Age effects in monetary valuation of reduced mortality risks: the relevance of age-specific hazard rates

Andrea M. Leiter

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Abstract This paper highlights the relevance of age-specific hazard rates in explaining the age variation in “value of statistical life” (VSL) figures. The analysis—which refers to a stated preference framework—contributes to the ongoing discussion of whether benefits resulting from reduced mortality risk should be valued differently depending on the age of the beneficiaries. By focussing on a life-threatening environmental phenomenon I show that the consideration of the individual’s age-specific hazard rate is important. If a particular risk affects all individuals regardless of their age so that their hazard rate is age-independent, VSL is rather constant for people at different age; if hazard rate varies with age, VSL estimates are sensitive to age. The results provide an explanation for the mixed outcomes in empirical studies and illustrate in which cases an adjustment to age may or may not be justified. Efficient provision of live-saving measures requires that such differences to be taken into account.

Keywords Health risk prevention · Value of statistical life · Age effects · Hazard rate · Contingent valuation

JEL Classification D81 · J17 · Q26

Introduction

To reduce mortality risks and hence save people’s lives, various risk reduction programmes are generally available.

They differ in their effectiveness regarding the number and groups of beneficiaries. For example, reducing air pollution leads to a reduction in respiratory diseases, which saves the lives of primarily the youngest and oldest groups of the population, while only working people benefit from reduced work place risks. If budget constraints are relevant, the question emerges how restricted resources should be distributed across the available life-saving measures so that social benefits are maximised.

An economic approach to evaluate the benefits resulting from reduced health risks is the concept of “value of statistical life” (VSL). The VSL provides a monetary measure of health benefits and represents the ratio at which people are willing to exchange income for risk changes. The VSL is often inferred from information about the individual willingness-to-pay (WTP) to prevent mortality risks. It is an ongoing discussion whether the financing of life-saving measures should be adjusted to individual characteristics (for a comprehensive discussion, see Sunstein 2004). Adjustment according to age has provoked particularly intense debate. Government agencies pursue different approaches regarding the use of such a “senior discount”. For example, while the European Commission DG Environment recommends an adjustment to age (European Commission 2000), an age-dependent VSL is not applied by the US Environmental Protection Agency (Environmental Protection Agency 2003, p. 37). These different governmental approaches may result from ambiguous findings in the literature with respect to age effects on VSL.

The purpose of this paper is to investigate empirically the importance of hazard rates in explaining the ambiguity discussed in theoretical and empirical literature regarding the age-sensitivity of the VSL. In contrast to previously published preference studies, the relevance of an individuals’ probability of dying for VSL estimates is analysed by

A. M. Leiter (✉)
Department of Economics and Statistics, University
of Innsbruck, Universitätsstraße 15, 6020 Innsbruck, Austria
e-mail: andrea.leiter@uibk.ac.at

using information on a particular risk specification that allows for distinguishing explicitly between two groups exposed to the same risk type. In this paper, mortality risk is defined as the probability of dying in a snow avalanche. While one group (skiers) faces an age-dependent hazard rate, the hazard rate of the others (non-skiers) is rather insensitive to individual characteristics. The paper addresses the question of whether people benefit differently from reduced mortality risks, in particular, whether WTP and VSL is sensitive to age once the individual mortality risk (which can be either sensitive or insensitive to age) is taken into account. Age is considered by calculating the WTP and VSL for particular age classes.

I find that the individual hazard rate associated with a particular risk plays a crucial role in explaining the age dependency of VSL measures. Age effects do occur for skiers but are not present for non-skiers. Accordingly, adjustment to age may be justified only in cases where the individual probability of dying varies with age.

The paper is organised into the following sections: “[Review of literature](#)” examines the literature dealing with the estimation of VSL and its age dependency, “[Survey design](#)” describes socio-economic characteristics, survey setting and wording of risk. “[Estimation procedure](#)” explains model specification, VSL, and age effects. “[Results](#)” summarises the overall effects. “[Conclusion](#)” presents resolving remarks.

Review of related literature

The literature dealing with estimation of VSL is extensive. VSL is discussed in various contexts, such as valuation of reduced health risks (e.g. cancer, respiratory diseases, cardiovascular diseases), work place risks, traffic risks, or risks arising from natural hazards.¹ In general, VSL estimates are dependent on whether they are based on one’s overall risk of dying or on a very specific risk of dying, the profile of future income, the remaining life expectancy or the individuals’ baseline risk. Among these determinants, the relevance of age in mortality risk assessment is of ongoing interest and has been discussed and analysed in several studies.² The theoretical literature defines two key components of how age affects the monetary valuation of reduced mortality risks: (1) the individual hazard rate (probability of dying), and (2) the level of optimal consumption.

¹ For example, see Alberini et al. (2004, 2006), Johannesson et al. (1997), Jones-Lee et al. (1985), Liu et al. (2007).

² See Hammitt (2007), Aldy and Viscusi (2007), and Krupnick (2007) for a comprehensive discussion of the background and overview of the relevant literature.

Shepard and Zeckhauser (1984) discuss the trade-off between an increase in survival probability and the level of consumption. In their simulations, the authors demonstrate that the profile of WTP with respect to age depends on the existence of markets for borrowing and annuities, as such markets influence the individuals’ income over time and, hence, the individual consumption path. If no markets exist, the WTP for risk reductions follows an inverted-U shape, with lower values for the youngest and oldest individuals in the population and a peak of payments at the age of 40. However, this shape is dampened considerably when perfect markets for borrowing and annuities are available. A further theoretical discussion of age effects on VSL is provided in Johannesson (2002) or Alberini et al. (2004). These authors also analyse the role of individual hazard rates and the utility of income and argue that theory does not support a general decline of VSL with age. They conclude that, depending on the age sensitivity of the hazard rate and the utility of income, the VSL can either remain age-independent, increase, or decrease with increasing age.

Such theoretical discussions show that age can influence the VSL quite differently. Empirical studies provide evidence for this ambiguous picture. For example, Smith et al. (2004) estimate the VSL for older workers by observing their behaviour (wage-risk trade-offs) on the labour market. Their findings show an increase of compensation requirements with increasing age, which is mirrored in higher VSL figures for older employees. Viscusi and Aldy (2007) examine how VSLs vary with age across the working population considering age-specific fatality risks. Their VSL estimates for different age classes project an inverted U-shape, indicating that VSL figures first rise and then fall with age. A considerable decrease of VSL with age is found in Alberini et al. (2005), in which the authors estimate the WTP for reduced cardiovascular and respiratory risks. According to their results, people in their 70s state values that are about three-quarters lower than the statements of 30-year-old respondents. Alberini et al. (2004) examine the influence of age and health risks on VSL using data from two contingent valuation studies conducted in Canada and the US. They analyse the individuals’ WTP for a reduction in their overall mortality risk—without pointing at a specific risk—and find weak (no) evidence for decreasing VSL with increasing age in the Canadian (US) sample. Liu et al. (2005) refer to mortality risks due to severe acute respiratory syndrome (SARS) and do not find any influence of age on WTP to eliminate the chance of becoming infected.

