Willingness to Pay and Sensitivity to Time Framing: A Theoretical Analysis and an Application on Car Safety*

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Abstract

Stated preference (SP) surveys attempt to obtain monetary values for non-market goods that reflect individuals' "true" preferences. Numerous empirical studies suggest that monetary values from SP studies are sensitive to survey design and so may not reflect respondents' true preferences. This study examines the effect of time framing on respondents' willingness to pay (WTP) for car safety. We explore how WTP per unit risk reduction depends on the time period over which respondents pay and face reduced risk in a theoretical model and by using data from a Swedish contingent valuation survey. We find that WTP is sensitive to time framing; the theoretical model predicts that the effect is likely to be nontrivial, and empirical estimates from an annual scenario are about 70 percent higher than estimates from a monthly scenario.

Keywords Car safety, Contingent valuation, Time frame, Willingness to pay

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1 Introduction

The monetary value of reducing road mortality risk is, together with the monetary value of reduced travel time, one of the dominant components of the benefit side in a benefit cost analysis (BCA) of transport investments and policies. This can explain the substantial literature on studies estimating the value of traffic safety (Andersson and Treich, 2011). The dominant approach to derive the value of safety is the willingness to pay (WTP) (or willingness to accept) approach, where the tradeoff between risks and wealth is estimated. For mortality risks, this value is usually referred to as the value of a statistical life (VSL).

VSL is a measure of individuals' preferences that descibes the amount of wealth individuals are prepared to trade for small reductions in mortality risk. To estimate VSL, since there are no market prices for mortality risk reductions, analysts have to rely on non-market evaluation techniques. These techniques can, broadly speaking, be classified as revealed- (RP) or stated-preference (SP) techniques. The former refers to an approach where individuals' market choices are used to derive the VSL. The hedonic regression technique (Rosen, 1974) has dominated this approach to estimate the VSL. It has mainly been used on the labor market where workers' willingness to accept riskier jobs for larger monetary compensation has been estimated (Viscusi and Aldy, 2003). It has also been used in the car market to derive car consumers' WTP for safer cars (Atkinson and Halvorsen, 1990; Dreyfus and Viscusi, 1995; Andersson, 2005, 2008).

The SP approach enables the analyst to tailor the survey/experiment to elicit preferences for specific risks, even when no market exists (e.g., because of potential free riding (Carson and Hanemann, 2005)), and has been used in a large number of studies (Hammitt and Graham, 1999; Andersson and Treich, 2011). This flexibility is its major advantage compared to the RP approach. However, its major drawback is the hypothetical scenario itself, and the fact that respondents are often asked to state their preferences for goods that are unfamiliar and for which they have little experience. This unfamiliarity with the good could explain some of the evidence suggesting survey respondents do not have well-defined preferences. For instance, numerous empirical studies have found evidence of preference reversals as a result of variations of survey and experimental design (Tversky et al., 1990; Tversky and Thaler, 1990; Irwin et al., 1993). Similarly, some SP studies have found that respondents exhibit anchoring/starting-point bias, where their stated WTP is influenced by the bid levels presented in the survey (Herriges and Shogren, 1996; Boyle et al., 1997, 1998; Green et al., 1998; Roach et al., 2002). Results have also been found to be influenced by the amount of information given and the possibility of learning as part of the survey/experiment (Corso et al., 2001; Bateman et al., 2008). Other problems often raised in relation to SP studies are hypothetical and strategic bias and, in the case of eliciting preferences for risk changes, a lack of understanding of small probability changes (Hammitt and Graham, 1999; Andersson and Svensson, 2008; Bateman et al., 2002; Blumenschein et al., 2008).

The aim of this study is to estimate VSL for car safety. The main objective, beyond estimating values that can be considered for policy use, is to examine how VSL is related to the time frame presented to respondents. When considering their WTP for a good, survey respondents must consider the time frame, i.e., when and how often payments are to be made, and for how long the good will be provided. Hence, it is important that the analyst, when deciding on the time frame, considers what is the best design to create a scenario that is both understandable (e.g. by using a longer time period to avoid very small/incomprehensive risks) and familiar payments (e.g. per time, such as annual, or per unit, such as a meal). The objective of this study is, therefore, to develop a theoretical model to examine whether respondents' rate of substitution between wealth and car safety is sensitive to the time framing of the scenario, and then to test our hypothesis using empirical data from a survey.

This question is of policy and research relevance, since studies vary in the period over which respondents are supposed to pay and to benefit. While many studies evaluate annual payment for annual benefit, others have chosen to ask respondents whether they would purchase a safety product that would reduce their risk over a 10 year period, where payments were to be made annually (Krupnick et al., 2002, 2006; Alberini et al., 2004, 2006a,b), without examining the effect the chosen time frame had on the estimates. Hammitt and Haninger (2007) asked respondents about WTP to reduce risk of food-borne illnes when the payment and risk reduction was framed per meal or per month (using the respondent's reported frequency of eating the specific food). They found that the rate of substitution between money and risk was similar in the two conditions. Beattie et al. (1998) examined the effect of time framing using a one and a five year safety program. Their results revealed a framing effect, with annual equivalent WTP ratios for means and medians of 1.54-2.05 and 2.56-4.38, respectively. However, for the five year program Beattie et al. (1998) told their respondents to think about a per-year amount and multiply it by five, which may have confounded their test. A difference between Hammitt and Haninger (2007) and Beattie et al. (1998) is that the analysis in the former was based on external (between groups) tests, whereas the latter was based on internal (within groups) tests.

