusted life year

The VPF can be decomposed into a value of a life year (VOLY) and a quality-adjusted life year (QALY) when appropriate data for quality of life adjustment exists. The relationship between lives and life years, quality-adjusted or not, is far from determined (HM Treasury, 2005; Kenkel, 2006). A linear relationship is clearly the simplest and involves dividing the VPF by a person's life expectancy (Hirth *et al.,* 2000). Alternatively, the VOLY can be estimated as an annuity by applying discounting to the residual life expectancy of the individuals affected by the intervention (Pearce, 2000). From this, if individuals use a constant discount rate, the monetary value of a VOLY should theoretically increase with age.

However, with wealth effects and mental accounting constraints (Jones-Lee *et al.,* 1995; Carthy *et al.,* 1999), there are many possible relationships between the VPF and the VOLY. Mason *et al.* (2004) examined whether being alive *per se* affected the VPF and the extent to which the VPF varied by age. They suggest that an individual's WTP for a reduction in the risk of death depends on remaining life expectancy, which would imply a reduction in the value of each additional life year by approximately 50–75% compared with the simple linear case. Loomes (2002) suggests that a 'love-of-life' element may explain why the VPF does not diminish completely as people approach the end of their life.

The various approaches to establishing a VOLY can also be used to identify the value of a QALY (Tolley *et al.,* 1994; Hirth *et al.,* 2000). For instance,

Mason *et al.* (2004) used general population values of health states, described in terms of the EQ-5D (Dolan, 1997), to apply a quality of life weight to the probability of each potential year of life. Clearly, the QALY value will be greater than the VOLY value, since the VPF is divided by the product of an individual's life expectancy and a health state value that is less than 1. Mason *et al.* (2004) demonstrated that a QALY is roughly 1.2 times the value of a VOLY, which equates to a value between £49,000 and £69,000 when discounted at the pure rate of time preference of 1.5% (the undiscounted figures were between £37,000 and £55,000). These values are similar to earlier results presented in the literature (Johannesson and Meltzer, 1998; Abelson, 2003). In a meta-analysis of CV studies, Hirth *et al.* (2000) found a median value of £111,000 for a QALY. In the current debate about the appropriateness of the threshold used by NICE, it is noteworthy that all of these indirect estimates are significantly higher than the threshold currently inferred from recent decisions by NICE.

While most estimates of a VOLY derive indirectly from estimates of the VPF, some CV studies have tried to estimate a VOLY directly. Johannesson and Johansson (1996) applied a single bounded dichotomous choice CV elicitation format to elicit values for an increase in life expectancy from 10 to 11 years for individuals aged 75 as a result of an improvement in medical treatment. Using a sample of adults aged 18 to 69, they found the VOLY to be £1,160 based on non-parametric regression and £460 from logistic regression resulting in an estimate of the VPF between £92,000 and £253,000. To arrive at an estimate of a VOLY, Morris and Hammitt (2004) examined the WTP for a hypothetical pneumonia vaccine, where half of the sample valued a vaccine benefit in terms of a gain in life expectancy and the other half valued an equivalent benefit in terms of a reduction in the average annual probability of death. The VOLY estimates varied between £242 and £508.

Chilton *et al.* (2004) examined the VOLY for immediate deaths (defined as a death resulting from poor health) and chronic effects (defined as reduced life expectancy due to long-term exposure in normal health) with benefits of one, three and six month increases in life expectancy. Interestingly, they found severe insensitivity to the scope of benefits; the VOLY implied by WTP for one month was greater than the VOLY implied by three month WTP and the VOLY implied by the six month WTP. The one month extra VOLYs for normal and poor health were £29,300 and £7,700 respectively. Using the former to estimate a VPF, produces a figure close to that proposed by the UK DfT.

The insensitivity to the size of the benefits was also demonstrated by Hammar and Johansson-Stenman (2004) who estimated a VOLY for a sample of smokers from Sweden. The smokers were asked to place a value on newly developed cigarettes with (1) no adverse health effects and (2) 50% less adverse health effects compared with normal cigarettes. They found the WTP for cigarettes with 50% less adverse health effects to be nine-tenths of the WTP for cigarettes with no adverse health effects, irrespective of the method of elicitation (dichotomous

choice and open-ended questions). They estimated that given that someone loses 0.00042 years per packet of cigarettes consumed, the VOLY would be £2,900 according to the dichotomous choice method and £1,800 when using open-ended questions. Therefore, it is clear that these direct methods would provide QALY estimates below the current NICE threshold.

5. Discussion

The theory and measurement of the VPF has developed greatly since the 1970s and many regulatory agencies now use the VPF in CBA for various public interventions and investments. The European Organisation for the Safety of Air Navigation, for instance, now requires the use of CBA in all investment decisions on new safety schemes (EUROCONTROL, 2005). By publishing a specific set of standard inputs for CBA, they expect greater comparability between economic evaluations, and hence consistency in resource allocation. The VPF recommended in that document has an upper limit of £1.7 million; a figure equivalent to that applied by the US Federal Aviation Administration.

The UK Department for Transport (DfT) publish annually their economic evaluations of the benefits of preventing road traffic accidents and casualties, including the value per life saved from safer means of transportation. While their cost–benefit evaluations are based on the VPF, there are instances where new safety measures, such as train protection warning systems, are still implemented even though the cost per fatality avoided is well in excess of published VPF estimates. The DfT values are also used by local authorities in prioritizing local safety schemes, such as traffic calming.