Based on these examples, I argue that the individual probability of dying associated with a particular risk type plays a crucial role. For instance, while workplace risks or cardiovascular risks are age-dependent and affect a

particular group of individuals (job risks: working population; cardiovascular risks: elderly people), people of all ages are potentially in danger of becoming infected with some viruses. The following sections describe in detail how the assumption that the individual probability of dying is an important factor in the monetary valuation process for reduced health risks is tested in a stated preference framework.³

Survey design

Socio-economic characteristics

This paper analyses responses from a contingent valuation survey conducted in September/October 2004 and February 2005 in Tyrol, a federal state of Austria. A randomised quota sample of 1,997 individuals was drawn from the Tyrolean population aged over 15 years. The quota applied to the subjects' district of residence and size of domicile. Within the quota, random sampling was used. The respondents were asked in face-to-face interviews at their permanent residences about their WTP to prevent an increase in the risk of dying in a snow avalanche.⁴ Table 1 compares the socio-demographic characteristics of survey participants and the population of Tyrol to give an insight into how well the sample represents the population.

A comparison of the sample characteristics with the census attributes shows a good approximation to the population characteristics in gender, birth place, and income,⁵ while the divergence in age, children per capita, and smoking behaviour is considerable. The self-reported

health⁶ in the sample conforms quite well with the census average. The differences between the sample and census with respect to education and employment may result from the younger age of individuals in the sample.

Survey setting and wording of risk

In order to control for the sensitivity of WTP to the dimension of risk variation (=“scope effects”) two different risk changes were incorporated in the questionnaire: participants in the winter survey were asked about their WTP to prevent a doubling or quadruplication of the baseline risk.⁷ The initial risk level was inferred from official statistics. Risk prevention was assumed to come from passive control measures against avalanches, i.e. fatal avalanche accidents could be reduced by means of constructions such as tunnels or barriers. In the underlying study it was assumed that an increase in risk is avoidable by means of maintenance of pre-existing risk reduction programmes. The reduction in question was described as follows (divergence in wording for the larger risk variation in parentheses):

Several risk reduction programmes against avalanches on roads and in residential areas have been implemented in Tyrol. At present, on average 2.35 people out of 100,000 inhabitants are killed by avalanches annually. Assume that all public funds for maintaining these measures will be cut, and so servicing costs henceforth have to be paid exclusively out of private funds. If aggregate private contributions are too small, maintenance is not carried out, and the probability of a fatal avalanche doubles (quadruples). Then, on average, 4.7 (9.4) people out of 100,000 inhabitants die in avalanche-related accidents (see Fig. 1). Would you be willing to pay—given your income constraint—a monthly insurance premium of € 2.5/5/10 to maintain the effect of previous risk reduction programmes to save human lives?

Respondents were assigned randomly to one of three versions that differ in the bid vector. The initial bids of versions 1, 2 and 3 are 2.5, 5, and 10, respectively. Depending on the response to the first question,

³ Viscusi and Aldy (2007) provide a discussion of how an individuals' hazard rate influence VSL estimates in a revealed preference framework.

⁴ Snow avalanches are a common phenomenon in winter and affect skiers but also residents. This is due to the topographical characteristics of residential areas in Tyrol. Tyrol is situated in the middle of the Alps. One-third of its 12,600 km² area is not habitable (glaciers, rocks, mountain pastures). Residential areas are often located in rather steep terrain or are at least surrounded by mountains. Although public and private institutions (communities, ski resorts) take various precautions (e.g. construction and maintenance of tunnels and barriers, premature blasting of dangerous accumulations of snow) to protect individuals on roads, in residential areas and in ski resorts an element of risk remains. The 10-year average of avalanche-related fatalities amounts to 16 deaths per year.

⁵ Unfortunately 43.5% did not answer the question relating to their income, which complicates the estimation of the income effect. In order to avoid losing these observations, a single imputation method (Davey et al. (2001), Little and Rubin (1987), Whitehead (1994)) was applied and missing income is replaced by the mean income of employed persons in the individual's residence. In addition, a dummy variable is generated which equals 1 in cases where a replacement has been made to control for potential influences of the imputation.

⁶ Health categories were provided in the form of functionality examples (healthy: no diseases or only occasional short-lived diseases such as flu; moderate illness: chronic diseases such as hay fever and allergies; severe illness/severe disability: severe chronic illness or severe physical impairment, in need of long-term care).

⁷ 992 respondents in autumn and 672 in winter were asked to value the prevention of an increase from 1/42,500 to 2/42,500 (=group 1). 333 individuals (=group 2) in the winter sample based their decisions on a hypothetical prevention of a three times higher increase from 1/42,500 to 4/42,500 (=quadruplication of baseline risk).

Table 1 Sample and population characteristics

Variable	Sample		Census
	Observations ^f	Mean	Mean
Sex of respondent (female = 1, 0 otherwise)	1996	0.53	0.52 ^a
Age of respondent (in years)	1954	37.08	43.79 ^a
Marital status of respondent (single = 1, 0 otherwise)	1958	0.39	0.35 ^a
Number of household members	1982	2.82	2.56 ^{b,c}
Children per capita	1997	0.42	0.23 ^a
Birthplace of respondent (Austria = 1, 0 otherwise)	1997	0.89	0.88 ^{a,c}
Smoking behaviour (smoker = 1, 0 otherwise)	1988	0.51	0.30 ^c
Personal take-home income per month (in 1,000 €)	1128	1.08	1.11 ^d
Self reported health status of respondent			
Healthy	1937	0.76	0.80 ^c
Moderate illness	1937	0.20	0.16 ^c
Bad illness/bad disability	1937	0.04	0.04 ^c
Education of respondent			
Elementary/junior high school	1967	0.22	0.37 ^a
Apprenticeship	1967	0.33	0.33 ^a
Vocational school	1967	0.16	0.13 ^a
Secondary school/post-secondary courses ^{II}	1967	0.20	0.10 ^a
College/university	1967	0.09	0.07 ^a
Employment status of respondent			
Employed full time (38 working hours per week)	1967	0.53	0.48 ^c
Employed part-time	1961	0.10	0.07 ^c
Employed short-time (monthly income not over € 323.46)	1967	0.02	0.03 ^c
Retired	1961	0.12	0.22 ^c
Homemaker	1961	0.03	0.10 ^c
Student	1961	0.11	0.06 ^c
Unemployed	1961	0.02	0.03 ^c
Others	1961	0.06	0.02 ^c

The survey sample refers to Tyroleans ≥ 15 years old interviewed in September/October 2004 and February 2005. The Census represents the whole population of Tyrol (=673,504) in 2001 (exceptions are noted). Where feasible, children < 15 (=123,855) were excluded from comparisons

^f Differences in numbers of observations due to missing data

^{II} The Austrian educational system provides a 2-year-programme (“post-secondary courses”) designed for students who did not get vocational education in their secondary school

^a Population in 2001. Source: Statistics Austria. Statistical Yearbook 2005, Table 2.14

^b Source: Tyrolean Provincial Government 2004. Tyrolean Population—Results of the Census 2001, Table 25

^c Population in 1999 > 15 years. Source: Tyrolean Provincial Government 2003. Gesundheitsbericht 2002, Table 3.4.1

^d Monthly take-home income (=annual income/14; in 1,000 €) of employees in 2003. Source: Statistics Austria, Statistical Yearbook 2005, Table 9.07

^e Exclusion of children was not possible

participants were asked whether they would also pay 5 (version 1)/10 (version 2)/20 (version 3) Euros in case of a “yes” answer to the initial question, or 1.3 (version 1)/2.5 (version 2)/5 (version 3) Euros if the reply to the first question was “no”.⁸ If the interviewees’ answers were “no; no” or “do not know; no” they were asked whether they

would pay anything at all and why they refused payment.⁹ Individual responses were classified as protest answers if the interviewees stated that they generally refuse payments for protection against natural hazards or if it was argued

⁸ To define the range of the bid vector, information from a previous pre-test sample was used.

⁹ Though only yes/no answer possibilities were offered, a “do not know” response was accepted. To ensure conservative estimates, the “do not know” responses were interpreted as negative responses and are included in the analysis. See Carson et al. (1998) for a related discussion.