The results in Beattie et al. (1998) showed that the time frame of the WTP scenario is a research question of major policy relevance, and of general interest to the evaluation of non-market goods. If the estimated rate of substitution is indeed sensitive to the time frame, BCA will require values that are appropriate to the time frame relevant to a specific policy. If the sensitivity is too great, it suggests that SP methods may not measure a stable rate of substitution that is relevant to BCA. This study build on the analysis of Beattie et al. (1998) by: (i) showing the theoretical prediction on the estimated WTP from time framing, and (ii) presenting the respondents in the different subsamples with only one time frame. We argue regarding the latter that our results are more relevant than Beattie et al. (1998) to answering how important is the choice of the frame, since in most SP studies only one frame is used.

In the following section 2 we describe the VSL framework in the single- and multi-period model with their theoretical predictions. To estimate VSL and study the effect of time framing, we conduct a contingent valuation (CVM) survey using a double-bounded dichotomous choice format (Hanemann et al., 1991) on a Swedish sample of ca. 900 individuals, which is described in section 3. It is not obvious which is the relevant time frame for different non-market goods, but often an annual scenario is used. We examine how stated WTP is affected by dividing our sample into two subsamples, presented with annual and monthly time frames, respectively. The scenarios are designed so that if the rate of substitution between wealth and current mortality risk is stable, the two time frames will yield similar estimates of the VSL.

The empirical models are shown in section 4 and we present our results in section 5. Our results suggest the choice of the time frame can be important when designing the survey. As shown in the numerical examples of the theoretical model, the time frame can have a significant effect on the estimated VSL. Our empirical analysis reveal some evidence of time framing, but that the magnitude of the effect may be small compared with other problems related to estimating VSL in SP studies. In section 6 we discuss our findings and draw some conclusions.

2 The theoretical framework

2.1 Standard single-period model

The VSL is the marginal rate of substitution (MRS) between risk and wealth (Jones-Lee, 1974; Rosen, 1988). Considering a standard single-period model, the individual is assumed to maximize his state-dependent indirect expected utility,

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

where w, p, and $u_s(w),\ s \in \{a,d\}$, denote wealth, baseline probability of death, and the state dependent utilities, respectively, with subscripts a and d denoting survival and death. We adopt the standard assumptions that $u_a(w)$ and $u_d(w)$ are twice differentiable with

$$u_a > u_d,\ u_a' > u_d' \geq 0,\ \text{and}\ u_s'' \leq 0, \tag{2}$$

i.e. $u_s(w)$ is increasing and weakly concave, and $\forall\ w$ utility and marginal utility are larger if alive than dead. Totally differentiating Eq. (1) and keeping utility constant results in the standard expression for the MRS(w,p),

$$\text{VSL} = \left.\frac{dw}{dp}\right|_{EU\text{ constant}} = \frac{u_a(w) - u_d(w)}{pu'_d(w) + (1-p)u'_a(w)}. \tag{3}$$

Under the properties of (2), VSL is positive and increasing with w and p (Jones-Lee, 1974; Weinstein et al., 1980; Pratt and Zeckhauser, 1996).

Equation (3) denotes marginal WTP. In surveys respondents are asked about their WTP for a small but finite risk reduction, Δp, and VSL is then the ratio between WTP and Δp. The respondents' WTP for Δp is then approximated as,

$$WTP = \text{VSL} \cdot \Delta p, \tag{4}$$

hence, WTP should be near-proportional to Δp, a necessary (but not sufficient) condition for WTP from CVM-studies to be valid estimates of individuals' preferences (Hammitt, 2000).[1]

2.2 Multi-period model

Equation (4) defines the respondents' WTP in a single-period model, e.g. a year. In this study we are interested in how respondents' WTP is affected by how this time period is defined, i.e. the length of the time period. Since a longer time period can be seen as a series of shorter time periods, it also means that respondents' WTP for a risk reduction during a longer time period can be redefined as a series of payments and risk reductions (Δp_t). WTP at τ for a series of discrete risk reductions can be evaluated by,

$$\text{WTP}_\tau = \frac{1}{(1-p_\tau)} \sum_{t=\tau}^{T} \left\{ \frac{q_{\tau,t}}{(1+i)^{t-\tau}} \frac{u_a(c_t)}{u'_a(c_\tau)} \Delta p_t \right\}, \tag{5}$$

where p_τ is the probability of dying during period τ conditional on entering the period alive, $q_{\tau,t} = (1-p_\tau)\dots(1-p_{t-1})$ is the probability at τ of surviving to period t, i is the utility discount rate, and c_t is the optimal consumption level at t (Johansson, 2001, 2002; Morris and Hammitt, 2001).