In health care, it has been inferred from recent decisions by NICE that the agency apply values of a QALY around £30,000. While acknowledging this unofficial threshold, the Chair of NICE also admits that it is arbitrary and linked more to affordability than any underlying evidence on the value of a QALY (Rumbelow and Miles, 2007). Evidence derived indirectly by estimates of VPF suggests that this threshold could be higher; between £49,000 to £69,000 by estimates of Mason *et al.* (2004) or even as high as £111,000 (Hirth *et al.,* 2000), while estimates derived directly for a VOLY suggest a threshold significantly lower than £30,000. Interestingly, NICE does appear willing to apply different thresholds for different diseases as evident from recent decisions on new oncology drugs (NICE Guidance 116, 2007; NICE Guidance 93, 2005). Such differentiation is in line with the UK Health and Safety Executive applying a higher value per life saved for cancer treatment compared with other government interventions (HSE, 2001).

In estimating the VPF, the use of the CV method has resulted in more informed and consistent resource allocation decisions for prevention of health hazards. However, use of the VPF is still not a straightforward matter in this context.

For instance, it is not clear how the VPF should vary according to theoretically important factors based on the empirical evidence available today. Generally speaking, evidence supports theory in how wealth should have a positive effect on the VPF and how latency should have a negative effect. While theory does not give a clear-cut prediction as to how the VPF varies with age, empirically the VPF decreases with higher age, yet this seems only to be the case after the age of 70. The VPF should increase as baseline risk increases and decrease as background risk increases (Chilton *et al.,* 2006), although further studies are needed to partition these two effects. While a uniform VPF across the public sector may not be wholly desirable (Sunstein, 2004), it would be helpful if there were clear guidance on the relevance of the different factors in the contexts in which the VPF is applied.

On the basis of the evidence currently available, risks borne disproportionately by higher income groups (e.g. the risk of death from flying) may be valued more highly than risks borne by lower income groups (e.g. the risk of air pollution by proximity of low income neighbourhoods to industrial areas) if the VPF is allowed to differ by the wealth of the affected groups. Similarly, the VPF applied to risks affecting those of working age might be higher than that used in contexts where the at-risk population is made up of a higher proportion of pensioners. Such application of the VPF values raises a number of important normative issues and policy-makers may quite legitimately consider that the VPF should not be allowed to differ by wealth or age.

More problematic from a positive point of view is the insensitivity of the VPF to factors that should matter and the sensitivity to factors that should not be important. The insensitivity to the magnitude of the risk change in CV studies, and hence the variability in VPF according to risk change is a particularly pervasive problem that researchers have yet to overcome. This problem is of fundamental importance for both the internal and external validity of the VPF. For example, Chilton *et al.* (2004) go to great lengths to reduce possible biases in responses but gross insensitivity to the scope of benefits still remains. This makes the VPF highly dependent on the risk changes being valued. For policy purposes, it might be argued that the true risks should be used in any valuation study, but these may be so small that respondents do not understand them fully or they lead to particular biases. For example, Kahneman and Tversky (1979) and Kahneman *et al.* (1982) provide strong evidence that people systematically overweight very small probabilities.

It may be possible to generate more robust WTP estimates, such as by mitigating the problem of the hypothetical nature of stated preferences (Cummings *et al.*, 1995; List, 2001). Nevertheless, insensitivity to scope and many of the other anomalies in CV studies can be attributed to differences between the logic of preferences and the logic of attitudes, i.e. responses may reveal attitudes rather than preferences (Kahneman and Sugden, 2005). For instance, in a classic study, Desvousges *et al.* (1993) found that values to prevent the drowning of 2,000 birds

and 200,000 birds were very similar, suggesting that the responses were driven in large part by attitudes to saving birds and much less so by the number of birds saved.

It has been found that these emotive reactions are susceptible to framing and focusing effects (Loewenstein and O'Donoghue, 2004). These emotive reactions are different to tastes in that they are more likely to have direct hedonic consequences, more likely to be stimulated by external circumstances, more volatile, and reliant on different neuro-physiological mechanisms (Loewenstein, 1996). Emotive reactions are prominent when analysing risk since they are sensitive to the vividness of associated imagery, proximity in time, and a variety of other variables that play a minimal role in cognitive evaluations (Loewenstein *et al.*, 2001). It has also been found that individuals are less sensitive to changes in probability when valuing the chance to receive emotional outcomes, e.g. kisses, as opposed to monetary outcomes (Rottenstreich and Hsee, 2001). As such, these factors may be partly responsible for the premium attached to deaths in some contexts e.g. during a pandemic (Gyrd-Hansen *et al.*, 2008) but not others, e.g. road deaths. The degree to which the VPF should vary across such contexts and according to the expression of such attitudes and emotions is a largely unresolved area of normative debate (see Sunstein, 1997; and Viscusi, 1998).

The preference-based approach stipulates that utility can be inferred from choices. Ultimately, however, CV responses cannot avoid some kind of focusing effect (Kahneman and Sugden, 2005), and CV questions necessarily draw respondents' attention to what is being valued, in a way that may not reflect the true underlying utility of the good in question (Dolan and Kahneman, 2008).

With these arguments in mind, is it possible to generate more meaningful and robust estimates of health and risk than those derived from either revealed or stated preferences? We suggest that a possible, but under researched, alternative approach is to focus on people's experiences, or subjective well-being (SWB), rather than on their preferences (Kahneman *et al.*, 1997; Dolan *et al.*, 2008). By SWB, we mean a global assessment of their life, such as happiness of life satisfaction (Dolan, 2008). There have also been other constructions of SWB, such as moment-to-moment utility (Kahneman *et al.*, 2004), but economists have used global assessments more often.

