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Paying for Safety: Preferences for Mortality Risk Reductions on Alpine Roads

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Summary

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Keywords: Value of Statistical Life, Choice Experiment, Natural Hazard Mitigation, Traffic Safety

JEL Classification: D81, J17, R42

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Christoph M. Rheinberger [1,2]

Abstract: This paper presents a choice experiment, which values reductions in mortality risk on Alpine roads. These roads are on one hand threatened by common road hazards, on the other hand they are also endangered by natural hazards such as avalanches and rockfalls. Drawing on choice data from frequently exposed and barely exposed respondents, we are not only able to estimate the VSL but to explore how the respondents differ in their individual willingness-to-pay depending on personal characteristics. To address heterogeneity in preferences for risk reduction, we use a non-linear conditional logit model with interaction effects. The best estimate of the VSL in the context of fatal accidents on Alpine roads is in the range of €4.9–5.4 million with distinct differences between the urban and the mountain sample groups. We find the VSL to be significantly altered by socio-economic factors but only marginally altered by the type of hazard.

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1 Introduction

Alpine countries invest large amounts of money to mitigate natural hazards such as avalanches, floods, and rockfalls. Switzerland, for example, spends approximately 0.6% of its annual GDP on the mitigation of, and the recovery from, natural hazards (PLANAT 2005). While a part of these efforts is financed through private sources, public expenditures cover the lion's share. Publicly funded mitigation programs have so far been focused on the cost-efficient supply of mitigation. An optimal resource allocation would, however, not only consider the supply side but also the societal demand for safety improvements.

Stated preferences provide an operational basis to deduce the societal demand for safety improvements. Surprisingly, few empirical studies have addressed these preferences in the context of natural hazards. Brouwer and Bateman (2005) studied society's valuation of flood control measures in the Netherlands, Zhai and Ikeda (2006) analyzed the economic value of evacuations during flood events in Japan, and Leiter and Pruckner (2009) estimated the societal willingness-to-pay (WTP) for reductions in avalanche risk in Austria. All of these studies used the contingent valuation approach to elicit WTP measures. This paper contributes to the scarce literature by presenting a choice experiment to value improvements in traffic safety on Alpine roads. It has been shown that this stated-preference approach is well-suited to the study of societal preferences for mortality risk reductions and even allows individuating these preferences (see Alberini et al. 2007; Bosworth et al. 2008; Tsuge et al. 2005).

Three research objectives guide our experimental investigation. First, we want to find out how much society is willing to pay for reductions in mortality risk on public roads in the Swiss Alps. Users of these roads are on one hand threatened by natural hazards such as snow avalanches and rockfalls. On the other hand, road users face the common risk of car accidents, whether it be through poor road conditions or through the dangerous behavior of other drivers. Our experiment confronted survey respondents with discrete choices from among hypothetical traffic safety programs to protect against these hazards and to reduce mortality risks on Alpine roads. Based on their choices, we estimate the value of statistical life (VSL), which has become the common metric to value lifesaving programs and environmental regulations involving risks to human life (Hammitt 2000).

Second, psychometric research on risk suggests that characteristics such as voluntariness, controllability, and origin of a hazard affect people's risk perception (Slovic 1987; Slovic et al. 2000). Presumably, these factors affect the economic valuation of mortality risk reductions (McDaniels et al. 1992; Subramanian and Cropper 2000), but empirical evidence for these effects is relatively small (Chilton et al. 2002; Leiter and Pruckner 2009). To broaden this evidence, we analyze how specific characteristics of the hypothetical traffic safety programs and their perceived benefits affect the size of the VSL estimates.

Third, there is an ongoing discussion as to whether the VSL should be individuated according to age, wealth, health, and baseline risk (see Alberini et al. 2004; Baker et al. 2008; Eeckhoudt and Hammitt 2001; Pratt and Zeckhauser 1996; Sunstein 2004). We study how people differ in the WTP for risk reductions based on their socio-economic characteristics and their exposure to natural hazards. In other words, we analyze preference heterogeneity in the context of mortality risk, using a non-linear conditional logit model as introduced by Alberini et al. (2007).

To address these research objectives, the paper is organized as follows. Section 2.2 begins with a brief overview of mortality risks on Alpine roads and compares these risks to other causes of death. We then describe the design of our survey, including the attributes and levels selected to characterize the choice tasks, and summarize the characteristics of the survey respondents. In Section 2.3, we theoretically deduce the VSL within the random utility framework of discrete choice analysis and explain our modeling approach to analyze preferences for mortality risk reductions. Selected results of the model estimations are presented in Section 2.4. We first report the results for different specifications of the non-linear conditional logit model. We then test the scope and sensitivity of these results. In Section 2.5, we summarize our results and their implications for valuing mortality risk reductions in the context of natural hazards.

2 Survey development, choice task, and sample characteristics

2.1 Overview of mortality risks on Alpine roads

Alpine roads are frequently exposed to natural hazards such as snow avalanches and rockfalls. Within the last 15 years, three individuals per year have been killed on average in accidents caused by rockfall or avalanche events on Swiss roads, while approximately 500 individuals per year have died in car accidents (BFS 2007a). Although the population at risk is larger in the case of car accidents (only about one quarter of the Swiss residents frequently drive on Alpine roads), the probability of dying in a rockfall or avalanche accident on a road is statistically small compared to other causes of death (Fig. 1). Yet, many people experience feelings of dread when considering the risks from natural hazards since they are involuntarily borne and are out of self-control. Dread has been found to be a perceptional factor that tends to increase the WTP for mitigation (Chilton et al. 2002; Chilton et al. 2006; Subramanian and Cropper 2000). In comparison, car accidents are a well-known risk and frequently analyzed in VSL studies (de Blaeij et al. 2003). In our survey, we used car accidents as a reference risk to see whether perceptional factors of natural hazards decrease or increase the societal WTP for traffic safety on Alpine roads.

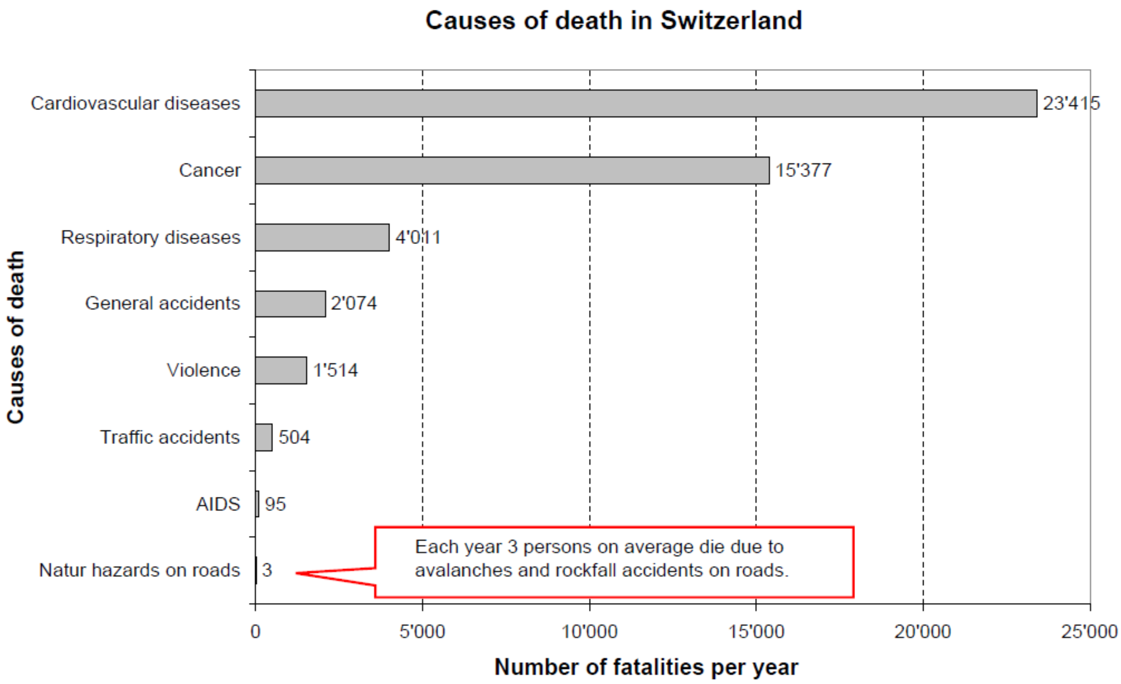

Fig. 1 League table of statistical causes of death in Switzerland (compiled from BFS 2007a).