When examining WTP in a multiperiod setting we need to address how it varies with age. The life-cycle period model has been used to predict how WTP varies with age, and it can be shown that WTP over the life cycle will depend on the consumption path (Shepard and Zeckhauser, 1984; Johansson, 2002). In the life-cycle model an individual's expected utility is given by

$$EU_\tau = \sum_{t=\tau}^{\infty} q_{\tau,t}(1+i)^{\tau-t} u(c_t^*), \tag{6}$$

where c_t^* is the optimal consumption level at t. Johansson (2002) showed that the optimal consumption path will depend on the assumptions of the model and that the effect of age on WTP is indeterminate.

[1] Equation (3) can be used to illustrate the effect on VSL from Δp, which will be less than or equal to $1/[1+\Delta p/(1-p)]$. The income effect on VSL is not constrained by the theoretical model. Empirical evidence suggests that within a country the income elasticity of VSL is between zero and one (Hammitt and Robinson, 2011), evidence that can be used to show that the income effect will only cause a small departure from near-proportionality (Hammitt, 2000).

Our focus is not on the effect of age on the WTP, instead we use the life cycle model to examine how WTP per unit of risk reduction is affected by the time framing of the scenario. In the empirical scenario that we analyze, and of those in SP studies for which this analysis is relevant, the length of the intervals and the size of T is short enough that we can assume that the optimal consumption level is constant during the interval, thus $c_t^* = c_\tau$.

Our objective is to examine how an individual's WTP at $t = \tau$ differs between a risk reduction that lasts over the interval $[\tau, \tau + T]$ and a series of risk reductions over T intervals. For instance, in our empirical analysis our time intervals last a month and $T = 12$, i.e. they correspond to one year. We assume that the risk reduction is constant ($\Delta p_t = \Delta p_\tau$), and that the aggregated risk reduction is the same in the one- and multiperiod setting. The WTP for for the risk reduction that lasts over $[\tau, \tau + T]$ can then defined as follows,

$$\mathrm{WTP}_\tau^s = \frac{u_a(c_\tau)}{(1 - Tp_\tau)u_a'(c_\tau)} T\Delta p_\tau, \tag{7}$$

which is our single period model (equivalent to Eq. (3) with no bequest motives, i.e. $u_d = 0$). Based on our assumptions and by substitution, Eq. (5) can then be written as follows,

$$\mathrm{WTP}_\tau^m = \underbrace{\left[\frac{1 - Tp_\tau}{T(1 - p_\tau)} \sum_{t=\tau}^{T} \frac{q_{\tau,t}}{(1 + i)^{t-\tau}}\right]}_{\Gamma(T)} \mathrm{WTP}_\tau^s, \tag{8}$$

where it can be shown that $\Gamma(T) < 1$ and, ceteris paribus, decreasing with T. Hence, the multiperiod model will result in a WTP per unit of risk reduction that is strictly less than the single period model. The result that the multiperiod model will yield a lower bound WTP of the single period model is identical to the findings of Johannesson et al. (1997) when they examined the relationship between WTP for a "blip" (an infinitesimally short-duration change), and a permanent change of the hazard rate, i.e. they concluded that the WTP for a series of blips yields a lower bound for a permanent change.

From Eq. (8) we see that the effect from time framing will be a function of not only T, but also of p and i. In Table 1 we provide some numerical examples of $\Gamma(T)$. Let, for instance, T, p, and i refer to annual levels, and our numerical examples show that elicited WTP can be influenced by the analyst's decision on how to frame the WTP question. For shorter time periods, a small baseline risk, and most importantly a zero discount rate, the effect from choosing one over the other can be considered negligible, considering other methodological problems eliciting WTP from SP studies. However, even with a low and reasonable discount rate the effect will be non-negligible also for shorter time periods. In our empirical analysis we compare a monthly 12 period scenario with an annual single period. Assuming that the annual baseline risk and discount rate is 3/1000 and 4 percent, respectively, we expect $\Gamma(T)$ to be equal to 0.978. Hence, we expect WTP per unit of risk reduction to be close to identical between our scenarios.

[Table 1 about here.]