One reason for the increased interest in SWB is the not wholly unrealistic assumption that each of us has a good idea about the degree to which we are satisfied with our life (Frey and Stutzer, 2002). Within economics, SWB has become popular for two main reasons: (i) it allows new ways of testing the basic assumptions of the economic approach, for example whether people actually maximize utility as defined by SWB; and (ii) the increasing availability of panel data that allows us to control for individual heterogeneity and begin to make inferences about causality. Since the seminal work of Easterlin (1974), there has been an increasing literature examining cross-country differences in SWB (Di Tella *et al.*, 2001; Alesina *et al.*, 2004; Blanchflower and Oswald, 2004), and how SWB can

be used to value life events, such as unemployment (Clark and Oswald, 2002) and noise pollution (van Praag and Baarsma, 2005). It is possible that SWB is a robust measure of underlying well-being, and it is correlated with actual behaviour (Di Tella *et al.*, 2003; Bray and Gunnell, 2006) and physiological outcomes (Steptoe *et al.*, 2005; Blanchflower and Oswald, 2008).

The basic idea is to directly measure the utility associated with changes in non-market goods, such as health (Dolan and Kahneman, 2008). In order to value a health state, we need to firstly specify the SWB function, which is usually given by[3]

$$v = h[u(y, H)] + \varepsilon, \tag{3}$$

where v is the individual's subjective well-being (on a bounded ordinal scale), y is individual or household income, and H is the health state (Blanchflower and Oswald, 2004). The $u(y, H)$ function is the respondents' true utility, which is only observable by the individual. Therefore, $h[.]$ is a non-continuous non-differentiable function that maps actual well-being to subjective well-being. The error term, ε, captures the fact that individuals do not accurately map true utility (u) on to well-being (v).

In order to estimate a function such as (3), we can use an ordinary least squares (OLS), ordered logit or ordered probit regression (van Praag and Ferrer-i-Carbonell, 2004; Ferrer-i-Carbonell and Frijters, 2005)

$$SWB_i = \beta_0 + \beta_1 y_i + \beta_2 H_i + \beta' X + \varepsilon_i, \tag{4}$$

where SWB_i is individual i's SWB, y_i is household income, H_i is the health state, X are the personal and social characteristics, and ε_i is the standard error term. By using the estimated coefficients for the health state ($\hat{\beta}_2$) and household income ($\hat{\beta}_1$), it is possible to calculate the income compensation (IC) for the health state. Alternatively the implicit utility-constant trade-offs between health and income can be calculated.

The IC is defined as the decrease in income necessary to hold utility constant if an individual has better health (over another individual who has poor health)

$$IC = \hat{\beta}_2 / \hat{\beta}_1. \tag{5}$$

It may not be possible to generate a VPF directly using ICs, yet it should be possible to estimate a VOLY/QALY from existing data on SWB and then work backwards to the VPF (Kenkel, 2006). To illustrate this, we draw on recent work by Oswald and Powdthavee (2008) using the British Household Panel Survey (BHPS), which is an annual survey of around 10,000 people that gathers information on SWB as well as data on health and income and many other characteristics. Let us suppose that a change in health leads to an average half-point change in SWB on a 1–7 scale, and, from Oswald and Powdthavee (2008),

3 For simplicity, we have removed all other determinants from the utility function.

that an increase in income of £1 increases SWB by 1.05×10^{-5} on the same scale, then controlling for other factors and assuming linearity of income on happiness, a well-being adjusted life year (WALY) can be obtained. If the average age of the sample was 40 years old and life expectancy was 75, the VPF predicted from the WALY would be around £1.6 million.[4] This figure is based on the assumption that the health state has the same per annum, and causal, marginal effect on SWB.

As a future research agenda, existing datasets, such as the BHPS, could be used to estimate precisely the kinds of relationships and income compensations mentioned above. If we are to express QALYs in monetary terms, we need to estimate a robust income coefficient by determining the most appropriate utility function. This is far from being a straightforward issue, but data of this kind could be used to provide an alternative basis for judging the appropriateness of NICE's unofficial VPF threshold. SWB can avoid many of the problems inherent in individual preferences, particularly those that are elicited in unfamiliar contexts, and it avoids the focusing effect since respondents are not asked to attribute anything to their experienced utility (the estimated 'SWB function' does this). While the approach is still very much in its infancy in terms of methodology and economic appraisals (Dolan 2008), it provides at least another way of estimating values for health and safety that have proved so far very elusive.

References

Abelson, P. (2003), 'The value of life and health for public policy', *The Economic Record*, **79**: S2–S13.

Adler, M.D. (2003), 'Risk, death and harm: the normative foundations of risk regulation', *Minnesota Law Review*, **87**: 1293–1445.

Alberini, A. and Chiabai, A. (2007a), 'Discount rates in risk versus money and risk versus risk tradeoffs', *Risk Analysis*, **27**: 483–498.

Alberini, A. and Chiabai, A. (2007b), 'Urban environmental health and sensitive populations: how much are the Italians willing to pay to reduce their risks?', *Regional Science and Urban Economics*, **37**: 239–258.

Alberini, A., Cropper, M., Krupnick, A., and Simon, N.B. (2004), 'Does the value of statistical life vary with age and health status? Evidence from the United States and Canada', *Journal of Environmental Economics and Management*, **48**: 769–792.

Alberini, A., Cropper, M., Krupnick, A., and Simon, N.B. (2006a), 'Willingness to pay for mortality risk reductions: does latency matter?', *Journal of Risk and Uncertainty*, **32**: 231–245.

Alberini, A., Hunt, A., and Markandya, A. (2006b), 'The willingness to pay for mortality risk reductions: an EU 3-country survey', *Environmental and Resource Economics*, **33**: 251–264.