Fig. 1 Causes of deaths in Tyrol in the year 2002

that the protection of citizens was the responsibility of the government. Protesters ($N = 329$) were excluded from further analyses.¹⁰

Avalanche protection of roads and residential areas are usually financed by national, federal and municipal funding. Analogous to the Austrian social security system, which finances publicly provided health services through compulsory insurance premiums, ‘insurance premium’ was used as a parafiscal payment vehicle that respondents are familiar with. This approach was chosen to avoid respondents’ negative attitudes towards taxes.¹¹

In order to reduce the difficulty of interpreting small risk variations (Kunreuther et al. 2001, Shanteau and Ngui 1989), I considered the recommendation of Corso et al. (2001) and visualised the risk change in question. In the Tyrolean study, a logarithmic scale was implemented to picture the risk variation (see Fig. 1; graph shown for the smaller change). The bottom and top indicate low and high risk, respectively. Along the risk ladder, other mortality risks, such as cancer, AIDS, or car accidents were plotted to enable a comparison and relative estimate. Additionally, the magnitude of the risks was also stated as number of affected persons in differently sized populations (e.g. small town, city).

¹⁰ A sensitivity analysis shows that the results and implications regarding age effects still hold if this group were included.

¹¹ Supportive arguments for this procedure are given in Hackl and Pruckner (2005) and Olsen et al. (2004).

Estimation procedure

Model specification

This section links the theoretical background of VSL and the econometric approach chosen in this paper and refers to the arguments given in Johansson (2001).

Reductions in mortality risk are commonly evaluated within a state-dependent utility framework (Jones-Lee 1974; Pratt and Zeckhauser 1996; Weinstein et al. 1980). It is assumed that individuals substitute income, y , for a risk change, Δp , so as to maximise their expected utility. Johansson (2001) looks at this maximisation problem using a life-cycle VSL approach, explicitly considering the influence of age on the VSL. This approach assumes that individuals maximise their expected remaining present value utility (ERPvU) subject to a dynamic budget constraint. Solving the maximisation problem results in the maximal ERPvU at age τ , denoted by $V_\tau(\tau)$, conditional on having survived until age τ (for details, see Johansson 2001):

$$V_\tau(\tau) = \int_{\tau}^{\infty} u[c^*(t)]e^{-\theta(t-\tau)}\mu(t;\tau)dt \quad (1)$$

$u[c^*(t)]$ denotes the utility derived from the optimal consumption level at age t , $c^*(t)$, with $t \geq \tau$, θ represents the marginal rate of time preference and is assumed to be a constant, and $\mu(t;\tau) = \frac{\mu(t)}{\mu(\tau)}$ stands for the survival function conditional on attaining age τ with

$\mu(t) = e^{-\int_0^t \gamma(s)ds}$ and the hazard function $\gamma(s)$.¹² Consider a decrease in the hazard rate and the associated change in the ERPVU:

$$dV_\tau(\tau) = \int_{\tau+T}^{\infty} u[c^*(t)]e^{-\theta(t-\tau)} d\mu(t; \tau) \quad (2)$$

with $\tau + T$ referring to the point in time when the risk reduction starts and $d\mu(t; \tau)$ representing the time change in the survival function resulting from the change in the hazard rate. In the VSL context, this change in the hazard rate is outweighed by a payment CV so that the ERPVU remains unchanged. Using the first order condition, one obtains

$$\int_{\tau+T}^{\infty} u[c^*(t)]e^{-\theta(t-\tau)} d\mu(t; \tau) - \lambda^*(\tau)dCV(\tau) = 0 \quad (3)$$

The first term represents the change in utility due to the change in risk. $\lambda^*(\tau)$ stands for the dynamic Lagrange multiplier that results from differentiating the Hamiltonian function (Johannesson et al. 1997). The dynamic Lagrange multiplier can be interpreted as the expected present value of marginal utility of income at age τ (Johansson 2001). dCV describes the amount of money an individual at age τ is willing to pay today to achieve a decrease in the hazard rate for the rest of the individual's lifetime. If consumption does not change over time,¹³ Eq. 3 can be written as

$$\frac{u[c^*]}{\lambda^*(\tau)} = \frac{dCV(\tau)}{\int_{\tau+T}^{\infty} e^{-\theta(t-\tau)} d\mu(t; \tau)} \quad (4)$$

which can be again converted to

$$\frac{V_\tau(\tau)}{\lambda^*(\tau)} = dCV(\tau) \frac{\int_{\tau}^{\infty} e^{-\theta(t-\tau)} \mu(t; \tau) dt}{\int_{\tau+T}^{\infty} e^{-\theta(t-\tau)} d\mu(t; \tau)} \quad (5)$$

The left hand side of Eq. 5 denotes the ERPVU, which is transformed to monetary units by dividing by the marginal utility of income $\lambda^*(\tau)$. The numerator on the right hand side summarises the expected remaining discounted life years, and the denominator indicates the expected increase in discounted life years due to risk reducing programmes. Equation 5 defines the VSL $\left(\frac{V_\tau(\tau)}{\lambda^*(\tau)}\right)$ as the trade-off between

income ($dCV = WTP$) and reduced mortality risk (gain in life expectancy).

In the present contingent valuation survey, respondents were asked directly about their maximum WTP to avoid an increase in avalanche risks (Δp) from current levels. Individuals' WTP statements are summarised into six age classes. In this case, the VSL in a particular age group j is approximated by

$$VSL_j = WTP_j / \Delta p. \quad (6)$$

The payment question has a double bounded dichotomous choice (DBDC) format. It follows that the "true" WTP cannot be observed but has to be estimated from the yes/no answers of the respondents. One can thus infer whether WTP is above (below) a specific amount if the respondent answers "yes" ("no") to the payment question. Let us assume that WTP can be described as unobserved latent variable WTP_i^* by:

$$WTP_i^* = \mathbf{X}_i \beta + \epsilon_i \quad (7)$$

where $\mathbf{X}_i$ is a $1 \times k$ matrix of variables representing characteristics of individual i as well as risk relating attitudes, β is a $k \times 1$ vector of coefficients which has to be estimated and ϵ stands for the error term. What is known is the probability of an affirmative response to the payment question. The sequence of the yes (y) and no (n) answers is pictured by the following dummy variables:

$$\begin{aligned} d_i^{yy} &= 1 \text{ if } WTP_i^* \geq B_i^H; \\ d_i^{yn} &= 1 \text{ if } B_i^L \leq WTP_i^* < B_i^H; \\ d_i^{ny} &= 1 \text{ if } B_i^L \leq WTP_i^* < B_i^L; \\ d_i^{nn} &= 1 \text{ if } WTP_i^* < B_i^L; \end{aligned} \quad (8)$$

where B^H , B^L , and B^L represents the higher, initial, and lower bids, respectively. WTP is estimated using a maximum likelihood procedure. In the corresponding likelihood function, each response is represented by the probability:

$$\begin{aligned} &Pr(\mathbf{X}_i \beta + \epsilon_i \geq B_i^H)^{d_i^{yy}} * Pr(B_i^L \leq \mathbf{X}_i \beta + \epsilon_i < B_i^H)^{d_i^{yn}} * \\ &Pr(B_i^L \leq \mathbf{X}_i \beta + \epsilon_i < B_i^L)^{d_i^{ny}} * Pr(\mathbf{X}_i \beta + \epsilon_i < B_i^L)^{d_i^{nn}} \end{aligned} \quad (9)$$

In the underlying valuation, it is assumed that an increase in risk can be avoided by maintenance of pre-existing risk reduction programmes. Thus, negative aspects of new constructions (e.g. interference with the environment, natural scenery), which may cause negative WTP values, should not impact the valuation process. Given the individuals' and the public's preference for safety, a reduction in mortality risks increases welfare. Hence, respondents are expected to have at least non-negative WTP values so that a distribution that allows only zero or positive values is appropriate. A naturally positive distribution is therefore used to estimate WTP.