2.3 Multiperiod models and a background risk

So far we have assumed one aggregated measure of the baseline risk, p. We now extend our model and assume that the baseline mortality risk can be separated into a specific risk (r) and an aggregated measure of other mortality risks that is allowed to depend on the age of the respondent ($\pi(t)$). These risks can be either multiplicative (Eeckhoudt and Hammitt, 2001) or additive (Evans and Smith, 2006; Andersson, 2008). We assume that the risks are multiplicative, r is constant, and $\dot{\pi}(t) > 0$, i.e. the background risk is increasing with age. The single period survival probability is then $(1-r)(1-\pi(t))$. It is straightforward that if $\pi(t)$ is constant and the survival probability is the same in Eqs. (8) and (9), then the background risk will not affect $\Gamma(T)$,

By differentiating $\Gamma(T)$ in Eq. (8) w.r.t. t we can examine how the effect of time framing will be influenced by a background risk that is increasing with age. Let $\lambda = 1 - r$, then

$$\frac{\partial\Gamma(T)}{\partial t} = -\frac{1 - Tp_\tau}{T(1-p_\tau)} \sum_{t=\tau+1}^{T} \frac{\lambda^{t-\tau}\dot{q}_{\tau,t}}{(1+i)^{t-\tau}}, \tag{9}$$

where $\dot{q}_{\tau,t} > 0$, since $\pi_t < 1$ and $\dot{\pi}(t) > 0$. Thus, a background risk that is increasing with age will reduce the size of $\Gamma(T)$ and increase the effect of time framing. The effect will be the largest when $i = 0$.

We will use a numerical example to illustrate the effect. Let $\pi(t) = a\exp(bt)$, where $a = 0.000081$ and $b = 0.087$ (Johannesson et al., 1997), and $r = 1/10,000 \Rightarrow \lambda = 0.9999$. Since the effect will be the largest when the discount rate is zero, we also assume that $i = 0$. For a series of 12 monthly risk reductions we can show that the effect on an average 40 year old (for whom the annual mortality risk is 0.003) will be negligible, and that the effect for an average 70 year old (with annual mortality risk 0.036) will also be small,

$$\begin{aligned} \frac{\partial\Gamma(12)_{40}}{\partial t} &= -0.0013, \\ \frac{\partial\Gamma(12)_{70}}{\partial t} &= -0.0138. \end{aligned} \tag{10}$$

From Eq. (10) we conclude, when allowing for a background risk that is increasing with age, that the effect of time framing will increase with the age of the examined population However, Eq. (10) shows that also for older age groups, the effect of time framing will be small.

3 Contingent valuation survey

3.1 Survey administration and design

The CVM survey was conducted in Sweden in the fall of 2006. Prior to the main survey the questionnaire was tested in focus groups and in a pilot.[2] The main survey was distributed to 1,898 randomly chosen individuals as a postal questionnaire. A total of 34 surveys could not be delivered because "recipient unknown" (e.g. the respondents had moved or the address was incorrect). Respondents who returned their questionnaire were awarded a lottery ticket (nominal value of SEK 25), and after two reminders a 49.4 percent response rate was reached, i.e. $n = 920$.[3] Respondents were also informed in the accompanying cover letter that they had the opportunity to complete the questionnaire on the web. Only 49 respondents chose that option, however, and in order to mitigate survey heterogeneity only the answers from the postal questionnaire are analyzed.

In the main questionnaire all respondents were asked about their WTP for food and car safety. Bid and risk-reduction levels were randomly assigned, but all respondents were asked about WTP for food safety before WTP for car safety. The main questionnaire consisted of five sections, in the following order: (i) questions related to food, such as risk perception, handling, consumption, experience, etc., (ii) an evaluation example to train respondents in trading wealth for safety, (iii) WTP for food safety, (iv) WTP for car safety, and (v) follow-up questions on demographics and socio-economics. The effect of time framing was tested in the car safety scenario and so we report only results from the analysis of car safety.

In the training section respondents were asked to choose between two goods, with one cheaper but with a higher baseline risk. Unlike some other studies, we did not include a dominant alternative and so cannot use this question as an exclusion criterion for probability comprehension (Krupnick et al., 2002; Alberini et al., 2004). Instead we used two other exclusion criteria based on an assumption of general survey comprehension. Respondents were excluded if they: (i) stated that their health status would be higher if they developed salmonellosis than if they did not, or (ii) gave inconsistent answers to the double-bounded dichotomous-choice WTP questions for car safety. The latter was possible due to the

[2] The pilot, a postal questionnaire, was sent out to 202 randomly chosen individuals, out of whom 91 returned completed questionnaires (44.1 percent response rate). The sample for the pilot was split into two groups; one received questions on food and car safety, the other only on food safety. The objective was to test if the survey length had a negative effect on the response rate. We did not find any evidence of that, in fact, the response rate was slightly higher in the group who had to answer the longer questionnaire, 45.4 against 42.9 percent. For a fuller description of the survey and the subgroups, see Sundström and Andersson (2009).

[3] The lottery ticket had the effect that some empty questionnaires were returned, 103 in the main survey and 8 in the pilot. (Empty questionnaire not included in response rates reported here.) All prices are in 2006 price level. USD 1 = SEK 7.38 (www.riksbank.se, 2/11/2008)

postal format of the questionnaire.[4]

Respondents were informed in the training section that the social security system would cover any financial losses and medical expenditures due to illness and were reminded about their budget constraint. Hence, respondents' WTP should reflect their WTP to reduce the risk of an adverse health effect excluding financial consequences, which is parallel to the CVM scenarios in sections (iii) and (iv) of the questionnaire. After their decision, respondents were given feedback and once again reminded of the coverage of the social security system and their budget constraint.