4 To compute this, we firstly use equation 5, i.e. $(0.5/1.05 \times 10^{-5}) = £48{,}000$, and then assume the VPF is an annuity that can be discounted over future time periods. Therefore, $VPF = (WALY \times A)$, where $A = [1 - (1 + r)^{-n}]/r$ and where r is the discount rate (e.g. 0.3% from Pearce and Ulph, 1995), and n is expected life years remaining (e.g. 35).

Aldy, J.E. and Viscusi, W.K. (2004) 'Age variation in workers' value of a statistical life', mimeo, John M. Olin Center for Law, Economics, and Business.

Alesina, A., Di Tella, R., and MacCulloch, R. (2004), 'Inequality and happiness: are Europeans and Americans different?', *Journal of Public Economics*, **88**: 2009–2034.

Arabsheibani, R.G. and Marin, A. (2000), 'Stability of estimates of the compensation for damage', *Journal of Risk and Uncertainty*, **20**: 247–269.

Arrow, K.J., Cropper, M.L., Eads, G.C., Hahn, R.W., Lave, L.B., Noll, R.G., Portney, P.R., Russell, M., Schmalensee, R., Smith, V.K., and Stavins, R.N. (1996), 'Is there a role for benefit–cost analysis in environmental, health, and safety regulation?', *Science*, **272**: 221–222.

Arrow, K., Solow, R., Leamer, E.E., Radner, R., and Schuman, H. (1993), 'Report of the NOAA Panel on Contingent Valuation', *Federal Register*, **58**: 4601–4614.

Bateman, I.J. and Brouwer, R. (2006), 'Consistency and construction in stated WTP for health risk reductions: a novel scope-sensitivity test', *Energy and Resource Economics*, **28**: 199–214.

Bateman, I.J., Carson, R.T., Day, B., Hamemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., Pearce, D.W., Sugden, R., and Swanson, J. (2002), *Economic Valuation with Stated Preferences: A Manual,* Edward Elgar.

Bateman, I.J., Covey, J., and Loomes, G. (2005), 'Valuing risk reductions: testing for range biases in payment card and random card sorting methods', CSERGE Working Paper EDM 05-02, University of East Anglia.

Bateman, I.J. and Jones, A.P. (2003), 'Contrasting conventional with multi-level modelling approaches to meta-analysis: an illustration using UK woodland recreation values', *Land Economics*, **79**: 235–258.

Beattie, J., Covey, J., Dolan, P., Hopkins, L., Jones-Lee, M., Loomes, G., Pidgeon, N., Robinsion, A., and Spencer, A. (1998), 'On the contingent valuation of safety and the safety of contingent valuation: part 1–caveat investigator', *Journal of Risk and Uncertainty*, **17**: 5–25.

Blanchflower, D.G. and Oswald, A.J. (2004), 'Well-being over time in Britain and the USA', *Journal of Public Economics*, **88**: 1359–1386.

Blanchflower, D.G. and Oswald, A.J. (2008), 'Hypertension and happiness across nations', *Journal of Health Economics*, **27**: 218–233.

Blomquist, G.C. (2004), 'Self protection and averting behavior, values of statistical lives, and benefit–cost analysis of environmental policy', *Review of Economics of the Household*, **2**: 89–110.

Boyle, K.J., Johnson, F.R., McCollom, D.W., Desvousges, W.H., Dunford, R.W., and Hudson, S.P. (1996), 'Valuing public goods: discrete versus continuous contingent valuation responses', *Land Economics*, **72**: 381–396.

Bray, I. and Gunnell, D. (2006), 'Suicide rates, life satisfaction and happiness as markers for population mental health', *Social Psychiatry and Psychiatric Epidemiology*, **41**: 333–337.

Brookshire, D.S. and Coursey, D.L. (1987), 'Measuring the value of a public good: an empirical comparison of elicitation procedures', *American Economic Review*, **77**: 554–566.

Carlsson, F., Johansson-Stenman, O., and Martinsson, P. (2004), 'Is transport safety more valuable in the air?', *Journal of Risk and Uncertainty*, **28**: 147–163.

Carthy, T., Chilton, S., Covey, J., Hopkins, L., Jones-Lee, M., Loomes, G., Pidgeon, N., and Spencer, A. (1999), 'On the contingent valuation of safety and the safety of contingent valuation: part 2–the CV/SG "chained" approach', *Journal of Risk and Uncertainty*, **17**: 187–213.

Carson, R.T. (1997), 'Contingent valuation: theoretical advances and empirical tests since the NOAA Panel', *American Journal of Agricultural Economics*, **79**: 1501–1507.

Carson, R.T., Flores, N.E., and Meade, N.F. (2001), 'Contingent valuation: controversies and evidence', *Environmental and Resource Economics*, **19**: 173–210.

Chilton, S., Covey, J., Jones-Lee, M., Loomes, G., and Metcalf, H. (2004), *Valuation of Health Benefits Associated with Reductions in Air Pollution: Final Report*. London: Department for Environment, Food and Rural Affairs.

Chilton, S., Jones-Lee, M., Kiraly, F., Metcalf, H., and Pang, W. (2006), 'Dread risks', *Journal of Risk and Uncertainty*, **33**: 165–182.

Clark, A. and Oswald, A.J. (2002), 'A simple statistical method for measuring how life events affect happiness', *international Journal of Epidemiology*, **31**: 1139–1144.

Corso, P.S., Hammitt, J.K., and Graham, J.D. (2001), 'Valuing mortality-risk reduction: using visual aids to improve the validity of contingent valuation', *Journal of Risk and Uncertainty*, **23**: 165–184.

Coursey, D.L., Hovis, J.J., and Schulze, W.D. (1987), 'The disparity between willingness to accept and willingness to pay measures of value', *Quarterly Journal of Economics*, **102**: 679–690.