Since the individual risk of dying in rockfall or avalanche accidents is small and the occurrence of such accidents is hardly predictable, it is *a priori* unknown whose life will be saved by the implementation of a traffic safety program. Anybody traveling on Alpine roads may potentially benefit from the risk reduction and, as far as public roads are concerned, no one can be excluded from this benefit. Thus, traffic safety on Alpine roads is a public good. The valuation of mortality risk reductions in the public goods context implies three major challenges. First, the respondent's WTP for risk reduction depends on the size of the affected population or on the size that the respondent thinks of when evaluating the choice tasks (Green et al. 1994; Kahneman et al. 1993). Second, the magnitude of the cost figures is used as a mental anchor. Green et al. (1998) showed that the anchoring of prompted costs systematically influences the responses in stated-preference studies. This can cause large biases in the valuation of public goods, particularly if respondents have strategic incentives to over- or understate their true WTP. Third, respondents may have preferences for reductions in their own risk, in the risk to others, or in expressing mercy and solidarity with those people exposed to a risk (Jones-Lee 1991; Viscusi et al. 1988).

We addressed the former two challenges by making the survey instrument as realistic as possible. We presented the risk reduction as a hypothetical referendum for financing the future maintenance of hazard mitigating infrastructure and clearly stated how many fatalities each traffic safety program could avert at which cost. To reduce strategic answering, we used a relative bid vehicle that personalized the cost of each of the alternative programs relative to a percentage of the respondent's last tax payment. The advantage of this relative bid vehicle is that, when converted to absolute values, it corresponds to the cost incurred to the respondent if the program were to be eventually implemented (Schläpfer 2008).

The third challenge can hardly be resolved because the respondents' preferences may be simultaneously composed of egoistic, altruistic and warm glow motives (Jones-Lee 1991; Kahneman and Knetsch 1992; Kahneman et al. 1999). In our study context, the individual risk is small and the benefits of the proposed traffic safety programs are concentrated on the most exposed people. We therefore conducted the choice experiment with respondents from two different regions of Switzerland. One sample consisted of people from the mountainous region around Davos, who are frequently exposed to natural hazards on Alpine roads. The other sample consisted respondents from the city of Zurich, who are unlikely to be frequently exposed. This split-sampling allows testing whether less exposed respondents may have altruistic values, resulting in concerns about the safety of others (Rodriguez and Leon 2004).

2.2 Choice attributes and levels

In the design phase of the study, four focus groups, with participants from both sample regions, were held to explore the relevant attributes of traffic safety on Alpine roads, the understanding of the relative bid vehicle, and the use of various risk communication aids (see Corso et al. 2001). The exploratory research also assisted in specifying the levels of each of the relevant attributes so that respondents could understand improvements in traffic safety as a result of changing attribute levels.

For this purpose, we discussed the current level of mitigation measures to protect Alpine roads against natural hazards with a number of natural hazard experts consisting of representatives of the responsible authorities, civil engineers, and scientists. These expert interviews provided a semi-quantitative assessment of the current level of traffic safety on Alpine roads, upon which we developed 'what-if' scenarios for the case that mitigation measures would no longer be maintained.

The exploratory research resulted in the selection of four attributes to describe traffic safety programs for Alpine roads: (1) the number of fatalities per year that are averted by a specific traffic safety program; (2) the number of years over which the program would reduce the risk; (3) the type of road hazard against which this program is effective; and (4) the cost of this program to the taxpayer. Table 1 summarizes the selected attributes and levels used in the choice experiment.

Table 1 Attributes and attribute levels in the discrete choice tasks.

Attribute		Levels of the attribute
(1)	Number of avoided fatalities per year	10, 12, 14, 16
(2)	Duration of protection in years	10, 20, 30
(3)	Type of road hazard	snow avalanches, rockfalls, car accidents
(4)	Relative costs of the program as percentage of the last tax payment	1%, 2%, 3%

Attribute (1) describes the benefit of the traffic safety programs in terms of averted fatalities. Based on the expert interviews, we assumed that the number of fatalities caused by natural hazards on Alpine roads would increase to 20 fatalities per year if current mitigation measures were no longer maintained, but could be kept at the current level if these measures were maintained into the future. Levels of the risk reduction were thus selected at 10, 12 14, and 16 averted fatalities per year.

Attribute (2) captures the permanence of the risk reduction. We attempted to suggest realistic periods of mitigation benefits based upon the life expectancy of different mitigation measures to protect roads. In the focus groups, we observed that participants had difficulties in calculating the total number of averted fatalities over the proposed period of mitigation benefits. We therefore decided against presenting different mitigation periods between choice alternatives, but changed the period of mitigation between choice sets.

Attribute (3) appoints the type of road hazard against which protection is provided. Avalanches and rockfalls were selected as natural hazards endangering traffic on Alpine roads, while car accidents were chosen as a reference risk to test for perceptional factors associated with these natural hazards. We explained that car accidents can be caused by blind curves, weak crash barriers, or speeding of other drivers to avoid emphasizing the self-controlled factors of driving.

Attribute (4) names the cost of each traffic safety program by describing it as a onetime payment proportional to the respondents' last annual tax payment. We provided respondents with a conversion table through which they could easily derive their personalized cost-sharing for each of the programs (Fig. 2). Married respondents who have a joint tax invoice, were asked to divide their last tax payment by two in order to derive their personalized cost for each program.

How much tax did you pay last year?	1% of your last tax bill corresponds to:	2% of your last tax bill corresponds to:	3% of your last tax bill corresponds to:
(1) Less than CHF 2,000	20	40	60
(2) Between CHF 2,000 and 6,000	40	80	120
(3) Between CHF 6,000 and 10,000	80	160	240
(4) Between CHF 10,000 and 14,000	120	240	360
(5) Between CHF 14,000 and 18,000	160	320	480
(6) More than CHF 18,000	180	360	540
Your cost of the traffic safety program:	**1%: CHF _____**	**2%: CHF _____**	**3%: CHF _____**

Fig. 2 Conversion tool to calculate absolute bid amounts from percentages of taxes.

Two premises determined the size of the relative bids. First, the aggregated bids should cover future expenditures for maintaining the protection of cantonal and communal roads against avalanches and rockfalls over the next 30 years. Second, the prompted bid amounts should allow for a large range of possible VSL values (Alberini et al. 2007). To comply with these validity requirements, we estimated the public mitigation expenditures for Alpine roads based on statistical data (BFS 2006; PLANAT 2005). Assuming that the annual mitigation expenditures will remain at their current level, the present value of mitigation expenditures over the next 30 years amounts to CHF 480–960 million, which is equal to 1.2–2.4% of the annual tax payments in Switzerland (BFS 2007b).[3] Consequently, the relative bid sizes were selected as 1%, 2%, and 3% of the last tax payment.

Taking the average annual per capita tax payment of CHF 5,400 (BFS 2007b), the relative bids would mean a onetime payment of CHF 54 (€35), CHF 108 (€70), and CHF 162 (€105).[4] Using the basic VSL model outlined in Section 3 and assuming discount rates for mortality risks between 0–15% (Viscusi and Aldy 2003), the absolute bids for the average taxpayer imply VSL values in the range of CHF 0.3–6.3 million (€0.2–4.1 million); the absolute bids for the highest tax class imply VSL values in the range of CHF 0.8–20.9 million (€0.5–13.6 million); and the absolute bids for the lowest tax class imply VSL values in the range of CHF 0.1–2.3 million (€0.1–2.7 million). This range is in-line with values found in two meta-analyses of VSL estimates (Mrozek and Taylor 2002; Viscusi and Aldy 2003).

[3] For deriving these present values, we used a discount rate of 1.5% based on the inflation-adjusted ten-year spot interest rate on Swiss Confederation bonds.

[4] At the time of the data collection, one Swiss franc corresponded to 0.65 Euro.

2.3 Survey structure

To collect the data, we developed a mail survey consisting of five parts. The first part opened with some attitudinal questions about the perception of natural hazards in general and their perceived threat to roads in particular. In the second part, respondents had to balance infrequent and severe avalanche accidents against frequent but less severe avalanche accidents. The third part contained the actual choice task, which prompted respondents to consider the hypothetical privatization of maintaining current mitigation measures against rockfall, snow avalanche and car accidents on cantonal and communal roads in the Swiss Alps.