¹² The hazard function denotes the probability of dying after age s conditional on attaining age s .

¹³ The central findings in this paper are based on the comparison of two sub samples that consist of individuals of all ages (but differ in their hazard rate). Hence, potential changes in consumption patterns should occur in both samples and the size may be similar for both groups. In the following derivations, the potential age-dependency of consumption is ignored (i.e. consumption is considered as constant over time so that ERPVU is proportional to the discounted remaining life expectancy) and the focus is on the influence of age-specific hazard rates for VSL estimates.

The estimates in this paper are based on a Weibull distribution assumption of the error term.¹⁴ The cumulative distribution function for a Weibull distribution is

$$F(WTP_i^*) = 1 - \exp(-(B_i^*/\psi_i)^\rho) \quad (10)$$

with the bid level B_i^* , shape parameter ρ and scale parameters ψ_i .¹⁵ Thus, using Eqs. 8, 9 and 10, the log-likelihood function for the Weibull can be written as

$$\text{Log}L_{\text{weib}} = \sum_{i=1}^N \left\{ \begin{aligned} & d_i^{mn} \ln[1 - \exp(-(\frac{B_i^L}{\psi_i})^\rho)] + \\ & d_i^{yy} \ln[\exp(-(\frac{B_i^H}{\psi_i})^\rho)] + \\ & d_i^{yn} \ln[\exp(-(\frac{B_i^L}{\psi_i})^\rho) - \exp(-(\frac{B_i^H}{\psi_i})^\rho)] + \\ & d_i^{ny} \ln[\exp(-(\frac{B_i^L}{\psi_i})^\rho) - \exp(-(\frac{B_i^H}{\psi_i})^\rho)] \end{aligned} \right\} \quad (11)$$

The maximum likelihood estimates resulting from Eq. 11 are used to calculate the mean WTP, which is the appropriate welfare measure informing cost benefit analysis (CBA) of avalanche risk reduction programmes.¹⁶ In the case of the Weibull distribution, mean WTP is calculated as

$$\text{mean}_{\text{weib}} = \psi_i \Gamma\left(\frac{1}{\rho} + 1\right) \quad (12)$$

where $\Gamma(\bullet)$ represents the gamma function (see Cameron and Trivedi (2005), p. 584).

Value of statistical life, age effects and age-specific hazard rate

The VSL describes the rate at which individuals are willing to forgo money for a (small) risk reduction. It is calculated by dividing the annual WTP by the given risk change. Here, WTP and VSL figures are presented for six different age classes to examine variations in VSL with age.

In order to examine the influence of age on WTP for the two groups of hazard rates (skiers/non-skiers), indicator

variables for age classes—defined according to Viscusi and Aldy (2007)—are included as explanatory variables in the regressions.¹⁷ The observations of respondents aged 18 and older were used, and were classified into six age classes: 18–24, 25–34, 35–44, 45–54, 55–62, and 63+.

The theoretical arguments given in Shepard and Zeckhauser (1984), Johansson (2002), and Alberini et al. (2004) show that the impact of age on the VSL is ambiguous and depends primarily on the individual hazard rate and optimal level of consumption. Under the assumption that skiers and non-skiers differ only in their hazard rate (higher age-specific avalanche risks for skiers vs age-independent risks for non-skiers), the skier's VSL is expected to have a larger age-gradient than the non-skier's VSL. For non skiers, the VSL should even be quite constant over age as their hazard rate is age-independent (see the theoretical analysis above).

The empirical evidence also suggests that the age-specific mortality risk (hazard rate) may be a crucial argument. Thus, the following analysis focuses on examining the relevance of the hazard rate in individual valuations. If it is true that the type of hazard rate (age-dependent vs age-independent) influences individual utility differently, this pattern has to be considered in the evaluation of corresponding life-saving measures and in designing an optimal policy.

Due to the topographical characteristics of residential areas in Tyrol (see Footnote 1), the present survey of WTP to reducing avalanche risks allows two types of hazard rates to be distinguished: one refers to the risk for non-skiers and the other to mortality risks for skiers. While the former face a baseline risk of dying in an avalanche, which is relevant for most residents (independent of their age), the group of skiers are confronted with additional avalanche risks by pursuing their hobby. The following paragraphs describe the different hazard rates with respect to avalanche risks for skiers and non-skiers.

Non-skiers as well as skiers who live in Alpine regions are confronted with a basic avalanche risk. Exposure to this basic avalanche risk is related mainly to the location of residential areas and the traffic routes chosen by residents while carrying out their daily business (working, shopping, ...). The risk of getting caught in an avalanche in their own homes or while in a car, bus or train is independent of the individual resident's age.¹⁸ Therefore, it is reasonable to assume that the avalanche risk for non-skiers is

¹⁴ Previous sensitivity analyses have shown that models assuming a Weibull or log-normal distribution of the error term leads to similar findings concerning the sensitive factors on WTP. Additionally, also a logistic and normal distribution was used, simultaneously allowing for a positive probability of zero responses (analogous to Tobit models). The results in these models also correspond quite well with the findings for the Weibull and log-normal distribution. However, regarding the log likelihood values, the Weibull model is superior to the other distribution assumptions.

¹⁵ The error term in the Weibull follows the Type I extreme value distribution where the scale parameter varies across individuals: $\psi_i = \exp(\mathbf{X}_i\beta)$.

¹⁶ CBA are associated with potential pareto improvements. A change is favoured if nobody is getting worse but at least one individual can improve his/her status or, respectively, if the winner of an action could compensate the loser. The mean takes into account such considerations (Carson 2000).

¹⁷ Conducting separate regressions for each age class would postulate an adequate sample size for each group, which is not given by the Tyrolean data set.

¹⁸ Clearly, an individual's health status and their fitness also determine the probability of survival once caught in an avalanche. As this holds for skiers and non-skiers alike, this does not explain the different hazard rates across the two groups.

Table 2 Skiing behaviour and avalanche fatalities per age class

Age (years) class	Skiers in sample		Population ^a		Average deaths/year ^b	
	<i>N</i>	Share ^c	<i>N</i>	<i>N</i> skiers ^d	<i>N</i>	Conditional probability ^e
18–24	261	63.20	63,651	40,225	1.4	0.004
25–34	232	61.21	95,299	58,336	4.6	0.008
35–44	162	57.65	119,248	68,748	3.8	0.006
45–54	90	45.92	93,961	43,145	4.4	0.010
55–62	43	36.13	60,971	22,032	0.6	0.003
63+	34	21.66	118,328	25,625	1.2	0.005

^a Tyrolean population on a 5-year (2004–2008) average

^b Five-year average (winter 2004/2005–2008/2009) of avalanche fatalities. Source: ASI-Tirol, and Kuratorium fuer Alpine Sicherheit, Austria

^c Percentage of skiers (per age class) in the survey sample

^d Number of skiers in Tyrol, estimated by multiplying the proportion of skiers in the survey sample by the number of residents

^e Age-dependent fatality risk (in percent). Calculation: Number of avalanche-related deaths divided by number of skiers in the population (e.g. $1.4/40,225 \times 100$)

age-independent, as all people who live in Alpine regions are—independent of their age—exposed to this basic avalanche risk.