Cropper, M.L., Aydede, S.K., and Portney, P.R. (1994), 'Preferences for life saving programs: how the public discounts time and age', *Journal of Risk and Uncertainty*, **8**: 243–265.

Cummings, R.G., Harrison, G.W., and Rutström, E.E. (1995), 'Homegrown values and hypothetical surveys: is the dichotomous choice approach incentive-compatible?', *American Economic Review*, **85**: 260–266.

Department for Transport (2007), 'Highway Economics Note No. 1: 2005 Valuation of the Benefits of Prevention of Road Accidents and Casualties', www.dft.gov.uk./pgr/roadsafety/ea/

Desaigues, B. and Rabl, A. (1995), 'Reference values for human life: an econometric analysis of a contingent valuation in France', in N. Schwab Christie and N. Soguel (eds), *Contingent Valuation: Transport Safety and the Value of Life*, Boston: Kluwer, pp. 85–112.

Desvousges, W.H., Johnson, F.R., Dunford, R.W., Hudson, S.P., Wilson, K.N., and Boyle, K.J. (1993), 'Measuring natural resource damages with contingent valuation: tests of validity and reliability', in J.A. Hausman (ed.), *Contingent Valuation: A Critical Assessment*, Amsterdam: North-Holland, pp. 91–164.

Dickie, M. and List, J. (2006), 'Economic valuation of health for environmental policy: comparing alternative approaches – introduction and overview', *Environmental and Resource Economics*, **34**: 339–346.

Dillingham, A.E., Miller, T., and Levy, D.T. (1996), 'A more general and unified measure for valuing labour market risk', *Applied Economics*, **28**: 537–542.

Di Tella, R., MacCulloch, R.J. and Oswald, A. J. (2001), 'Preferences over inflation and unemployment: evidence from surveys of happiness', *American Economic Review*, **91**: 335–337.

Di Tella, R., MacCulloch, R.J. and Oswald, A.J. (2003), 'The macroeconomics of happiness', *Review of Economics and Statistics*, **85**: 809–827.

Dolan, P. (1997), 'Modeling valuation for EuroQol health states', *Medical Care*, **35**: 1095–1108.

Dolan, P. (2000), 'The measurement of health-related quality of life for use in resource allocation decisions in health care', in A.J. Culyer and J. Newhouse (eds), *Economics Handbook of Health*, Amsterdam: North-Holland, pp. 1723–1760.

Dolan, P. (2008), 'Developing methods that really do value the "Q" in the QALY', *Health Economics, Policy and Law*, **3**: 69–77.

Dolan, P. and Kahneman, D. (2008), 'Interpretations of utility and their implications for the valuation of health', *Economic Journal*, **118**, 215–234.

Dolan, P., Peasgood, T., and White, M. (2008), 'Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being', *Journal of Economic Psychology*, **29**: 94–122.

Donaldson, C., Thomas, R., and Torgenson, D. (1997), 'Validity of open-ended and payment scale approaches to eliciting willingness to pay', *Applied Economics*, **29**: 79–84.

Drèze, J. (1962), 'L'Utilitè Sociale d'une Vie Humaine', *Revue Française de Recherche Opèrationelle*, **6**: 93–118.

Dubourg, W.R., Jones-Lee, M.W., and Loomes, G. (1997), 'Imprecise preferences and survey design in contingent valuation', *Economica*, **64**: 681–702.

Easterlin, R. (1974), 'Does economic growth improve the human lot?', in P. David and M. Reder (eds), *Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz*, New York: Academic Press, pp. 98–125.

Eeckhoudt, L.R. and Hammitt, J.K. (2001), 'Background risks and the value of a statistical life', *Journal of Risk and Uncertainty*, **23**: 261–279.

Eom, Y.S. (1994), 'Pesticide residue risk and food safety valuation: a random utility approach', *American Journal of Agricultural Economics*, **76**: 760–771.

European Union (2001), *Recommended Interim Values for the Value of Preventing a Fatality in DG Environment Cost–Benefit Analysis,* Brussels: European Union.

EUROCONTROL – European Organisation for the Safety of Air Navigation (2005), 'Standard inputs for EUROCONTROL cost–benefit analyses', www.eurocontrol.int/eatm/gallery/content/public/library

Evans, M.F. and Smith, V.K. (2006), 'Do we really understand the age-VSL relationship?', *Resource and Energy Economics*, **28**: 242–261.

Ferrer-i-Carbonel, A. and Frijters, P. (2004), 'How important is methodology for the estimates of the determinants of happiness', *Economic Journal*, **114**: 641–659.

Frey, B.S. and Stutzer, A. (2002), *Happiness and Economics*, New Jersey: Princeton University Press.

Gyrd-Hansen, D., Halvoresen, P.A., and Kristiansen, I.S. (2008), 'Willingness-to-pay for a statistical life in the times of a pandemic', *Health Economics*, **17**: 55–66.

Guria, J., Jones-Lee, M.W., Leung, J., Loomes, G., and Keall, M. (1999), 'The values of statistical life and prevention of injuries', Draft Report for the New Zealand Land Transport Safety Authority.

Guria, J., Leung, J., Jones-Lee, M., and Loomes, G. (2005), 'The willingness to accept value of statistical life relative to the willingness to pay value: evidence and policy implications', *Environmental and Resource Economics*, **32**: 113–127.

Hammar, H. and Johansson-Stenman, O. (2004), 'The value of risk-free cigarettes – do smokers underestimate the risk?', *Health Economics*, **13**: 59–71.

Hammitt, J. (2000), 'Valuing mortality risk: theory and practice', *Environmental Science and Technology*, **34**: 1396–1400.