We introduced the choice task by stating that today only three individuals die each year in rockfall and avalanche accidents on roads, but that this number would quickly rise to 20 fatalities per year if mitigation measures would no longer be maintained. Respondents were presented with the league table of annual mortality causes depicted in Fig. 1 to understand the mortality risks involved with avalanche, rockfall and ordinary car accidents and to align these risks with other causes of death.[5]

Respondents were then asked to imagine a national referendum for financing a traffic safety program. They were told that every household would have to make such a onetime payment on condition that the referendum was passed. The alternative traffic safety programs were presented within six choice sets. For each choice set, respondents had to indicate which of three options they prefer: program A, program B, or neither program. The last option was a conditional status quo, whose choice implied the willingness to accept a rise in fatalities from currently three to 20 per year.

Since we selected three attributes with three levels and one attribute with four levels for describing the programs, 108 (= $3^3 \times 4$) different traffic safety programs were possible. Consequently, a full factorial design would have resulted in 1,944 different choice sets. (Remember that we did not vary the time attribute across alternatives in a specific choice set.) We used a shifted orthogonal experimental design built from conventional fractional factorials for linear models (Louviere et al. 2000) to reduce the number of choice sets. Based on this experimental design, we generated 54 pairs of alternative programs segmented into nine orthogonal blocks of six choice sets. According to Ferrini and Scarpa (2007), this experimental design is particularly appropriate when there is a high degree of uncertainty about the conditions that finally generate the choice-based dataset.

The outlined procedure resulted in nine survey versions, each of which contained six different choice sets. To test whether different framings of the risk reduction attribute had an

[5] This was the risk communication aid most preferred by the participants of the focus group research.

impact on the valuation of the traffic safety programs, we sent out two survey formats with different, but logically equivalent, framings. In this paper, we draw on the standard assumption that choice experiments are context-independent (Carlsson and Martinsson 2008). We therefore neglect the hypothesized framing effect in the discussion below, but will discuss it in a separate paper.[6]

Subsequent to the choice task, the fourth part of the survey posed some debriefing questions asking respondents to indicate how sure they were in their choices and whether they had applied specific decision heuristics. The survey closed with questions about the socio-economic characteristics of the respondents.

2.4 Respondents

The survey was mailed to 900 individuals who had previously agreed in a phone recruitment to participate in the study. The sample was stratified by age and gender, with the number of respondents roughly reflecting the age distribution of the Swiss residential population. Half of the respondents were recruited in the mountainous region around Davos (the mountain sample) and the other half in the city of Zurich (the urban sample). We required respondents to be at least 18 years old, which is the minimum age for voting and for obtaining a driver's license in Switzerland.

Table 2 compares the socio-economic characteristics of our respondents to those of the Swiss residential population, confirming that our study sample is representative. There is a good representation of all age groups, even though respondents older than 69 years are slightly underrepresented. With regard to the last tax bill, there is a under sampling of the lowest income group. This correlates with the observation that sample has somewhat fewer respondents who have had only primary education. Overall, there is a fair match-up of the survey participants with the census data.

In the choice analysis, we discarded respondents who had answered less than three of the six choice sets, assuming that they were either not willing or unable to respond. Three respondents chose only program A and one respondent chose only program B, even when this choice behavior was inconsistent with their earlier choices. These respondents were also excluded from the choice analysis. The data cleaning left us with 2,572 valid choices from 433 respondents, corresponding to a response rate of 48%.

[6] Preliminary results suggest that the framing effect is small and does not affect the VSL estimates.

Table 2 Comparison of the sample characteristics to the Swiss residential population.

Variable	Study sample (*N* =433)	Swiss Population
Respondents		
Mountain Sample	49.0%	–
Urban Sample	51.0%	–
Gender [a]		
Women	49.1%	52.0%
Men	50.9%	48.0%
Age [a]		
18–29	14.6%	17.0%
30–39	17.9%	15.5%
40–49	27.3%	19.4%
50–59	14.6%	16.9%
60–69	15.4%	14.2%
70 or older	10.3%	16.9%
Annual tax payments [b]		
CHF 2,000 or less	15.0%	27%
CHF 2,000–6,000	36.2%	36%
CHF 6,000–10,000	27.2%	16%
CHF 10,000–14,000	8.9%	12%
CHF 14,000–18,000	4.2%	2%
More than CHF 18,000	8.6%	7%
Educational attainment [a]		
Primary education	2.8%	13.3%
Secondary education	12.3%	8.3%
University education	25.2%	23.1%
Apprenticeship	43.8%	45.0%
Craftsman's diploma	15.9%	10.3%

[a] Based on (BFS 2007b).

[b] Approximation of the annual tax payments of the Swiss population based on the distribution of the direct federal tax payments (BFS 2009).

Since there are no official statistics of the number of people driving on Alpine roads, we asked respondents how often they travel on these roads. Based on this self-declared risk exposure and official census data for the mountainous and urban regions of Switzerland (Hornung and Röthlisberger 2005), we defined the baseline population at risk as those 2 million individuals who drive more than once a week on Alpine roads. As described below, we used this figure to quantify the annual statistical mortality risk reduction provided by each of the traffic safety programs.

3 Discrete choice model

3.1 Random utility framework for conditional logit models

Discrete choice models are founded in random utility theory (McFadden 2001). Applied to mortality risks on Alpine roads, random utility theory assumes that the unobserved utility of a specific traffic safety program *k* can be split into a deterministic component expressed by the indirect utility function *V* and a random component ε that captures moods, affects and other emotionally driven decision shortcuts used by individual *i* to evaluate the program *k*. Clearly, the indirect utility *V* from choosing program *k* is determined by the program's attributes and the personal characteristics of individual *i*.

Formally, let $\mathbf{X}_{ik}$ denote a vector of explanatory variables describing program *k* and individual *i*, and $\boldsymbol{\beta}$ denote the corresponding vector of coefficients to be estimated. Then, the random utility perceived by individual *i* from choosing program *k* can be written as:

$$U_{ik} = V(\mathbf{X}_{ik};\boldsymbol{\beta}) + \varepsilon_{ik} = V_{ik} + \varepsilon_{ik} \tag{1}$$

where ε_{ik} is the random component of an unknown distribution $\varepsilon_{ik} \sim \mathrm{D}(\theta_\varepsilon)$, with θ_ε denoting the parameters of this distribution.

The dichotomy of this random utility model (RUM) allows a decision framework to be constructed by assuming that individual *i* prefers mitigation program *k* over the alternative mitigation program *j*, if the utility entailed by this program *k* is larger than that of any other program in the choice set *J*. Formally, the probability of choosing mitigation program *k* over any other program *j* in the choice set is given by:

$$\Pr(k \mid \mathbf{X}_{ik};\boldsymbol{\beta},\theta_\varepsilon) = \Pr[V_{ik} + \varepsilon_{ik} > V_{ij} + \varepsilon_{ij}, \forall j \neq k]. \tag{2}$$

Based on distributional assumptions on the random component, several specifications of the RUM model have been proposed (Walker and Ben-Akiva 2002). The widely used conditional logit specification assumes that the random component is independently and identically (IID) drawn from a Type-I extreme value distribution, i.e. $\varepsilon_{ij} \sim \mathrm{EV1}(\theta_\varepsilon)$. The probability that individual *i* chooses the specific program *k* is:

$$\Pr(k \mid \mathbf{X}_i;\boldsymbol{\beta},\mu) = \exp[\mu V(\mathbf{X}_{ik};\boldsymbol{\beta})] \Big/ \sum_{\forall j \in J} \exp[\mu V(\mathbf{X}_{ij};\boldsymbol{\beta})], \tag{3}$$

where μ is a scale parameter usually normalized to one, implying constant error variance (Louviere et al. 2000).