To communicate the risks, respondents were provided with a visual aid in the form of a grid consisting of 10,000 white squares with the risks visualized as black squares in the training session and in the section on WTP for food safety. Previous research suggests that this form of visual aid can improve respondents' understanding of the risk/money tradeoffs (Corso et al., 2001). Since the visual aid had been presented twice to the respondents before the WTP scenario on car safety, we decided that it was not necessary to include it in that section.

3.2 Willingness to pay for car safety

Before answering the question on WTP for car safety, respondents were provided with some background questions related to driving and travelling by car (driving license, access to a car, "driving distance", injury experience, and risk perception). We had two objectives with these questions: (i) to gather information that could be used in the analysis, and (ii) to act as a "warm up" for the new scenario, i.e. we wanted to make sure that respondents were thinking about car and not food safety when answering the WTP question.

The respondents were split into two subsamples, one received a monthly scenario and the other an annual scenario. In each scenario both risks and payments were adapted to the time frame given. Respondents in the monthly and annual scenario were informed that the objective risk was 6 per 1,000,000 and 7 per 100,000, respectively. The design of the monthly scenario was such that if a respondent was prepared to pay for the safety device during a whole year, i.e. twelve identical payments, his risk reduction and payment would be equal to the annual scenario. Small adjustments were made to yield integer values and discount factors are assumed negligible and neglected.

The safety device was described as an abstract device (Jones-Lee et al., 1985) that the respondents had the opportunity to rent for a specific time period (a year or a month, depending on which subsample they belonged to). Respondents were told that they had to pay a lump sum and that they had the

[4] Due to the postal format we could not control how the respondents answered the survey. It was, therefore, possible for respondents to answer the wrong follow-up questions (e.g. answering the follow-up question to an initial no-answer, after stating that they were willing to pay the initial bid).

opportunity to extend the rental period, but that they then had to pay the lump sum again. The device was described as follows (freely translated from Swedish):

> *"You rent the safety device for a period of one [year], for which you pay a lump sum. If you want to continue using the device after one [year] you may extend the rental period, but then you have to pay anew. The safety device will only reduce the risk of dying, not the risk of being injured. The device only protects yourself and not any other passengers. The device will not affect the car's characteristics in terms of appearance, comfort or driving characteristics."*

Prior to the WTP question, respondents were asked about their perception on their own risk of dying as a result of a car crash. The baseline risk was randomly assigned (not based on the respondent's own perceived risk), though. We assigned one of two initial and two final risk levels, which resulted in three risk reductions. Final risks were always positive to avoid a potential certainty premium from risk elimination (Kahneman and Tversky, 1979; Viscusi, 1998). By varying both the initial and the final risk levels, we obtained risk reductions of different magnitude such that absolute and proportional risk reductions are not perfectly correlated. Risk levels were close to the average objective risk (i.e., 7 per 100,000 per year) to increase realism. The initial risk levels without the safety device were slightly larger, and those with the device they were slightly smaller, than the average objective risk. Risk and bid levels are summarized in Table 2.

[Table 2 about here.]

The bid levels in Table 2 are the initial bid levels. Follow-up bids for the double-bounded format are twice as large as the initial bid for respondents who answered yes to the initial bid, and half as large as the initial bid for respondents who answered no. We also calculate single-bounded estimate based only on respondents' answers to the first question.

4 Empirical models

This section briefly describes the econometric models and specifications used. We first describe the non-parametric estimation used to estimate our preferred policy values and then the parametric models for validity testing and potential use in benefit transfers. The non-parametric model was chosen to follow the recommendations of the NOAA panel NOAA (1993) to estimate a conservative WTP (Haab and McConnell, 2003; Carson et al., 2004).[5]

[5] Since we use standard and well known estimation techniques, this section has been kept to a minimum. For readers interested in more detailed descriptions of the models and techniques we recommend, e.g., Bateman et al. (2002) or Haab and McConnell (2003).

4.1 Non-parametric estimation

Non-parametric estimation offers an advantage over parametric estimation since it does not rely on distributional assumptions made by the analyst. In this study we use Turnbull's lower bound (TB) estimator of WTP (Turnbull, 1976).[6] As a lower bound, TB is a conservative estimate of WTP and of VSL that protects against the tendency for respondents in SP studies to overstate their WTP (Blumenschein et al., 2008), usually referred to as hypothetical bias. A drawback of using the TB is that it will not necessary be proportional to the size of the risk reduction, even if WTP is proportional. Hence, when using TB we cannot use proportionality of WTP to risk reduction as a validity test.