The difference in the hazard rate between skiers and non-skiers emerges from the skiers' additional risk of dying in an avalanche due to their presence in snowy Alpine areas. From the official statistics of avalanche fatalities [provided by the Alpine Safety and Information Centre (ASI-Tirol) and the Kuratorium fuer Alpine Sicherheit] in the past five winters it can be inferred that all deaths listed occurred among the group of skiers.¹⁹ Furthermore, the number of fatalities varies across age groups. On a 5-year average (winter 2004/2005—winter 2008/2009), the highest number of avalanche-related deaths, namely 4.6, occurred among 25- to 34-year-olds. The average death toll among those aged 35–44 and 45–54 years amounts to 3.8 and 4.4, respectively (see sixth column in Table 2). What is of relevance in this context is not the absolute number of skiers who died in avalanches but their probability of dying, which depends on the number of people exposed to additional avalanche risks (i.e. skiers). I combined information given in the survey with data from official statistics to obtain a rough estimate of this probability.

The second and third column in Table 2 report the number and proportion of skiers per age class in the sample. Overall, 822 out of 1,545 respondents were skiers but the proportion of skiers decreases steadily with age. The number of skiers in the population (fifth column) was calculated by multiplying the age specific proportion of skiers in the sample (third column) by the corresponding 5-year average of population size in each age class

(fourth column), which gives the number of skiers in the Tyrolean population assuming that the sample's proportion of skiers is constant over time and that the sample is representative of the Tyrolean population. Dividing the average number of avalanche-related fatalities of (back country) skiers in the 5-years period 2004/2005–2008/2009 by the number of skiers in the population leads to the skiers' conditional probability of dying in an avalanche (seventh column). This probability—conditional to being a skier—shows that the probability of dying in an avalanche is lowest for 55- to 62-year-olds and peaks for 45- to 54-year-olds.²⁰

The level and intensity of risk exposure (e.g. how often skiers go on ski trips or back country tours; the ability to adequately respond to challenging terrains) among skiers depend on their (physical) abilities and skills. As Table 2 indicates, the probability of being a skier and therefore being potentially at (higher) risk varies with age. Age-related variation is also seen in the absolute number of avalanche fatalities and, more important, for the probability (conditional on being a skier) of dying in an avalanche.

By splitting the sample into skiers and non-skiers, it is possible to examine age effects on the VSL implicitly by considering the different levels of individual hazard rates. According to Eq. 5, the VSL among the group of skiers is expected to vary across age classes and should be lower for individuals at higher avalanche risk [higher hazard rate, i.e. lower survival function $\mu(t; \tau)$]. On the contrary, the age-gradient of non-skiers should be less pronounced, and their VSL should be more constant due to their age-independent hazard rate. The relevance of age is considered by calculating the WTP and VSL for particular age classes.

¹⁹ However, statistics also show that avalanches can also affect residential areas, as was seen in the winter of 1998/1999 when 31 people died due to a single avalanche event (Amt der Tiroler Landesregierung, Lawinenwarndienst Tirol 2003).

²⁰ Considering only the corresponding numbers for the survey period (winter 2004/2005), the youngest (oldest) face the lowest (highest) risk.

Table 3 Explanatory variables

Variable	Description
Age 25–34	Dummies. 1 if respondent is 25–34, 35–44, 45–54, 55–62, and above 62 years old, respectively (reference group: age 18–24)
Age 35–44	
Age 45–54	
Age 54–62	
Age 63+	
Alevel	Dummy. 1 if respondent has a university entrance diploma; 0 otherwise
Anthropogen	Dummy. 1 if respondent always regards avalanches as a human-caused event; 0 otherwise
Famexp	Dummy. 1 if respondent has had personal experience with avalanches; 0 otherwise
Female	Dummy. 1 if respondent is female; 0 otherwise
Healthy	Dummy. 1 if respondent states that she is in good health; 0 otherwise
Housemember	Number of persons in the respondent's household
Impalter	Dummy. 1 if the respondent prefers alternative risk reduction programmes; 0 otherwise
Jobrisk	Dummy. 1 if respondent states that she faces workplace risks; 0 otherwise
Largereduct	Dummy. 1 if the predetermined risk variation = 3/42,500; 0 otherwise
Lnincome	Logarithm of personal monthly take home income
Lowrisk	Dummy. 1 if respondent assesses her personal risk of dying in an avalanche as below average
Lowriskvol	Interaction term: low risk and volunteer
Missaversion	Dummy. 1 if missing observations of risk aversion are replaced by zero; 0 otherwise
Missincome	Dummy. 1 if missing observations of income are replaced by mean income in the individual's residence; 0 otherwise
Natural	Dummy. 1 if respondent always regards avalanches as a natural event; 0 otherwise
Riskaversion	Respondent's behaviour in risky situations. Ranges between 0 (risk taker) and 21 (risk averse) ^a
Riskpercept	Respondent's perception of fatal avalanche risks. Ranges between 0 (no risk) and 131 (death)
Skiing	Dummy. 1 if respondent is a skier; 0 otherwise
Volunteer	Dummy. 1 if respondent volunteers; 0 otherwise
Winter	Dummy. 1 if the survey took place in February 2005; 0 otherwise

^a In this context, risk aversion refers not only to financial risk aversion but also to aversion to life-threatening risks

Further explanatory variables

Apart from the socio-demographic characteristics of the participants (age, gender, income, ...), the survey data provide information about risk-related attributes, such as individual behaviour in risky situations (e.g. using sunscreen, wearing seat belts), preferences for alternative risk reduction programmes (other than protection against avalanches), and risk perception.²¹ These variables are included in the regression to control for internal validity of WTP estimates. Table 3 provides a brief description of these explanatory factors.

²¹ As risk perception is a complex measure that might be influenced by factors that cannot be controlled for, this variable might be correlated with the error term. However, when risk perception is regressed on a set of variables and the error term is included as additional explanatory variable in the original equation, the error coefficient does not reveal a significant influence on WTP. This approach is analogous to that of Smith and Blundell (1986) and Rivers and Vuong (1988), who discussed the exogeneity test in a Tobit and probit framework.

Results

Maximum likelihood estimates

The intensive discussion of how age influences WTP for risk reduction programmes encourages a detailed analysis of age effects. I estimated an econometric model using all observations and also ran regressions for each sub sample (skiers and non-skiers) separately. This procedure allows one to determine whether the influence of age on the respondents' WTP differs between the two types of hazard rates. Table 4 presents the estimated coefficients.