The estimation of the coefficient vector $\boldsymbol{\beta}$ involves maximizing the likelihood of the stated choices. When N respondents are asked to engage in a series of Q choice tasks with J choice alternatives, the maximization requires defining a binary choice indicator λ_{ijq}. This binary indicator takes the value $\lambda_{ijq} = 1$ if individual i chooses the program j in choice task q, and otherwise takes the value $\lambda_{ijq} = 0$. Accordingly, the log-likelihood function LL to be maximized over all stated choices becomes:

$$LL(\lambda_i \mid \mathbf{X}_i; \boldsymbol{\beta}, \theta_\varepsilon) = \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{q=1}^{Q} \lambda_{ijq} \ln[\Pr(j \mid \mathbf{X}_i; \boldsymbol{\beta}, \theta_\varepsilon]. \quad (4)$$

3.2 Estimating the VSL from discrete choice data

Estimating the VSL from discrete choices on alternative traffic safety programs requires specifying the indirect utility function given in Eq. (1). In our study, the indirect utility of any traffic safety program j depends on its risk reduction R_j and on its cost C_{ij}, which varies for each individual i due to the use of the relative bid vehicle. Characteristics of the traffic safety program j, denoted by the vector $\mathbf{W}_j$, and of the respondent i, denoted by the vector $\mathbf{Z}_i$, may also go into the indirect utility function. Since these covariates do not vary over the repeated choices of an individual, their vectors have to be interacted with either the risk or the cost parameter. A generic form of the indirect utility function $V(\mathbf{X}_{ij}; \boldsymbol{\beta})$ is then obtained as:

$$V_{ij} = R_j(\alpha_1 + \mathbf{Z}_i\boldsymbol{\alpha}_2 + \mathbf{W}_j\boldsymbol{\alpha}_3) + C_{ij}(\beta_1 + \mathbf{Z}_i\boldsymbol{\beta}_2 + \mathbf{W}_j\boldsymbol{\beta}_3), \quad (5)$$

where α_1 and β_1 are the coefficients of the risk and cost parameter, and $\boldsymbol{\alpha}_2$, $\boldsymbol{\alpha}_3$, $\boldsymbol{\beta}_2$ and $\boldsymbol{\beta}_3$ are coefficient vectors of the interaction effects between these parameters and selected covariates.

The particular design of our choice task requires some additional specifications. While the cost C_{ij} of each program j was implemented as a onetime payment to respondent i, the risk reduction was implemented as a stream of annual risk reductions provided by program j over the period of mitigation T_j. We used a constant exponential discounting model to discount the stream of risk reduction, defining the discounted risk reduction R_j as:

$$R_j = \int_0^{T_j} \pi_j \exp(-\delta\, t)\, \mathrm{d}t = \pi_j \left[\frac{1 - \exp(-\delta\, T_j)}{\delta}\right], \quad (6)$$

where δ is the implicit discount rate and π_j denotes the annual risk reduction by program j, which is assumed to be constant over the period of mitigation.[7] By inserting Eq. (6) into the indirect utility function of Eq. (5), we may estimate the discount rate δ directly from the choice data. Technically, this makes our model a non-linear conditional logit model.

In line with Alberini et al. (2007), we then posit that the marginal utility of risk reduction for respondent i is given by the compound coefficient vector $\boldsymbol{\alpha} = (\alpha_1 + \mathbf{Z}_i\boldsymbol{\alpha}_2 + \mathbf{W}_j\boldsymbol{\alpha}_3)$ and the marginal utility of wealth is given by the compound coefficient vector $\boldsymbol{\beta} = (\beta_1 + \mathbf{Z}_i\boldsymbol{\beta}_2 + \mathbf{W}_j\boldsymbol{\beta}_3)$. Since the VSL is defined as the WTP for a marginal decrease in risk, it results from the ratio of the estimated coefficient vectors: $(\hat{\boldsymbol{\alpha}} / \hat{\boldsymbol{\beta}}) = (\partial V/\partial R_j)/(\partial V/\partial C_{ij})$.

4 Results

4.1 Qualitative results

The respondents had relatively homogenous attitudes toward natural hazards in general and to their perceived threat to Alpine roads in particular. When asked about how they assess their own risk of being killed through a snow avalanche or a rockfall, 69% of the respondents felt barely endangered, 27% felt somewhat endangered, and only 2% felt strongly endangered; another 2% found it hard to tell. When comparing the risk of snow avalanches or rockfalls to roads with common road hazards, 84% of the respondents stated that they found the latter risk more threatening, 11% found both risks equally threatening and only 3% found the risk of natural hazards more threatening; again 2% found it hard to tell. With regard to the current level of protection against snow avalanches and rockfalls, 67% of the respondents stated that roads are sufficiently protected while 33% would like to see better protection. Against our expectations, answers to these perceptional questions by the mountain and the urban samples were not statistically different.

In Table 3, we examine the choice frequencies for traffic safety programs against the different hazard types. Neither program was chosen in about 20% of the choice sets, suggesting that respondents were not rejecting the programs without due consideration. The choice frequency of programs against rockfall accidents was slightly higher than for programs that protect against car accidents or avalanche accidents.

[7] Since the number of people at risk on Alpine roads was determined at 2 million people, the annual risk reduction π_j provided by a traffic safety program j lies between 5×10^{-6} and 8×10^{-6} avoided fatalities.

Table 3 Pattern of preferences for traffic safety programs against different road hazards.

Preferred traffic safety program	Percentage of choices
… against snow avalanches	24.8%
… against rockfalls	28.0%
… against car accidents	26.3%
… neither	20.9%

4.2 The basic VSL model

In the next sections, we report on selected results of the non-linear conditional logit model as outlined in Section 2.3. We begin by presenting two estimates of the basic VSL model (Model I), whose indirect utility function includes only the personalized cost and the discounted risk reduction as explanatory variables (see Table 4). The two estimates of Model I differ only in the number of choice observations. While the first estimate includes the full sample of observations, the second is restricted to the observations of those respondents who also answered the attitudinal questions necessary to estimate the interaction models presented below (see Models III–IV).

The differences between the estimated coefficients are relatively small, indicating that our basic model is relatively robust against restrictions in the sample size. All coefficients are significant and have the expected signs. The coefficient of the risk parameter is positive, indicating that the respondents valued risk reductions as benefits, while the coefficient of the cost parameter is negative showing that spending private money on traffic safety programs entails a disutility. The discount rate δ was estimated at 11.8% and 11.1% respectively, which is at the upper range of discount rates reported in market-based VSL studies (Viscusi and Aldy 2003). The coefficient estimates in Table 4 imply a VSL of CHF 8.26 million (€5.35 million) for the full sample and of CHF 7.64 million (€4.95 million) for the restricted sample.[8] The corresponding WTP for the average traffic safety program is between CHF 49.70–53.70 (€32.30–34.90).[9] Standard errors around the VSL estimates were calculated at CHF 1.41 million (€0.91 million) for the full sample and at CHF 1.32 million (€0.85 million) for the restricted sample, using the Delta method (see Greene 2008: 69).

[8] Technically, the VSL is estimated as $[-\hat{\alpha}_1 / \hat{\beta}_1]$ × 1 million. The multiplication by one million is necessary since we coded the risk reduction as 5, 6, 7 and 8 instead of 5×10^{-6}, 6×10^{-6}, 7×10^{-6} and 8×10^{-6}.

[9] The individual mean WTP for the average traffic safety program is calculated by multiplying the VSL value by the mean risk reduction provided by the programs, which is equal to 6.5×10^{-6}.

Table 4 Model I: Basic conditional logit model (full and the restricted sample).

Parameters	Full Sample		Restricted Sample	
	Coefficient [a]	*t*-stat	Coefficient [a]	*t*-stat
Marginal utility of risk reduction (α_1)	0.02809 (0.00481)	5.814	0.02656 (0.00466)	5.700
Marginal utility of cost (β_1)	– 0.00340 (0.00031)	– 10.983	– 0.00348 (0.00032)	– 10.824
Discount rate (δ)	0.11808 (0.02580)	4.577	0.11102 (0.02529)	4.390
Number of observations (Q)	2,572		2,388	
Number of respondents (N)	433		402	
Log-likelihood function (LL_1)	– 2,578.46		– 2,398.46	
Likelihood ratio index [b]	0.0875		0.0858	

[a] Standard errors in parentheses;

[b] Calculated as $1 - LL_1/LL_0$, where LL_0 denotes the log-likelihood function of the constant-only model.