Let b_j and $F(b_j)$ denote the bid and the the proportion of no answers to the offered bid. The TB mean WTP is estimated by

$$E_{TB}[WTP] = \sum_{j=0}^{J} b_j \left(F(b_{j+1}) - F(b_j) \right), \tag{11}$$

where it is assumed that $F(0) = 0$ and $F(\infty) = 1$, i.e. no respondent has a negative or infinitive WTP, and that $F(b_j)$ is weakly monotonically increasing. When $F(b_j)$ is non-monotonic, the pooled adjusted violators algorithm (PAVA) needs to be used prior to estimation of Eq. (11) (Turnbull, 1976; Ayer et al., 1955). Equation (11) can be used for interval data when bid ranges are non-overlapping. The bid levels in our DB scenario result in bid ranges that are overlapping, however. We, therefore, have to use Turnbull's self consistency algorithm (TSCA). The TSCA divide the bids into "basic intervals" and allocate observations to each interval through an iteration process until the survival function converges (Bateman et al., 2002, pp. 232-237).[7]

4.2 Parametric estimation

The main purpose of the parametric estimation is to examine how different covariates influence WTP, not to examine the underlying structural model. Since the coefficient estimates of the bid-function approach show the marginal impact on WTP of different covariates (Cameron and James, 1987; Cameron, 1988; Patterson and Duffield, 1991; Cameron, 1991; Bateman et al., 2002), our parametric models are based on the bid-function approach (instead of the utility-function approach Hanemann (1984)).

We assume a multiplicative model. Taking logs results in the econometric model estimated,

$$\ln(WTP_i) = \alpha + \beta_1 \ln(\Delta p_i) + \sum_{k=2}^{K} \beta_k f_{k-1}(x_i) + \varepsilon_i, \tag{12}$$

[6] The Turnbull lower bound estimator is also known as the Kaplan-Meier estimator (Carson and Hanemann, 2005).

[7] We used a conversion criterium equal to 0.005.

where $f(x)$ defines dummy variables and the natural logarithm of continuous variables. Proportionality between WTP and Δp require that $\beta_1 = 1$.[8] Preliminary analysis showed that a normal distribution fits our logged data best, and we therefore estimate a log-normal model (Alberini, 1995). The log-normal model rules out the possibility of zero WTP and to allow for respondents' WTP being equal to zero, Eq. (12) is estimated as a mixture model (An and Ayala, 1996; Haab, 1999; Werner, 1999).[9] To estimate the mixture model we use the answers from a follow-up question to respondents who answered "no-no" which allow us to identify those respondents whose WTP equals zero.

5 Results

5.1 Descriptive statistics

The descriptive statistics are shown in Table 3. Our sample appears to be representative of the general Swedish population of the relevant age group (18-74). The exceptions are the proportion of female respondents, which is higher compared with the general population, 59.6 vs. 49.6 percent, and larger household size in the sample compared with the general population. One reason for the high share of female respondents could be because the first half of the survey concerned food risks and Swedish women are responsible for most of the household food production (> 60%) (Rydenstam, 2008).

The respondents reported a slightly lower annual distance traveling by car, 1,326 compared with 1,390 Swedish miles (1 mile = 10 kilometers), even if the share of respondents with a driving license and access to a car in the household was higher than the general population. Regarding injury experience it is hard to relate the number from the survey with objective data. Statistics on reported injuries from road accidents reveal an annual objective risk equal to 0.3 percent, which is considerably smaller than the 7.7 and 10.6 percent stated by the respondents. However, respondents were asked whether they or anyone in their household had *ever* been injured as a result of a road accident. Moreover, official statistics are likely to underestimate actual injury risk since not all injuries are reported. Further, individuals with injury experience may have more interest in completing a questionnaire related to road safety.

Respondents were asked to state how they perceived their own health status and mortality risk in road traffic. To obtain self-reported health status we used a visual analog scale in the form of a thermometer ranging from 0 to 100, where 100 is the best imaginable health state. Mean self-reported health

[8]When $\beta_1 = 1$ in Eq. (12) WTP will be strictly proportional to Δp since

$$\begin{aligned} WTP_i &= \exp(\alpha)(\Delta p_i)^{\beta} e^{\varepsilon_i}, \\ \ln(WTP_i) &= \alpha + \beta \ln(\Delta p_i) + \varepsilon_i. \end{aligned}$$

[9]For readers not familiar with the mixture model, see appendix A for a brief description of the difference between the conventional and the mixture model.

was slightly higher than previous Swedish estimates (Brooks et al., 1991; Andersson, 2007; Koltowska-Häggström et al., 2007). Regarding perceived mortality risk, more respondents stated that their own risk was lower than the average objective risk. However, due to a small number of large values, estimated arithmetic perceived means are higher than the objective risk.[10]

[Table 3 about here.]