Estimates using the information in the total sample are discussed first. The coefficient of the scope dummy (*large-reduct*) indicates that the results pass the sensitivity test; respondents who value higher risk prevention reveal a significantly higher WTP than those whose statements are based on the smaller variation. As expected, WTP increases with increasing income (*lnincome*) and increasing perception of avalanche risks (*riskpercept*). WTP is significantly higher for respondents who had personal experience with avalanches in

Table 4 Willingness-to-pay (WTP)—regressions

Variable	Total	Skier	Non-skier
Largereduct	0.491***	0.694***	0.250
Winter	−0.163*	−0.335***	0.039
Age 25–34	−0.117	−0.208	0.070
Age 35–44	−0.261**	−0.322**	−0.126
Age 45–54	−0.186	−0.240	−0.045
Age 55–62	−0.148	0.027	−0.156
Age 63+	−0.303*	−0.501*	−0.152
Female	−0.031	−0.029	−0.036
Lnincome	0.186**	0.103	0.291**
Missincome	−0.137	−0.099	−0.206
Alevel	−0.278***	−0.430***	−0.057
Housemember	0.027	0.037	0.013
Volunteer	0.418**	0.529***	0.112
Famexp	0.334***	0.332***	0.330*
Riskpercept	0.011***	0.013***	0.008**
Skiing	0.195**		
Lowrisk	0.091	0.191	−0.088
Lowriskvol	−0.321	−0.679***	0.238
Anthropogen	0.085	0.116	0.051
Natural	−0.054	−0.001	−0.106
Riskaversion	0.019	0.034*	0.016
Missaversion	0.048	0.339	−0.119
Impalter	−0.389***	−0.116	−0.653***
Healthy	−0.017	0.014	−0.044
Jobrisk	0.181**	0.229**	0.172
Constant	−0.425	0.066	−0.999
Observations	1,481	799	682
Log-L	−1,808	−1,005	−781

Dependent variable = WTP intervals; protest answers ($N = 329$) and respondents younger 18 ($N = 87$) excluded; reference group: age 18–24 years

* $P < 0.1$; ** $P < 0.05$; *** $P < 0.01$

the past (*famexp*), who volunteer their time for welfare services (*volunteer*), who are skiers (*skiing*), and who face workplace risks (*jobrisk*).²² Negative impacts on WTP show higher education (*alevel*) and existing preferences for alternative risk reduction programmes (*impalter*). Surprisingly, respondents in the winter sample state a significantly lower financial contribution although avalanche events often occur in this period. From previous analyses it can be inferred that

interviewees in winter who consider avalanches as human-caused events state a significantly lower WTP, and that the “outrage effect”, as discussed in Kahneman et al. (1993) or more recently in Bulte et al. (2005), is weaker than the “responsibility effect” (Walker et al. 1999) for respondents in winter.²³ The lower WTP statements of those who consider avalanches as human-caused events indicate that these respondents are not willing to support risk-reduction programmes in situations where people at risk voluntarily choose their level of risk exposure and, hence, are themselves responsible for their risk experience. This result also indicates that the claim for responsible behaviour outweighs the potential upset (outrage) involved with man-made adverse situations (i.e. those which would not have occurred without human intervention) and the individual’s willingness to correct man-made harm accordingly.

Once the sample is split into two groups, an interesting pattern concerning these significant variables can be observed. Skiers are in general much more sensitive to the above-mentioned characteristics than non-skiers—with two exceptions. (1) While the coefficient on income (*lnincome*) is positive in both groups it is significant only for non-skiers. (2) If non-skiers think that other risk reduction programmes to save human lives are more important than protection against avalanches they state a significantly lower WTP (*impalter*). This effect is not significant for skiers.

Which influences of age on WTP can be observed? Using the full sample, I found that respondents aged 35–44 (*age35–44*) and 63+ (*age63+*) reveal a significantly lower WTP (21 and 27%, respectively). The remaining age classes do not differ significantly from the youngest group. When the sample is divided into “Skier” and “Non-Skier”, the significantly lower WTP statements at higher age occur only among respondents facing an age-sensitive hazard rate (see column “Skier”). Furthermore, the significant effects are even more pronounced for skiers: people aged 35–44 and 63+ state significantly lower payments, which are 28% and 40% below the WTP of the reference group of 18- to 24-year-old individuals. No significant age effect is observable for the group of non-skiers who are equally affected by avalanches—independent of their age.

These results point to an age dependency of WTP for respondents whose hazard rate varies with age (skiers), while no age-related variation is observable for non-skiers whose avalanche-related fatality rate is independent of age.

²² The variables *healthy* and *jobrisk* were introduced to test for the “background risk hypothesis” (Eeckhoudt and Hammitt 2001). These authors found that if the marginal utility of bequest is positive and high competitive risks (background risks) occur, WTP for reducing a specific mortality risk is smaller due to lower benefits from risk reduction when respondents still face a high residual risk level. Assuming that healthy people (workers in risky jobs) face lower (higher) remaining risks the corresponding coefficients estimated do not support their hypothesis.

²³ Kahneman et al. (1993) show that WTP is higher for the correction of man-made harm than for damages from natural causes because the former seems to be considered more upsetting by the individual. However, Walker et al. (1999) find lower WTP to undo problems caused by humans compared to naturally occurring events, which relates to the individuals’ own responsibility to reduce their risk exposure.

WTP for preventing fatalities and VSL

Mean WTP for risk reduction programmes against avalanches is calculated by using the estimated coefficients shown in Table 4. The coefficients reported for “Skiers” and “Non-skiers” are combined with the characteristics of an average respondent in the particular group. Mean WTP is computed using Eq. 12. VSL figures can be calculated from WTP values by dividing the annual WTP by the dimension of prevented risks for the average respondent ($=1/42,500$).²⁴ Table 5 depicts WTP and VSL for each age class and type of hazard rate referring to the smaller risk change.

Monthly mean WTP (and therefore VSL) across age classes is quite similar for non-skiers and ranges from €4.77 to 5.98 (from €2.4 to 3.1 million). For non-skiers whose risk of dying in an avalanche is age-independent, no significant differences occur between the age classes. However, a more pronounced variation among age classes is observable for skiers: their WTP figures range from €3.45 to 5.85 ($=$ monthly WTP) and from €1.8 to 3.0 million ($=$ VSL), respectively. The differences in WTP between the reference group of 18- to 24-year-old skiers and the age classes 35–44 and 63+, respectively, are statistically significant.²⁵

This analysis supports the hypothesis made: age variation is more pronounced for the group of skiers and is statistically significant within this group only. There is evidence that age-sensitivity matters for the valuation of fatality risks and that age-dependent hazard rates play a crucial role in explaining the variation in VSL figures: age effects occur for individuals whose mortality risk due to avalanches is age-dependent, while no age effects are observable for respondents whose risk level is independent of their age.²⁶ These results suggest that policies that aim at an efficient provision of live-saving measures have to take into account such variations in the beneficiaries’ hazard rates. An overall approach would miss the diversity in benefits and would lead either to an over- or under-supply of risk-reducing measures.

Assuming that the utility of consumption and life expectancy is constant, another question can be addressed:

Table 5 WTP/month and value of statistical life (VSL) per age class

Age class (years)	Observations	WTP (€) ^a	VSL (million €) ^b
Skiers			
18–24	250	5.69 (0.977)	2.90
25–34	225	4.62 (0.881)	2.36
35–44	159	4.13 (0.755)	2.10
45–54	89	4.48 (1.003)	2.28
55–62	43	5.85 (1.572)	2.98
63+	33	3.45 (1.048)	1.76
Non-skiers			
18–24	137	5.58 (1.456)	2.85
25–34	143	5.98 (1.578)	3.05
35–44	110	4.92 (1.336)	2.51
45–54	101	5.34 (1.425)	2.72
55–62	73	4.77 (1.347)	2.43
63+	118	4.79 (1.350)	2.44

^a Standard errors (based on the delta method) in parentheses

^b Calculation of VSL: annual WTP/risk variation = (monthly WTP $\times$ 12)/(1/42,500)

do skiers know that they belong to a higher risk group? Jones-Lee (1974) or Weinstein et al. (1980) argue that the higher the individual’s mortality risk, the higher the WTP for reducing life-threatening risks. This means that, based on the tendency shown in Table 2, the 45–54 (55–62) year-olds with the highest (lowest) conditional probability of dying in an avalanche should reveal the highest (lowest) WTP. But the estimated WTP paints a different picture: WTP of 55–62 (45–54) year-olds is the highest (third lowest) value. This admittedly rough and simplified comparison could lead to a premature conclusion that skiers do not correctly predict their risk of dying in an avalanche (i.e. they rather base their decision on subjectively perceived risk levels). However, one has to keep in mind that such a statement is based on strong assumptions. The skiers’ remaining life expectancy and their potentially time-variant utility of consumption are further determinants of the VSL (see “[Estimation procedure](#)”), which may explain these deviations.