4.3 The effect of wealth on the VSL

The use of the relative bid vehicle allows exploration of how the VSL varies with wealth. Economic theory suggests that the VSL marginally increases with increasing wealth.[10] Hammitt and Treich (2007) provide two reasons for this wealth effect. First, wealthier people lose more in absolute terms when they die. Second, their utility cost of spending is smaller due to the standard assumption of decreasing marginal utility with respect to wealth. To test for this wealth effect, Model II includes an interaction between the personalized cost of the program C_{ij} and the logarithm of the last tax bill τ_i, i.e. $V_{ij} = \alpha_1 \times R_j + \beta_1 \times C_{ij} + \beta_\tau \times C_{ij} \times \ln(\tau_i)$,

---

[10] To prove this assertion, we draw on the definition of the VSL as the marginal rate of substitution between wealth and mortality risk. The standard model of WTP for changes in mortality risk defines the VSL as (Hammitt 2000): $\text{VSL} \equiv \frac{dw}{dp} = \frac{u(w)-v(w)}{(1-p)u'(w)+pv'(w)}$, where p is the individual's probability of dying during a defined period and $u(w)$ and $v(w)$ denote the utilities derived from wealth conditional on surviving or dying in that period. (The primes indicate first derivatives with respect to wealth.) Some assumptions are commonly made on the form of the utility functions: (i) survival is preferred to death: $u(w) > v(w)$; (ii) the marginal utility of wealth is non-negative and greater in life than in death: $u'(w) > v'(w) \geq 0$; and (iii) individuals are risk averse with respect to wealth: $u''(w) \leq 0$, $v''(w) \leq 0$. Under these assumptions, the first derivative of the VSL with respect to wealth is always positive ($\partial\text{VSL}/\partial w > 0$) and the second derivative is always non-negative ($\partial^2\text{VSL}/\partial w^2 \geq 0$).

whereby $\ln(\tau_i)$ serves as a measure of the utility of wealth.[11] The interaction term captures the difference between how much wealthier people and poorer people are willing to pay, relative to their wealth status. Table 5 presents the estimations of this model using both the full and the restricted sample of observations.

Table 5 Model II: Conditional logit model with tax interaction (full and restricted sample).

Parameters	Full Sample		Restricted Sample	
	Coefficient [a]	*t*-stat	Coefficient [a]	*t*-stat
Marginal utility of risk reduction (α_1)	0.03871 (0.00619)	6.255	0.03706 (0.00600)	6.180
Marginal utility of cost (β_1)	– 0.01677 (0.00158)	– 10.614	– 0.01718 (0.00164)	– 10.452
Interaction with the cost parameter:				
log of last tax payment (β_τ)	0.00502 (0.00050)	10.122	0.00515 (0.00052)	9.972
Discount rate (δ)	0.13948 (0.02652)	5.258	0.13281 (0.02590)	5.128
Number of observations (Q)	2,572		2,388	
Number of respondents (N)	433		402	
Log-likelihood function (LL_1)	– 2,538.99		– 2,360.06	
Likelihood ratio index [b]	0.1014		0.1004	

[a] Standard errors in parentheses;

[b] Calculated as $1 - LL_1/LL_0$, where LL_0 denotes the log-likelihood function of the constant-only model.

In line with theoretical expectations, we find that the VSL marginally increases with wealth, i.e. $\partial^2\text{VSL}/\partial\tau_i^2 > 0$. In other words, wealthier respondents are willing to pay proportionally more on the traffic safety programs than poorer respondents. Fig. 3 depicts the effect of the last tax bill on the size of the VSL estimates indicating that, at low wealth levels, the VSL is relatively inelastic toward changes in wealth (the elasticity of the VSL toward changes from CHF 2,000 to CHF 4,000 in tax payments is 0.53), but becomes increasingly elastic at higher wealth levels (the elasticity of the VSL toward changes from CHF 16,000 beyond CHF 18,000 in tax payments is 1.87). The arc elasticity of the VSL over the range of tax amounts is determined at 1.01, but shrinks to 0.84 when weighted by the class-frequency

[11] We tested other functional forms of the utility of wealth, but these functions did either provide much lower log-likelihood functions or did not converge. Consequently, we used the log form and estimated the tax-specific $\text{VSL}(\tau_i) \equiv (\partial V_{ij}/\partial R_j/\partial V_{ij}/\partial C_{ij}) = [\alpha_1/(\beta_1 + \beta_\tau \times \ln(\tau_i))]$. For computational ease, we coded the tax payment τ_i as 2, 4, 8, 12, 16 and 18.

of the taxpayers in the sample. It should, however, be warned that the estimation of VSL values of the second highest tax class was based on a limited number of respondents ($N = 18$).

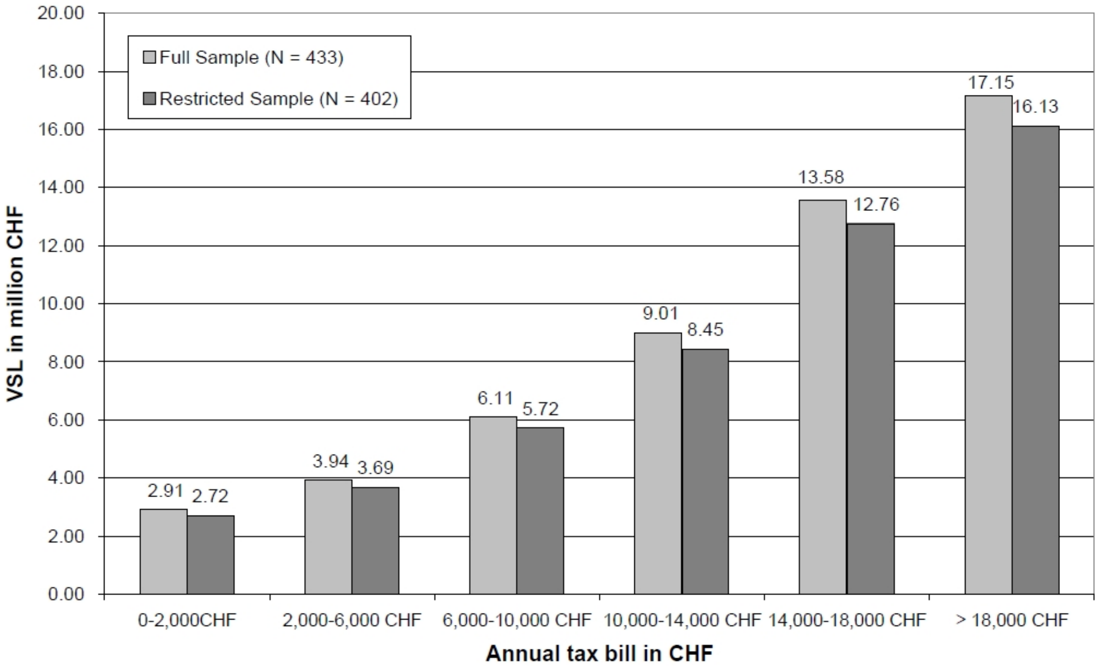

Fig. 3 Tax class-specific VSL values estimated based on Model II.

The above reported elasticity cannot be directly converted to income elasticities because the Swiss tax law permits tax deductions, which depend on the home canton and individual characteristics that are not necessarily related to income and wealth. However, since Switzerland has a progressive tax regime, the corresponding income elasticities of the majority of respondents are larger than unity. This is inline with assertions by McFadden and Leonard (1993) and Schläpfer (2008) that income elasticities of WTP less than unity constitute grounds for doubting the validity of stated-preference studies.

4.4 The effect of personal characteristics on the VSL

Personal characteristics other than wealth also affect the WTP for traffic safety on Alpine roads. Table 6 presents two interaction models estimated with the restricted sample, which individuate the marginal utilities of risk reduction and wealth, as urged by Sunstein (2004). In this way, it becomes possible to identify sources of heterogeneity in preferences for mortality risk reductions. Model III interacts the risk parameter with the personal socio-economic characteristics and the cost parameter with the last tax payment of the respondent, so that the VSL becomes conditional on the respondent's background.

Table 6 Models III–IV: Conditional logit model with personalized marginal utility of risk reduction and cost.