Hammitt, J.K. and Graham, J.D. (1999), 'Willingness to pay for health protection: inadequate sensitivity to probability?', *Journal of Risk and Uncertainty*, **18**: 33–62.

Hammitt, J. and Liu, J.-T. (2004), 'Effects of disease type and latency on the value of mortality risk', *Journal of Risk and Uncertainty*, **28**: 73–95.

Hammitt, J., Liu, J.-T. and Liu, J.-L. (2003), 'Is survival a luxury good? The increasing value of a satistical life', paper presented for the NBER Summer Institute on Public Policy, August 2000.

Hammitt, J.K. and Zhou, Y. (2006), 'the economic value of air-pollution-related health risks in china: a contingent valuation study', *Environmental and Resource Economics*, **33**: 399–423.

Hanemann, W.M. (1991), 'Willingness to pay and willingness to accept: how much can they differ?', *American Economic Review*, **81**: 635–647.

Herriges, J. and Shogren, J. (1996), 'Starting point bias in dichotomous choice valuation with follow-up questioning', *Journal of Environmental Economics and Management*, **30**: 112–131.

Hirth, R.A., Chernew, M.E., Miller, E., Fendrick, M.F., and Weissert, W.G. (2000), 'Willingness to pay for a quality-adjusted life year: in search of a standard', *Medical Decision Making*, **20**: 332–342.

HM Treasury (2003), *The Green Book: Appraisal and Evaluation in Central Government*, London: HMSO.

HM Treasury (2005), *Managing Risks to the Public: Appraisal Guidance*. Norwich: HMSO.

Ho, M.S. and Nielsen, C.P. (2007), *Clearing the Air: The Health and Economic Damages of Air Pollution in China*, Cambridge, MA: MIT Press.

Horowitz, J.K. and Carson, R.T. (1990), 'Discounting statistical lives', *Journal of Risk and Uncertainty*, **3**: 403–413.

Horowitz, J.K. and McConnell, K.E. (2002), 'A review of WTA/WTP studies', *Journal of Environmental Economics and Management*, **44**: 426–447.

Health and Safety Executive (HSE) (2001), *Reducing Risks Protecting People: HSE's Decision Making Process,* Norwich: HMSO.

Itaoka, K., Krupnick, A., Akai, M., Alberini, A., Cropper, M., and Simon, N. (2005), 'Age, health, and the willingness to pay for mortality risk reductions: a contingent valuation survey in Japan', *Resources for the Future Discussion Paper No. 05-34*. Washington, DC: Resources for the Future.

Johannesson, M. and Johansson, P.-O. (1996), 'To be, or not to be, that is the question: an empirical study of the WTP for an increased life expectancy at an advanced age', *Journal of Risk and Uncertainty*, **13**: 163–174.

Johannesson, M. and Meltzer, D. (1998), 'Some reflections on cost effectiveness analysis', *Health Economics*, **7**: 1–7.

Jones-Lee, M.W. (1974), 'The value in changes in the probability of death or injury', *Journal of Political Economy*, **99**: 835–849.

Jones-Lee, M.W. (1989), *The Economics of Safety and Physical Risk,* Oxford: Blackwell.

Jones-Lee, M.W. and Loomes, G. (1995), 'Discounting and safety', *Oxford Economic Papers*, **47**: 501–512.

Jones-Lee, M.W., Loomes, G., and Philips, P.R. (1995), 'Valuing the prevention of non-fatal road injuries: contingent valuation vs standard gambles', *Oxford Economic Papers*, **47**: 676–695.

Kahneman, D., Knetsch, J.L., and Thaler, R.H. (1990), 'Experimental tests of the endowment effect and the Coase Theorem', *Journal of Political Economy*, **98**: 1325–1348.

Kahneman, D. and Krueger, A.B. (2006), 'Developments in the measurement of subjective well-being', *Journal of Economic Perspectives*, **20**: 3–24.

Kahneman, D., Slovic, P., and Tversky, A. (1982), *Judgment under Uncertainty: Heuristics and Biases,* Cambridge: Cambridge University Press.

Kahneman, D., Wakker, P.P., and Sarin, R. (1997), 'Back to Bentham? Explorations of experienced utility', *Quarterly Journal of Economics*, **112**: 375–404.

Kahneman, A., Krueger, A.B., Schkade, D.A., Schwarz, N., and Stone, A.A. (2004), 'A survey method for characterizing daily life experience: the day reconstruction method', *Science*, **306**: 1776–1780.

Kahneman, D. and Sugden, R. (2005), 'Experienced utility as a standard of policy evaluation', *Environmental and Resource Economics*, **32**: 161–181.

Kahneman, D. and Tversky, A. (1979), 'Prospect theory: an analysis of decision under risk', *Econometrica*, **47**: 263–291.

Kaplow, L. (2005), 'The value of a statistical life and the coefficient of relative risk aversion', *Journal of Risk and Uncertainty*, **31**: 23–34.

Kealy, M.J. and Turner, R.W. (1993), 'A test of equality of closed-ended and open-ended contingent valuations', *American Journal of Agricultural Economics*, **75**: 321–331.

Kenkel, D. (2006), 'WTP- and QALY-based approaches to valuing health for policy: common ground and disputed territory', *Environmental and Resource Economics*, **34**: 419–437.

Kidholm, K. (1995), 'Assessing the value of traffic safety using the contingent valuation technique: the Danish survey', in N.G. Schwab Christie and N.C. Soguel (eds), *Contingent Valuation, Transport Safety and the Value of Life,* Boston: Kluwer, pp. 45–61.

Knetsch, J.L. and Sinden, J.A. (1984), 'Willingness to pay and compensation demanded: Experimental evidence of an unexpected disparity in measures of value', *Quarterly Journal of Economics*, **99**: 507–521.