Robustness checks

The estimation procedure described in “[Estimation procedure](#)” assumes a Weibull distribution of the error term. Both responses (initial and follow-up) to the payment questions are used, which implies that respondents show a consistent behaviour and think of a single amount when stating their WTP. It is often questioned whether it is appropriate to use both answers from a DBDC format. The resulting estimates are inconsistent when the responses to

²⁴ Out of 1,481 respondents, 254 cited the larger risk reduction. Hence, the average respondent refers the WTP statement to the smaller risk change. Calculating separate WTP values for the larger risk reduction would lead to imprecise estimates due to the low number of observations, particularly in the upper age classes.

²⁵ There are further considerable deviations in absolute WTP values (e.g. between age-class 35–44 and 55–62 or 55–62 and 63+) but they are statistically insignificant due to large standard errors and the small sample size in the penultimate age class.

²⁶ These findings are also in line with the findings in Viscusi and Aldy (2007), who discuss the relevance of age-specific hazard rates for VSL estimates in a revealed preference setting.

the follow-up questions do not reveal utility-maximising behaviour or rational preferences but are influenced by various factors such as yea-saying, weariness or free-riding (see for example, Herriges and Shogren 1996; Bateman et al. 2001; McFadden 1994; Park 2003). An alternative to deal with these problems would be to consider only the first response to the payment question. The disadvantage of this approach is that one forgoes a gain in statistical efficiency provided by the follow-up responses (e.g. Alberini 1995; Hanemann et al. 1991). This means that a trade off between bias and efficiency exists.

In order to check how the results vary using the single-bounded approach the same regressions discussed for the DBDC format but ignoring the responses to the second question are conducted. The coefficients estimated do not change considerably. For example, using the sample of skiers, the corresponding coefficients on the age dummies *age25–34*, *age35–44*, *age45–54*, *age55–62*, and *age63+* are -0.202 , -0.077 , -0.205 , 0.349 , and -0.655 . However, the age effects cannot be estimated precisely any more due to the large standard errors, which are at least twice as high as in the double-bounded case.

A second approach—the Turnbull distribution-free estimator described in Haab and McConnell (2002)—that imposes as few restrictions as possible on the estimation procedure is conducted to test for the robustness of age effects.²⁷ The calculation of the welfare measure is quite straightforward but this is at the cost of testing for covariate effects,²⁸ i.e., the Turnbull mean WTP is a descriptive unconditional estimate. Comparing the Turnbull WTP among age classes for the group of skiers, one finds that the WTP for people aged 25–34 and 63+ is significantly lower than WTP for the youngest. Further significant differences are observable between other age classes as well. The depreciation is strongest, and always highly significant, for the oldest. In the group of non-skiers, such a pronounced age pattern is not observable. There are only three pairs of age classes where WTP differs significantly from each other.²⁹ But WTP for non-skiers aged 63 and older does not show a statistically significant deviation from the mean values in the other age classes. As the Turnbull estimates represent a lower bound of WTP, mean WTP virtually always lies below the parametric mean values.

To summarise, among the group of skiers, strong evidence for a lower WTP for older people is found using the Turnbull estimator but this clear pattern does not occur

among non-skiers. As the Turnbull estimator is a distribution free estimator that uses only the first response to the bid question, one can conclude that the difference in age sensitivity between the two groups is dependent neither on the chosen distributional assumption nor on the presumptions imposed by using the DBDC format. The single-bounded estimates also suggest that the dimensions of age effects do not differ considerably when only the first response is used, so that the double-bounded approach is favoured and the additional information from the follow-up response is used.

Conclusion

This paper discusses a relevant feature of monetary valuation of reduced mortality risks: the age-sensitivity in an individuals' valuation of life-saving measures. I focus on comparing the WTP statements of two groups of beneficiaries who focus on the same type of risk but who face different hazard rates: for one group the hazard rate varies across age, for the other it is constant. The results indicate that the consideration of age-specific hazard rates is important and can explain the different findings regarding the age dependency of VSL estimates in the empirical literature.

The analysis is based on a CV survey carried out in Austria in two waves (autumn 2004/winter 2005). WTP for preventing fatal avalanche accidents is estimated by the method of maximum likelihood using an interval-data model and assuming a Weibull distribution of the error term. The sample is split into two groups (skiers and non-skiers) who differ in their levels of fatality risks. Age class dummies are included in the regression model to test for age effects among the two groups.

The results highlight the fact that the non-skiers' evaluation of risk reduction is almost constant and independent of age, while the skiers' WTP statements considerably vary over age. In other words, the estimates reveal age-sensitive VSLs for respondents to whom risk exposure is age-dependent (skiers). But no significant differences between the age classes are observable for non-skiers who face only an age-independent "baseline" risk due to the location of their residences. Average VSL for non-skiers ranges from 2.4 to 3.1 million Euro. For the group of skiers the VSL lies between 1.8 and 3.0 million Euro. Within the latter group a statistically significant depreciation of VSL for the age classes 35–44 and 63+ is observable: VSL is 28 and 40% lower than the VSL for the youngest.

What implications can be drawn from these findings for the efficient use of public funds to finance life-saving measures? The results in this paper indicate that the age pattern of individual hazards rates is a decisive determinant in explaining age variations in VSL figures and, hence, in

²⁷ Haab and McConnell (2002) provide a detailed explanation and examples how to calculate Turnbull mean values in a CV framework.

²⁸ See Haab and McConnell (2002), pp. 80–83, for a discussion.

²⁹ WTP is significantly lower for the 35–44 year-olds compared to the 18–24 group. Significantly higher WTP values are observable for non-skiers aged 45–54 and 54–64 compared to people at age 35–44.

justifying an adjustment of those measures to age. If protection measures that aim at protecting a wide population whose mortality risks do not depend on individual characteristics such as age are at stake (i.e. risk exposure is the same for all beneficiaries), an adjustment of the resulting benefits to age is not justified. In this setting, non-skiers belong to this group as they reveal similar WTP across all ages. A “senior discount” as sometimes proposed would contradict the individual statements. In the context of preventing fatal avalanche accidents, an age adjustment in VSL measures is appropriate solely for skiers. In this case, policies that simply use an overall value but do not control for such variation ignore the diversity in benefits and, hence, lead to an insufficient provision of (environmental) risk-reducing measures.

Considering the growing number and intensity of weather extremes it is of increasing importance to learn how residents evaluate protection measures against natural hazards to provide an efficient level of life-saving policies. Further research remains to be done to learn about the validity of these findings for, and the transferability to, other environmental risk or health risk valuations.