Parameters	Model III		Model IV	
	Coefficient [a]	*t*-stat	Coefficient [a]	*t*-stat
Marginal utility of risk reduction (α_1)	0.03783 (0.00668)	5.659	0.04475 (0.00764)	5.859
Interactions with the risk parameter:				
Age	– 0.00036 (0.00007)	– 4.791	– 0.00039 (0.00008)	– 4.900
Gender (female = 1)	0.00522 (0.00229)	1.884	0.00469 (0.00251)	1.871
University degree (yes = 1)	0.02649 (0.00723)	3.454	0.02732 (0.00787)	3.517
Sample affiliation (urban sample = 1)	0.01394 (0.00358)	3.414	0.01272 (0.00365)	3.484
Sample affiliation × university degree (urban academics = 1)	– 0.02035 (0.00687)	– 2.686	– 0.02021 (0.00748)	– 2.703
Experience with natural hazards (previous experience = 1)			– 0.00651 (0.00237)	– 2.752
Avalanche accident (yes = 1)			– 0.00277 (0.00123)	– 2.250
Rockfall accident (yes = 1)			– 0.00245 (0.00225)	– 1.091
Marginal utility of cost (β_1)	– 0.01706 (0.00167)	10.229	– 0.01841 (0.00171)	– 10.799
Interactions with the cost parameter:				
Log of last tax payment	0.00515 (0.00053)	9.693	0.00535 (0.00053)	10.172
Perceived safety on roads (current protection is insufficient = 1)			0.00256 (0.00062)	4.153
Discount rate (δ)	0.11023 (0.02150)	5.127	0.11071 (0.02149)	5.152
Number of observations (Q)	2,388		2,388	
Number of respondents (N)	402		402	
Log-likelihood function (LL_1)	– 2,304.51		– 2,286.26	
Likelihood ratio index [b]	0.1216		0.1285	

[a] Standard errors in parentheses;

[b] Calculated as $1 - LL_1/LL_0$, where LL_0 denotes the log-likelihood function of the constant-only model.

The significant coefficient of the interaction term between a sample indicator dummy (mountain sample = 0; urban sample = 1) and the risk parameter indicates that, *ceteris paribus*, respondents from the urban sample had a 30% higher marginal utility of risk reduction (see Table 6). While surprising at first glance, we offer two possible explanations for this result. First, people who are more familiar with natural hazards might have a higher risk acceptance, as they see these risks as part of living in the mountains. Corresponding statements made by focus group participants from the mountainous region support this explanation. Second, respondents from the urban sample have altruistic motives that increase their marginal utility of risk reduction (Rodriguez and Leon 2004), although their personal benefit from traffic safety on Alpine roads is smaller than that of respondents from the mountain sample. This explanation is supported by answers made by respondents from the urban sample to the debriefing questions at the end of the survey.

To further explore the first explanation, we included two interaction terms: a two-way interaction between the risk parameter and a dummy indicating whether the respondent holds a university degree, and a three-way interaction between this university dummy, the risk parameter and the sample indicator dummy. This revealed that respondents with an academic background generally had a higher marginal utility of risk reduction, and that this preference was particularly strong for academics from the mountain sample. Accordingly, non-academics from the mountain sample placed a much lower value on risk reduction than the rest of the respondents. The debriefing questions revealed that non-academics from the mountain sample feel entitled to the benefits of mitigation and are not willing to privately contribute to its financing.

The interaction term between the age of the respondent and the risk parameter indicates a decrease in the marginal utility of risk reductions by approximately 0.9% per life year. This is in line with empirical observations that the VSL decreases with age (Viscusi and Aldy 2003). Alberini et al. (2004) propose two explanations for this age effect that could affect the valuation of reduced mortality risk—the individual risk exposure and the utility of wealth. As risk exposure on Alpine roads presumably declines with increasing age (older people tend to travel less), we tested a three-way interaction between risk, self-reported exposure and age. This interaction term had a negligibly small effect on the age coefficient, suggesting that the age effect is not caused by correlations between exposure and age but by decreasing utility of wealth.

The interaction term between the gender of the respondent and the risk parameter was barely significant at the 5% level and further testing by means of a bootstrap re-estimation with 200 random resamplings resulted in a non-significant coefficient. This corresponds with observations by Davidson and Freudenburg (1996) who found that women and men have similar perceptions of most environmental risks. Since, in both samples, men were more likely to hold a university degree than women, we tested for a three-way interaction effect between the gender, the risk parameter and the university dummy, which also turned out to be insignificant. Thus, gender had no significant impact on the valuation tasks in this study.

The interaction term between the tax payment and the cost parameter resulted in qualitatively similar results to those in Model II. We additionally tested a three-way interaction between the cost parameter, the last tax payment and the sample indicator dummy, which rejected the hypothesis that the two samples differed with regard to wealth in a manner that influenced the valuation of the costs.

4.5 The effects of perceptional factors on the VSL

Model IV extends Model III by including further interaction terms between the risk parameter and the road hazard type, between the risk parameter and perceptional factors of risk, and between the cost parameter and the respondent's appraisal of the current level of safety on Alpine roads. To this end, car accidents were coded as the reference risk, i.e. negative (positive) coefficients of the avalanche and rockfall dummies in 6 imply a decrease (increase) in the perceived risk *compared to* car accidents.

The coefficient of the interaction term between the risk parameter and the rockfall dummy was not significant, indicating that the perceived risk from car accidents and rockfall accidents does not differ in a way that affects the demand for risk reduction. In comparison, the interaction term between the risk parameter and the avalanche dummy was significant and had a negative sign, suggesting that avalanche accidents were perceived as less worthy to be mitigated. One possible explanation for this different perception of the three road hazard types is that avalanche accidents are relatively rare whereas car accidents and rockfall accidents frequently occur, although they do not always cause fatalities. We tested an additional interaction effect between the risk parameter, the hazard type and the sample indicator dummy. This three-way interaction was not significant, indicating that the perception of the road hazard type was not systematically different between the sample groups.

The interaction term between self-reported experience and the risk parameter showed that respondents, who stated that they or their relatives had prior experiences with natural hazards, valued the marginal utility of risk reductions less than respondents who had no prior experiences. The same effect was found for the self-declared exposure but we omitted this variable in the presented models due to its strong correlation with the sample affiliation of the respondent, which would have induced problems of heteroscedasticity (Greene 2008). In line with observations from psychometric risk research (see Slovic et al. 2000), we conclude that respondents, who had more knowledge about natural hazards, perceived the risks on Alpine roads as less threatening than those who had no prior experiences.

As expected, the interaction term between the cost parameter and the attitude toward the current protection on Alpine roads was significant. Respondents who stated that the current level of safety against natural hazards on Alpine roads was insufficient were willing to spend 14% more on the traffic safety programs than those who felt that current safety was sufficient.

The coefficients of the other interaction effects in Model IV were of comparable size to those estimated in Model III (see 6). A likelihood ratio test (LRT) showed that the inclusion of the additional interaction terms between the risk parameter and the hazard type and between the cost parameter and the attitude toward current safety did significantly improve the model (LRT: $\chi^2_{\langle 13-9 \rangle} = 36.50$; $P < 0.001$). By applying the estimated coefficients to the actual choice observations of the respondents, one can generate distributions of the VSL values implied with these choices (Fig. 4). These distributions illustrate that, depending on the individual characteristics, the marginal rate of substitution between risk reduction and money varies within a broad range. The 95% percentile was CHF 16.4 million (€10.7 million) for the distribution based on Model III and CHF 19.2 million (€12.5 million) for the distribution based on Model IV. The mean values of these VSL distributions (Model III: CHF 5.7 million; Model IV: CHF 8.2 million) were substantially above the median values (Model III: CHF 4.2 million; Model IV: CHF 4.3 million), suggesting that wealthy taxpayers contribute over-proportionally to the VSL point estimate of Model I.