5.2 Distribution and non-parametric analysis of WTP and VSL

The distribution of yes answers to the WTP questions together with the non-parametric estimates of WTP and VSL are shown in Table 4. Due to the problem of anchoring often found in SP studies and our preliminary analyzes of our data we have more trust in the the respondents' answers to the initial bid, i.e. the SB data. We, therefore, from now on only report the SB results from the survey.[11] The distributions of the yes answers in Table 4 reveal that the proportion of yes answers is uniformly decreasing with the bid level for only half of the subsamples. For those that are not, the PAVA was used prior to the estimation of WTP (Turnbull, 1976; Ayer et al., 1955). Kanninen (1995) showed that bids that covered the center of the WTP distribution were most efficient for obtaining efficient estimates of mean and median WTP. As a rule of thumb, Kanninen suggested that bids should be limited to be within the 15th and 85th, and 10th and 90th, percentiles of the WTP distribution for SB and DB models, respectively. For the SB answers we find that the share of respondents accepting the lowest bid is higher than 85 percent in only one subsample, and the share of respondents accepting the highest bid is lower than 15 percent in all but one subsample.

[Table 4 about here.]

Estimated mean WTP reveals mixed results. WTP is increasing with the size of the risk reduction for all groups except for one, but confidence intervals are overlapping expect between the smallest ($\Delta p = 4$) and intermediate ($\Delta p = 6$) risk reduction in the annual scenario. Our main focus is, though, the effect from time framing. We find no effect for the subsample with the smallest risk reduction. For this group the reported time ratio of 1.02 is indeed equal to the numerical prediction based on reasonable assumption on the baseline risk and discount rate in section 2. We do find a statistical significant difference in WTP between the annual and monthly scenario for the two other risk reductions, however. The effect is considerable for the intermediate risk reduction; WTP per unit of risk reduction elicited in the annual scenario is more than twice the one elicited in the monthly scenario. Hence, we find with the non-parametric analysis some evidence of a framing effect.

[10] Respondents' perception on their mortality risk has been analyzed in Andersson (2011).

[11] Results from the DB format available upon request from the authors.

Our estimates of VSL are shown in the last column of Table 4. The values reported are the weighted average based on the number of respondents of the estimates for each risk reduction conditional on the time frame. Estimated VSL are SEK 43.89 and 74.30 million with a higher value for the annual scenario. The estimated VSL based on the annual scenario is 69 percent higher than the monthly scenario and our hypothesis of equal values between the scenarios is indeed rejected. These results suggest that aggregated values from a survey can be significantly (both statistically and absolutely) affected by the chosen time frame.

5.3 Parametric analysis

The regression results from the parametric analysis are shown in Table 5. To test the robustness of our results, we run three regressions: (i) a model only including variables related to the design of the survey (*Model 1*), i.e. the size of the risk reduction and the time frame, (ii) a model with the two survey variables and individual characteristics other than traffic related (*Model 2*), and (iii) a model with in addition to the variables in the previous models, variables containing traffic related information obtained in the survey (*Model 3*).

[Table 5 about here.]

In *Model 1* none of the two survey variables are statistical significant. When controlling for individual characteristics in *Model 2* WTP is scale sensitive according to theory, i.e. statistically significantly different from 0 but not from 1, as predicted by theory.[12] We again do not find any statistically significant effect on WTP from *Year*. We find that women are willing to pay more than men in contrast to other Swedish studies using the CVM that have not found a statistically significant relationship between gender and WTP to reduce transport related mortality risk (Johannesson et al., 1996; Hultkrantz et al., 2006; Andersson, 2007).[13] Moreover, we find that WTP is increasing with education level with *Secondary* and *University* being positive and significantly different from the reference group *Elementary*.

We expect *Income*, here measured as income per consumption unit, to be positively correlated with WTP.[14] We do not find a statistical significant relationship, though. The insignificant relationship between WTP and *Income* but significant relationship between WTP and schooling may suggests that

[12] A validity test of CVM studies with dichotomous choice questions is that the coefficient of the bid is negative and statistically significant, i.e. respondents should be less likely to accept the bid when the bid is higher. Regression with the bid and the same covariates as in Table 5 on the probability of accepting the bid showed that the bid coefficient was negative and highly significant ($p < 0.01$) in all regressions.

[13] Johannesson et al. (1996) found that WTP was statistically significantly higher among females for a public good, but not for a private good.

[14] Household income per consumption unit is calculated by dividing total household income with the the weighted sum of household members, where the weights are based on age and are from *Statistics Sweden*. The weights depend on the composition of the household and are smaller for younger than for older children.

schooling may be a better proxy for wealth than income, but this interpretation is only speculative. Moreover, *Age* and *Health* are not statistically significantly correlated with WTP. It seems intuitive that age and health status should be negatively and positively related to WTP. However, the theoretical predictions for age and health status are indeterminate (Johansson, 2002; Hammitt, 2002). Our finding that age and health status are not correlated with WTP is consistent with other empirical results in the CVM literature (Krupnick, 2007; Alberini et al., 2004, 2006b; Andersson, 2007).