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References

- Alberini, A.: Efficiency vs. bias of willingness-to-pay estimates: bivariate and interval-data models. *J. Environ. Econ. Manag.* **29**, 169–180 (1995)
- Alberini, A., Cropper, M., Krupnick, A., Simon, N.B.: Does the value of a statistical life vary with age and health status?. Evidence from the US and Canada. *J. Environ. Econ. Manag.* **48**, 769–792 (2004)
- Alberini, A., Hunt, A., Markandya, A.: Willingness to pay to reduce mortality risks: evidence from a three-country contingent valuation study. *Environ. Resour. Econ.* **33**, 251–264 (2006)
- Alberini, A., Scasny, M., Braun Kohlova, M.: The value of statistical life in the Czech Republic: evidence from a Contingent Valuation Study, Working Paper presented at the 14th Annual Meeting of the EAERE in Bremen, Germany. <http://www.webmeets.com/files/papers/EAERE/2005/24/alberini%20scasny%20EAERE%202005.pdf> (2005)
- Aldy, J.E., Viscusi, W.K.: Age differences in the value of statistical life: revealed preference evidence. *Rev. Environ. Econ. Policy* **1**, 241–260 (2007)
- Amt der Tiroler Landesregierung, Lawinenwarndienst Tirol: Schnee und Lawine 2002–2003. Innsbruck (2003)
- Bateman, I.J., Langford, I.H., Jones, A.P., Kerr, G.N.: Bound and path effects in double and triple bounded dichotomous choice contingent valuation. *Resour. Energy Econ.* **23**, 191–213 (2001)
- Bulte, E., Gerking, S., List, J., de Zeeuw, A.: The effect of varying the causes of environmental problems on stated WTP values: evidence from a field study. *J. Environ. Econ. Manag.* **49**, 330–342 (2005)
- Cameron, A.C., Trivedi, P.K.: *Microeconometrics: methods and applications*. Cambridge University Press, Cambridge (2005)
- Carson, R.T.: Contingent valuation: a User’s guide. *Environ. Sci. Technol.* **34**(8), 1413–1418 (2000)
- Carson, R.T., Hanemann, W.M., Kopp, R.J., Krosnick, J.A., Mitchell, R.C., Presser, S., Ruud, P.A., Smith, V.K., Conaway, M., Martin, K.: Referendum design and contingent valuation: the NOAA panel’s no-vote recommendation. *Rev Econ Stat* **3**, 484–487 (1998)
- Corso, P.S., Hammitt, J.K., Graham, J.D.: Valuing mortality-risk reduction: using visual aids to improve the validity of contingent valuation. *J. Risk Uncertain.* **23**(2), 165–184 (2001)
- Davey, A., Shanahan, M.J., Schafer, J.L.: Correcting for selective nonresponse in the National Longitudinal Survey of youth using multiple imputation. *J. Hum. Resour.* **36**(3), 500–519 (2001)
- Eeckhoudt, L.R., Hammitt, J.K.: Background risks and the value of a statistical life. *J. Risk Uncertain.* **23**(3), 261–279 (2001)
- Environmental Protection Agency: Technical addendum: methodologies for the benefits analysis of the Clear Skies Act of 2003. http://www.epa.gov/clearskies/tech_addendum.pdf (2003)
- European Commission: Recommended interim values for the value of Preventing a Fatality in DG Environment Cost Benefit Analysis. http://www.europa.eu.int/comm/environment/enveco/others/recommended_interim_values.pdf (2000)
- Haab, T.C., McConnell, K.E.: *Valuing environmental and natural resources: the econometrics of non-market valuation*. Elgar, Cheltenham (2002)
- Hackl, F., Pruckner, G.J.: Warm glow, free-riding, and vehicle neutrality in a health-related Contingent Valuation Study. *Health Econ.* **14**, 293–306 (2005)
- Hammitt, J.K.: Valuing changes in mortality risks: lives saved versus life years saved. *Rev. Environ. Econ. Policy* **1**, 228–240 (2007)
- Hanemann, M., Loomis, J., Kanninen, B.: Statistical efficiency of double-bounded dichotomous choice contingent valuation. *Am. J. Agric. Econ.* **73**(4), 1255–1263 (1991)
- Herriges, J.A., Shogren, J.F.: Starting point bias in dichotomous choice valuation with follow-up questioning. *J. Environ. Econ. Manag.* **30**, 112–131 (1996)
- Johannesson, M., Johansson, P.-O., Löfgren, K.-G.: On the value of changes in life expectancy: blips versus parametric changes. *J. Risk Uncertain.* **15**, 221–239 (1997)
- Johansson, P.-O.: Is there a meaningful definition of the value of a statistical life?. *J. Health Econ.* **20**, 131–139 (2001)
- Johansson, P.-O.: On the definition and age-dependency of the value of a statistical life. *J. Risk Uncertain.* **25**(3), 251–263 (2002)
- Jones-Lee, M.: The value of changes in the probability of death or injury. *J. Polit. Econ.* **82**, 835–849 (1974)
- Jones-Lee, M.W., Hammerton, M., Philips, P.R.: The value of safety: results of a national sample survey. *Econ. J.* **95**, 49–72 (1985)
- Kahneman, D., Ritov, I., Jacowitz, K.E., Grant, P.: Stated willingness to pay for public goods: a psychological perspective. *Psychol. Sci.* **4**(5), 310–315 (1993)
- Krupnick, A.: Mortality-risk valuation and age: stated preference evidence. *Rev. Environ. Econ. Policy* **1**, 261–282 (2007)
- Kunreuther, H., Novemsky, N., Kahneman, D.: Making low probabilities useful. *J. Risk Uncertain.* **23**(2), 103–120 (2001)
- Little, R.J.A., Rubin, D.B.: *Statistical analysis with missing data*. Wiley, New York (1987)
- Liu, J.T., Hammitt, J.K., Wang, J.D., Tsou, M.W.: Valuation of the risk of SARS in Taiwan. *Health Econ.* **14**(1), 83–91 (2005)
- McFadden, D.: Contingent valuation and social choice. *Am. J. Agric. Econ.* **76**(4), 689–709 (1994)
- Olsen, J.A., Kidholm, K., Donaldson, C., Shackley, P.: Willingness to pay for public health care: a comparison of two approaches. *Health Policy* **70**, 217–228 (2004)

- Park, J.H.: A test of the answering mechanisms of the double-bounded contingent valuation method. *Appl. Econ. Lett.* **10**, 975–984 (2003)
- Pratt, J.W., Zeckhauser, R.J.: Willingness to pay and the distribution of risk and wealth. *J. Polit. Econ.* **104**, 747–763 (1996)
- Rivers, D., Vuong, Q.H.: Limited information estimators and exogeneity tests for simultaneous probit models. *J. Econ.* **39**, 347–366 (1988)
- Shanteau J., Ngui M.L.: Decision making under risk—the psychology of crop insurance decisions. http://www.ksu.edu/psych/cws/pdf/insurance_paper90.PD (1989)
- Shepard, D.S., Zeckhauser, R.J.: Survival versus consumption. *Manag. Sci.* **30**, 423–439 (1984)
- Smith, R.J., Blundell, R.W.: An exogeneity test for a simultaneous equation tobit model with an application to labor supply. *Econometrica* **54**(3), 679–685 (1986)
- Smith, V.K., Evans, M.F., Kim, H., Taylor, D.H. Jr.: Do the near-elderly value mortality risks differently?. *Rev. Econ. Stat.* **86**(1), 423–429 (2004)
- Sunstein, C.R.: Valuing life: a plea for disaggregation. *Duke Law J.* **54**, 385–445 (2004)
- Viscusi, W.K., Aldy, J.E.: Labor market estimates of the senior discount for the value of statistical life. *J. Environ. Econ. Manag.* **53**, 377–392 (2007)
- Walker, M.E., Morera, O.F., Vining, J., Orland, B.: Disparate WTA–WTP disparities: the influence of human versus natural causes. *J. Behav. Decis. Mak.* **12**(3), 219–232 (1999)
- Weinstein, M.C., Shepard, D.S., Pliskin, J.S.: The economic value of changing mortality probabilities: a decision-theoretic approach. *Q. J. Econ.* **94**, 373–396 (1980)
- Whitehead, J.C.: Item nonresponse in contingent valuation: should CV researchers impute values for missing independent variables? *J. Leisure Res.* **26**(3), 296–303 (1994)