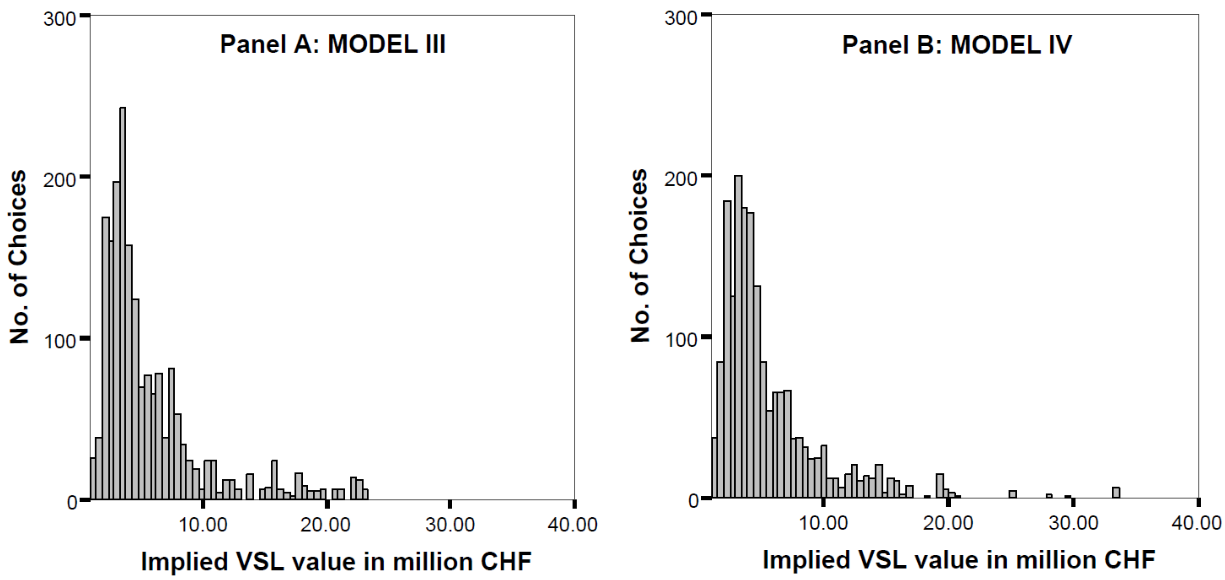

Fig. 4 Distributions of the personalized VSL estimated based on Model III (Panel A) and Model IV (Panel B). The distribution mean VSL values are CHF 5.74 million (Model III) and CHF 8.24 million (Model IV), the 95% percentiles are CHF 16.37 million (Model III) and CHF 19.22 (Model IV).

4.6 Scope and sensitivity tests

The validity of stated-preference studies is often challenged by opponents who argue that, being of hypothetical nature, the stated choices fail to be related to real transactions as observed in markets. It has therefore become standard to test the scope and sensitivity of the results obtained from stated-preference studies (Heberlein et al. 2005; Leiter and Pruckner 2009). The basic requirement in every scope test of VSL estimates is that respondents receive a positive marginal utility from risk reductions and a negative marginal utility of costs, i.e. they are willing to pay for risk reductions, but not at any price. The results of Models I–IV conform to these requirements.

To control for the reliability of our original estimates, we cross-validated these results using re-estimations with the bootstrap method (Efron and Tibshirani 1993). These re-estimations relied on 200 replications of random resamplings with replacement from the sample of observations, where each of these replications consisted of Q = 2,388 draws. The bootstrap estimations yielded robust standard errors around the bootstrap coefficients, which allowed computing 95% confidence intervals by multiplying the bootstrap standard errors of the coefficient estimates by 1.96.

We then re-estimated the models by dropping all observations (i) from those respondents who stated in the debriefing questions that they felt particularly uncertain about their choices and (ii) from the first and last choice set of every respondent. Neither of these re-estimations altered the broad picture of the model results. The coefficient estimates of these restricted models were all within their corresponding 95% confidence intervals, though some of the interaction effects deviated substantially from the original model estimates. Table 7 exemplifies this validity check for the re-estimations of Model IV, indicating that our original coefficient estimates are robust against confounding influences of hidden variables.

The validity of stated-preference studies is not only determined by scope sensitivity, but also by the robustness of the valuation measures toward changes in specific attribute levels. We therefore analyzed the effects of marginal changes in the risk and cost parameters of the traffic safety programs. First, consider a marginal increase in the cost C_{ik} of the traffic safety program k. We were interested in how much this increase would decrease the probability $\Pr(k|i)$ that individual i had chosen this program.

Table 7 Comparison of the coefficient estimates of the re-estimated Model IV with the 95% confidence intervals obtained from bootstrap standard errors.

Parameters	95% confidence interval		Restricted model coefficients	
	lower limit	upper limit	Coefficient [a]	Coefficient [b]
Marginal utility of risk reduction (α_1)	0.02806	0.06374	0.04461	0.04688
Interactions with the risk parameter:				
age	– 0.00057	– 0.00022	– 0.00032	– 0.00038
gender (female = 1)	– 0.00065	0.01048	0.00758	0.00555
university degree (yes = 1)	0.01139	0.04663	0.02199	0.02934
sample affiliation (urban sample = 1)	0.00522	0.02131	0.00885	0.01163
sample affiliation × university degree (urban academics = 1)	– 0.03794	– 0.00412	– 0.01140	– 0.02124
experience with natural hazards (previous experience = 1)	– 0.01215	– 0.00115	– 0.00857	– 0.00672
avalanche accident (yes = 1)	– 0.00522	– 0.00047	– 0.00287	– 0.00209
rockfall accident (yes = 1)	– 0.00776	0.00261	– 0.00292	0.00028
Marginal utility of cost (β_1)	– 0.02203	– 0.01497	– 0.01687	– 0.01997
Interactions with the cost parameter:				
log of last tax payment	0.00430	0.00647	0.00478	0.00590
perceived safety on roads (current protection is insufficient = 1)	0.00139	0.00370	0.00258	0.00253
Discount rate (δ)	0.06237	0.16703	0.10786	0.11643

[a] Sample restriction by dropping observations of uncertain respondents.

[b] Sample restriction by dropping observations of the first and of the last choice set for each respondent.

By taking the partial derivative of the choice probability as defined in Eq. (3) with respect to the cost parameter, the marginal effect becomes (the detailed derivation is given in the Appendix):

$$\mathrm{M}(C_{ik}) = \frac{\partial \Pr(k \mid i)}{\partial C_{ik}} = (\beta_1 + \mathbf{W}_k \boldsymbol{\beta}_2 + \mathbf{Z}_i \boldsymbol{\beta}_3) \Pr(k \mid i)(1 - \Pr(k \mid i)) = \boldsymbol{\beta} \Pr(k \mid i)(1 - \Pr(k \mid i)), \qquad (7)$$

where $\boldsymbol{\beta} = (\beta_1 + \mathbf{Z}_i\boldsymbol{\beta}_2 + \mathbf{W}_j\boldsymbol{\beta}_3)$ denotes the compound coefficient vector of the cost interactions. Similarly, the marginal effect of a change in the discounted risk reduction R_k on the choice probability of program k is given by (the detailed derivation is given in the Appendix):

$$\mathrm{M}(R_k) = \frac{\partial \Pr(k \mid i)}{\partial R_k} = (\alpha_1 + \mathbf{W}_k \boldsymbol{\alpha}_2 + \mathbf{Z}_i \boldsymbol{\alpha}_3) \Pr(k \mid i)(1 - \Pr(k \mid i)) = \boldsymbol{\alpha} \Pr(k \mid i)(1 - \Pr(k \mid i)), \qquad (8)$$

where $\boldsymbol{\alpha} = (\alpha_1 + \mathbf{Z}_i\boldsymbol{\alpha}_2 + \mathbf{W}_j\boldsymbol{\alpha}_3)$ denotes the compound coefficient vector of the risk reduction interactions.

Since the marginal effects differ across individuals and choice sets, we calculated the weighted marginal mean effects over all choice observations Q, using the weighting procedure outlined by Louviere et al. (2000) to adjust for outlying estimates of choice probabilities that could otherwise lead to overestimations of marginal effects.[12] Table 8 gives the weighted mean marginal effects of changes in the risk and cost parameter for Models III–IV. These mean marginal effects show that a unit change, either in the discounted risk reduction or in the cost of a program, has an insignificantly small impact on the choice probability of a traffic safety program.

Table 8 Marginal effects and point elasticities of changes on the choice probability of traffic safety programs.

Variable	Model III	Model IV
Marginal mean effect of change in cost	– 0.00149	– 0.00151
Point elasticity of cost	– 0.35096	– 0.35101
Marginal mean effect of change in risk reduction	0.00727	0.00747
Point elasticity of risk reduction	0.73851	0.74664

Based on the marginal effects, it is straightforward to derive the (weighted) point elasticities of changes in risk reduction and in costs as $\mathrm{E}(R_k) = \mathrm{M}(R_k) \times R_k \times \Pr(k|i)^{-1}$ and $\mathrm{E}(C_{ik}) = \mathrm{M}(C_{ik}) \times C_{ik} \times \Pr(k|i)^{-1}$, respectively (Greene 2008). These point elasticities measure the percentage change in the choice probability of a particular program with respect to a 1% change in either the risk reduction or the cost parameter of this particular program. For the most extensive Models III–IV, the choice probability was found to be relatively inelastic ($-1 < \mathrm{E}(C_{ik}) < 0$, $0 < \mathrm{E}(R_k) < 1$; see Table 8), suggesting that the VSL estimations based on our non-linear conditional choice model are robust against small changes in the key attributes of the traffic safety programs.