Kniesner, T.J. and Leeth, J.D. (1991), 'Compensating wage differentials for fatal injury risk in Australia, Japan, and the United States', *Journal of Risk and Uncertainty*, **4**: 75–90.

Kniesner, T.J. and Viscusi, W.K. (2005), 'Value of a statistical life: relative position vs. relative age', *American Economic Review*, **95**: 142–146.

Kniesner, T.J., Viscusi, W.K., Woock, C. and Ziliak, J.P. (2006), 'Pinning down the value of a statistical life', Center for Policy Research Working Paper No. 85, Maxwell School of Citizenship and Public Affairs, Syracuse University.

Kochi, I., Hubbell, B. and Kramer, R. (2006), 'An empirical Bayes approach to combining and comparing estimates of the value of a statistical life for environmental policy analysis', *Environmental and Resource Economics*, **34**: 385–406.

Kriström, B. (1993), 'Comparing continuous and discrete contingent valuation questions', *Environmental and Resource Economics*, **3**: 63–71.

Krupnick, A., Alberini, A., Cropper, M., Simon, N., O'Brien, B., Goeree, R., and Heintzelman, M. (2002), 'Age, health, and the willingness to pay for mortality risk reductions: a contingent valuation survey of Ontario residents', *Journal of Risk and Uncertainty*, **24**: 161–186.

Lin, C.-T.J. and Milon, J.W. (1995), 'Contingent valuation of health risk reductions for shellfish products', in J.A. Caswell (ed.), *Valuing Food Safety and Nutrition* Boulder, CO: Westview Press, pp. 83–114.

List, J.A. (2001), 'Do explicit warnings eliminate the hypothetical bias in elicitation procedures? Evidence from field auctions for sportscards', *American Economic Review*, **91**: 1498–1507.

Liu, J.-T., Hammitt, J.K., and Liu, J.-L. (1997), 'Estimated hedonic wage function and value of life in a developing country', *Economics Letters*, **57**: 353–358.

Loewenstein, G. (1996), 'Out of control: visceral influences on behavior', *Organizational Behavior and Human Decision Processes*, **65**: 272–292.

Loewenstein, G.F., Hsee, C.K., Weber, E.U. and Welch, N. (2001), 'Risk as feelings', *Psychological Bulletin*, **127**: 267–286.

Loewenstein, G. and O'Donoghue, T. (2004), 'Animal spirits: affective and deliberative processes in economic behavior', mimeo, Carnegie-Mellon University.

Loomes, G. (2002), 'Valuing life years and QALYs: transferability and convertibility of values across the UK public sector', in A. Towse, C. Pritchard and N. Devlin (eds), *Cost-effectiveness Thresholds: Economic and Ethical Issues*, Kings Fund, pp. 46–55.

Mason, H., Marshall, A., Jones-Lee, M., and Donaldson, C. (2004), 'Estimating a monetary value of a QALY from existing UK values of prevented fatalities and serious injuries', mimeo. University of Newcastle.

Miller, T.R. (2000), 'Variations between countries in values of statistical life', *Journal of Transport Economics and Policy*, **34**: 169–188.

Miller, T. and Guria, J. (1991), *The Value of Statistical Life in New Zealand*, Wellington, NZ: New Zealand Ministry of Transport.

Mitchell, R.C. and Carson, R.T. (1986), *Valuing Drinking Water Risk Reductions Using the Contingent Valuation Method: A Methodological Study of Risks from THM and Giardia*, Washington, DC: Resources for the Future.

Mitchell, R.C. and Carson, R.T. (1989), *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington, DC: Resources for the Future.

Moore, M.J. and Viscusi, W.K. (1990), 'Models for estimating discount rates for long-term health risks using labor market data', *Journal of Risk and Uncertainty*, **3**: 381–401.

Morris, J. and Hammitt, J.K. (2004), 'Using life expectancy to communicate benefits of health care programs in contingent valuation studies', *Medical Decision Making*, **21**: 468–478.

Mrozek, J.R. and Taylor, L.O. (2002), 'What determines the value of life? A meta-analysis', *Journal of Policy Analysis and Management*, **22**: 253–270.

NICE Guidance 93 (2005), 'Irinotecan, oxaliplatin, and reltitrexed for the treatment of advanced colorectal cancer', *Review of Technology Appraisal* **33**.

NICE Guidance 116 (2007), 'Gemcitabine for the treatment of metastatic breast cancer', *NICE Technology Appraisal Guidance 116*.

Olson, C.A. (1981), 'An analysis of wage differentials received by workers on dangerous jobs', *Journal of Human Resources*, **16**: 167–185.

Oswald, A. J. and Powdthavee, N. (2008), 'Death, happiness, and the calculation of compensatory damages', *Journal of Legal Studies*, forthcoming.

Pearce, D. (2000), 'Valuing risks to life and health: towards consistent transfer estimates in the European Union and accession states', Prepared for the European Commission (DGXI) Workshop on Valuing Mortality and Valuing Morbidity, 13 November 2000, Brussels, Revised December 2000.

Pearce, D., Atkinson, G., and Mourato, S. (2006), *Cost–Benefit Analysis and the Environment: Recent Developments*, Paris: OECD.

Pearce, D.W., Dubourg, R., Day, B., Atkinson, G., Navrud, S., Ready, R., Kuik, O., Spanincks, F., Labandeira-Villot, X., Vasques Rodrigues, M., Machado, F., and Mourato, S. (1999), 'Benefit transfer and the economic valuation of environmental damage in the European Union with special reference to health', Final Report: Summary, Final Report, Annexes, CEC, DGXII, Brussels.