[12] Louviere et al. (2000) define the weighted marginal effect of changes in the attribute X for all observations Q as: $\overline{\mathrm{M}}(X) = \sum_{q=1}^{Q} [\mathrm{M}_q(X) \Pr(q) / \sum_{q=1}^{Q} \Pr(q)]$, where q denotes one choice observation, $\mathrm{M}_q(X)$ is the marginal effect of a change in X in this particular observation, and $\Pr(q)$ denotes the choice probability of every single choice observation q.

5 Discussion and conclusions

This article has analyzed public preferences for mortality risk reductions on Alpine roads. Using a choice experiment, we asked respondents how much they would be willing to contribute in order to maintain the current level of traffic safety on these roads. The prompted tradeoffs between risk reduction and money imply a VSL in the range of CHF 7.6 to 8.3 million (€4.9 to 5.4 million), which is in the ballpark of VSL estimates obtained from other stated preference studies in the context of public risk to life and limb (Alberini et al. 2007; Hultkrantz et al. 2006). Our VSL estimates are somewhat above the figure of CHF 5 million (€3.25 million) currently used by the Swiss administration to evaluate mitigation programs against natural hazards (PLANAT 2005). On the other hand, they are distinctly lower than estimates of a Swiss labor market study (Baranzini and Ferro Luzzi 2001), which obtained inflation adjusted VSL values in the range of CHF 10.8 to 16.2 million (€7.0 to 10.5 million).

Mortality risks on Alpine roads are predominantly borne by frequent road users and are thus unevenly spread over the population. We therefore recruited respondents from a mountainous region and from an urban region of Switzerland, representing exposed and unexposed people. To our surprise, respondents from the mountain group were *ceteris paribus* willing to pay less for the proposed traffic safety programs, though they are more exposed and would hence benefit more from the reductions in risk. We find two explanations for this apparent violation of rational choice behavior.

First, an interaction effect between the origin and the education of the respondents revealed that non-academics from the mountain sample had a significant lower marginal utility of risk reduction. As indicated by comments on returned survey questionnaires, this group of respondents felt that it was the duty of the government to take care of their safety on Alpine roads. They refused to make private contributions to the proposed safety traffic programs more often than the rest of the respondents. (The choice frequency of the neither option was at 25% for non-academics from the mountain sample, while it was at 16% for the remaining respondents.) We conclude that a withdrawal of public resources for the protection of Alpine roads, as hypothesized in the description of our choice task, caused protest behavior among respondents who feel entitled to safety on Alpine roads.

Second, past research has found that preferences for public goods are determined by complicated patterns of egoistic and altruistic motives (Kahneman and Knetsch 1992; Kahneman et al. 1999). Altruism is a non-use value that becomes relevant for the economic valuation of mortality risk reductions if individuals are concerned about the safety of others but indifferent with respect to further determinants of welfare (Jones-Lee 1991). While our results suggest the existence of altruist values for road safety in the Alps, we could not determine whether these values are driven by such paternalistic motives. What we found is, however, that respondents who are rarely or never exposed to hazards on Alpine roads were obviously concerned about the reduction of risks threatening the lives of others. Frequently exposed people showed a higher risk tolerance. In line with Chilton et al. (2006), we argue that the marginal utility of risk reduction of these respondents is smaller, because they are more familiar with natural hazards and feel therefore less threatened.

Clearly, the perception of mortality risks involved with driving on Alpine roads played an important role in the valuation of the traffic safety programs. This is not astonishing, since the standard economic model of choice implies that preferences over levels of consumption of goods are made up of the individual's subjective perceptions of these goods. The expressed preferences are functions of attitudes, experiences, and beliefs, including both observed and unobserved components (McFadden 2001). We find it, therefore, surprising that the hazard type played a minor role in the overall valuation of the alternatives traffic safety programs although the attitudinal questions in the survey indicated that the respondents perceived the risk of car accidents as most threatening. In fact, the hazard type had an insignificant effect on the stated WTP, which was only about 6% lower for programs directed against avalanches than for programs against car accidents. There was no statistical difference between programs directed against rockfall or car accidents. We conclude that most respondents did not paid attention to the hazard type, but emphasized on the costs and expected risk reductions.

The experimental design of our study allowed the investigation of several aspects of heterogeneity in preferences for mortality risk reductions. The results provide evidence for discerning the VSL based upon the personal background of the people at risk (Sunstein 2004). Besides personal characteristics such as the age or education of a respondent, the *individuated* VSL is mainly driven by the marginal utility of wealth. We found that the WTP for risk reductions increases over-proportionally with wealth. Though this observation corresponds with the assumption of marginally decreasing utility of wealth, the wealth effect is rather strong. We attribute the size of the wealth effect to the use of the relative bid vehicle, which implied high bid amounts to wealthy respondents. However, this bid structure reflects the progressive Swiss tax regime due to which public programs are foremost financed through taxes provided by wealthier citizens.

In conclusion, we provide new insights to the valuation of road hazards on Alpine roads. By testing several interaction effects of personal characteristics and individual risk perceptions, we were able to identify sources of heterogeneity in preferences for mortality risk reductions. We found evidence that the utility of wealth plays a key role in the valuation of the proposed traffic safety programs. These results suggest that individuating the cost parameter—and possibly also the risk parameter—is a promising way to analyze differences in the individual WTP for mortality risk reductions.

Appendix

A1 Marginal effect of a change in the cost of a mitigation program

The marginal effect of a change in the cost parameter $C_{i,k}$ on individual i's probability $\Pr(k|i)$ to choose the mitigation program k is derived as:

$$\mathrm{M}(C_{i,k}) = \frac{\partial \Pr(k \mid i)}{\partial C_{i,k}} = \partial\left(\frac{\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]}{\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]}\right)\left(\frac{1}{\partial C_{i,k}}\right) =$$

$$\frac{(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)\left(\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)] - (\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)])^2\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)^2} =$$

$$\frac{(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)^2} =$$

$$\frac{(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)} =$$

$$\frac{(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)\Pr(k \mid i)\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]} =$$

$$(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)\Pr(k \mid i)(1 - \Pr(k \mid i)) = \boldsymbol{\beta}\Pr(k \mid i)(1 - \Pr(k \mid i)), \tag{A1}$$

where $\boldsymbol{\beta} = \beta_1 + \mathbf{Z}_i\boldsymbol{\beta}_2 + \mathbf{W}_j\boldsymbol{\beta}_3$ denotes the compound coefficient vector of the cost interactions.

A2 Marginal effect of a change in the risk reduction provided by a mitigation program

The marginal effect of a change in the risk parameter R_k on on individual i's probability $\Pr(k|i)$ to choose the mitigation program k is derived as:

$$\mathrm{M}(R_k) = \frac{\partial \Pr(k\mid i)}{\partial R_k} = \partial\left(\frac{\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]}{\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]}\right)\left(\frac{1}{\partial R_k}\right) =$$

$$\frac{(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3)\left(\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)] - (\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)])^2\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)^2} =$$

$$\frac{(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3)\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)^2} =$$

$$\frac{(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3)\exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)\left(\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)} =$$

$$\frac{(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3)\Pr(k\mid i)\left(1 - \exp[R_k(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,k}(\beta_1 + \mathbf{W}_k\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]\right)}{\sum_{j\in J}\exp[R_j(\alpha_1 + \mathbf{W}_j\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3) + C_{i,j}(\beta_1 + \mathbf{W}_j\boldsymbol{\beta}_2 + \mathbf{Z}_i\boldsymbol{\beta}_3)]} =$$

$$(\alpha_1 + \mathbf{W}_k\boldsymbol{\alpha}_2 + \mathbf{Z}_i\boldsymbol{\alpha}_3)\Pr(k\mid i)(1 - \Pr(k\mid i)) = \boldsymbol{\alpha}\Pr(k\mid i)(1 - \Pr(k\mid i)),$$

(A2)

where $\boldsymbol{\alpha} = \alpha_1 + \mathbf{Z}_i\boldsymbol{\alpha}_2 + \mathbf{W}_j\boldsymbol{\alpha}_3$ denotes the compound coefficient vector of the risk reduction interactions.

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