Pearce, D. and Ulph, D. (1995). 'A social discount rate for the united kingdom', Working Paper GEC 95-01, Centre for Social and Economic Research on the Global Environment, UK.

Persson, U. and Cedervall, M. (1991), 'The value of risk reduction: results of a Swedish sample survey', IHE Working Paper 1991: 6, Swedish Institute of Health Economics.

Persson, U., Norinder, A., Halte, K., and Gralen, K. (2001), 'The value of a statistical life in transport: findings from a new contingent valuation survey in Sweden', *Journal of Risk and Uncertainty*, **23**: 121–134.

Persson, U., Lugner Norinder, A., and Svensson, M. (1995), 'Valuing the benefits of reducing the risk of non-fatal road injuries: the Swedish experience', in N.G. Schwab Christie and N.C. Soguel (eds), *Contingent Valuation, Transport Safety and the Value of Life*, Boston: Kluwer, pp. 63–83.

Pratt, J.W. and Zeckhauser, R.J. (1996), 'Willingness to pay and the distribution of risk and wealth', *Journal of Political Economy*, **104**: 747–763.

Rosen, S. (1988), 'The value of changes in life expectancy', *Journal of Risk and Uncertainty*, **1**: 285–304.

Rottenstreich, Y. and Hsee, C.K. (2001), 'Money, kisses, and electric shocks: on the affective psychology of risk', *Psychological Science*, **12**: 185–190.

Rumbelow, H. and Miles, A. (2007), 'When caring clashes with costs – the nasty business of being NICE', *The Times*, 13 January 2007. www.timesonline.co.uk/to1/newspapers/sundaytimes/britain/article1292310.ece

Ryan, M., Scott, D.A., and Donaldson, C. (2004), 'Valuing health care using willingness to pay: a comparison of the payment card and dichotomous choice methods', *Journal of Health Economics*, **23**: 237–258.

Shepard, D.S. and Zeckhauser, R.J. (1982), 'Life-cycle consumption and willingness to pay for increased survival', in M.W. Jones-Lee (ed.), *Valuation of Life and Safety*, Amsterdam: North-Holland, pp. 95–141.

Slovic, P. (1987), 'Perception of risk', *Science*, **236**: 280–285.

Slovic, P., Fischhoff, S. and Lichtenstein, S. (1980), 'Facts and fears: understanding perceived risk', in R. Schwing and W.A. Albers Jnr (eds), *Societal Risk Assessment: How Safe is Safe Enough?* New York: Plenum, pp. 181–216.

Smith, R.D. (2003), 'Construction of the contingent valuation market in health care: a critical assessment', *Health Economics*, **12**: 609–628.

Smith, R.D. (2006), 'It's not just *what* you do, it's the *way* that you do it: the effect of different payment card formats and survey administration on willingness to pay for health gain', *Health Economics*, **15**: 281–293.

Smith, R.D. and Richardson, J. (2005), 'Can we estimate the ''social'' value of a QALY? Four core issues to resolve', *Health Policy*, **74**: 77–84.

Smith, V.K., Evans, M.F., Kim, H., and Taylor, D.H. (2004), 'Do the near-elderly value mortality risks differently?', *Review of Economics and Statistics*, **86**: 423–429.

Steptoe, A., Wardle, J., and Marmot, M. (2005), 'Positive affect and health-related neuroendocrine, cardiovascular, and inflammatory processes', *Proceedings of the National Academy of Science of the United States*, **102**: 6508–6512.

Stewart, J.M., O'Shea, E., Donaldson, C., and Shackley, P. (2002), 'Do ordering effects matter in willingness to pay studies of health care?', *Journal of Health Economics*, **21**: 585–599.

Sugden, R. (2005), 'Anomalies and state preference techniques: a framework for a discussion of coping strategies', *Environmental and Resource Economics*, **32**: 1–12.

Sunstein, C.R. (1997), 'Bad deaths', *Journal of Risk and Uncertainty*, **14**: 259–282.

Sunstein, C.R. (2004), 'Are poor people worth less than rich people? Disaggregating the value of statistical lives', University of Chicago Law and Economics, Olin Working Paper No. 207; AEI-Brookings Joint Center Working Paper No. 04-05.

Tolley, G.S., Kenkel, D.S., and Fabian, R. (1994), *Valuing Health for Policy: An Economic Approach*, Chicago: University of Chicago Press.

Tversky, A. and Kahneman, D. (1991), 'Loss aversion in riskless choice: a reference-dependent model', *Quarterly Journal of Economics*, **106**: 1039–1061.

US Environmental Protection Agency (1997), 'The benefits and costs of the Clean Air Act: 1970–1990', 410-R-97-002.

van Praag, B.M.S. and Baarsma, B.E. (2005), 'Using happiness surveys to value intangibles: the case of airport noise', *Economic Journal*, **115**: 224–246.

van Praag, B.M.S. and Ferrer-i-Carbonell, A. (2004), *Happiness Quantified: A Satisfaction Calculus Approach*, Oxford: Oxford University Press.

Viscusi, W.K. (1998), *Rational Risk Policy*, Oxford: Oxford University Press.

Viscusi, W.K. and Aldy, J. (2003), 'The value of statistical life: a critical review of market estimates throughout the world', *Journal of Risk and Uncertainty*, **27**: 5–76.

Weinstein, M.C., Shepard, D.S., and Pliskin, J.S. (1980), 'The economic value of changing mortality probabilities: a decision-theoretic approach', *Quarterly Journal of Economics*, **94**: 373–396.

Whynes, D.K., Wolstenhulme, J.L. and Frew, E. (2004), 'Evidence of range bias in contingent valuation payment scales', *Health Economics*, **13**: 183–190.