When including the traffic related variables in *Model 3* we find that the relationship between WTP and the size of the risk reduction is no longer statistically significant. The results for the other covariates are left unchanged. Focusing on the added variables we find that respondents who perceive their own risk to be higher than the average objective risk have a significantly higher WTP than the reference group (perceived risk equal to objective risk). This significant correlation suggests that respondents may base their decision to accept the bid on their own perceived baseline risk, instead of the baseline risk given in the questionnaire. For the group that perceived its risk level to be lower than the objective risk, no significant correlation is found. We also find that those who drive or travel by car have a higher WTP than those who do not. Finally, injury experience (own and household) are not statistically significantly correlated with WTP.

6 Discussion

In this study we have estimated Swedish respondents' WTP for car safety and examined how the time frame presented to them influences the results. With our theoretical model and numerical examples we showed that the choice between different time frames is not trivial, especially when the time period is longer and when discount rates are positive. To test our theoretical predictions in an empirical setting we used data from a Swedish dichotomous DB CVM study. Our results suggest that respondents' WTP and, thus, the estimated VSL are sensitive to the time framing of the question. Hence, in empirical applications it may be problematic to treat a one period risk reduction as equivalent to a series of risk reductions (Krupnick et al., 2002; Alberini et al., 2004). We do not find a statistical significant relationship in the parametric analysis, but in the non-parametric analysis estimates of the weighted average estimate of VSL for all respondents based on the SB format was 69 percent higher in the annual than the monthly scenario. Overall, we conclude that our results suggest that preference elicitation for car safety is sensitive to time framing, but that the problem may be modest in comparison with other aspects of preference elicitation for mortality risk reductions, i.e. especially scale insensitivity.

The fact that the estimated VSL from the annual scenario is higher than the estimates from the monthly scenario is in line with our theoretical model. However, based on Eq. (8) in section 2 which showed that VSL should be close to identical under reasonable assumptions, the difference is larger than expected. One plausible explanation, which would suggest that the monthly scenario may be preferred to the annual in SP studies, is that respondents might have found the monthly scenario easier to evaluate. Wages and salaries are often received on a monthly basis and many expenditures are paid monthly, e.g. rent and telephone bills. Thus, it may be easier to relate the cost to the budget constraint in the monthly scenario, and the lower estimates might, therefore, reflect less yes-saying and hypothetical bias (Boyle et al., 1998; Blumenschein et al., 2008). It could also have been the case that respondents were more reluctant to accept the amount offered in the monthly scenario due to the small risk reduction (per million compared with per 100,000 in the annual scenario). However, if the respondents were influenced by the risk reduction and bid levels, the effect of the former would have been offset by the effect of the latter, with the combined effect being indeterminate. Hence, any explanation about the difference is only speculative, but the results highlight the importance of the time frame chosen by the analyst when estimating WTP.[15]

Our preferred VSLs from the non-parametric model are SEK 43.89 and 74.30 million, depending on the time frame. These values are considerably higher than the official VSL in use in Sweden, SEK 21.00 million (SIKA, 2008).[16] The range is also considerably higher than the findings in Persson et al. (2001), SEK 24.70 million. However, when analyzing the same data as Persson et al., Andersson (2007) estimated VSL to be in the range SEK 28.20 to 142.96 million, the wide range being a consequence of model assumptions and the rejection of near-proportionality. For a risk reduction in the form of a private good, Hultkrantz et al. (2006) and Johannesson et al. (1996) estimated VSL to be 53.95 and 49.41 million, values that are within the range of our estimates.[17]

To summarize, theory predicts that the effect of the time frame on the estimated VSL, can be important or negligible depending on the length of the period and the discount rate. In the empirical analysis, in which theory predicted a negligible effect from the time frame, we found evidence that respondents were influenced by the time frame of the scenario to which they were presented. Hence, our analysis suggest that single- and multi-period settings should not in general be treated as equivalent. More research is needed to examine the effect of time framing on respondents' WTP. Future research should test over time frames with greater diversity (daily, monthly, annual, etc.) than we we have, but also based on other framing issues such as per trip, meal, etc.

[15]Respondents were in a follow-up question asked whether they found the scenario realistic. The distribution of respondents who found it realistic was nearly identical between the annual and monthly subsamples.

[16]All values in 2006 price level in this paragraph.

[17]Corresponding estimates for a public good risk reductions were SEK 20.46 and 36.64 million.

Appendix

A The mixture model

When assuming a log-normal distribution, WTP equal to zero is ruled out. Incorporating zero WTP can be done by employing the mixture model (An and Ayala, 1996; Haab, 1999; Werner, 1999). This section briefly describes the difference between the DB conventional (WTP>0) and mixture model. For a more detailed description of the mixture model see, e.g., An and Ayala (1996).

Let $i = 1, ..., N$, b_i, b_i^L and b_i^H, denote the index for each respondent, the initial bid, and the follow-up bids, respectively, with the superscripts referring to lower (L) and higher (H) follow-up bids. The respondents' answers in a DB CVM are represented by the following four indicator variables:

$$\begin{cases} D_{1i} = 1 \text{ iff } \mathrm{WTP}_i < b_i^L & \text{(“no-no” response)} \\ D_{2i} = 1 \text{ iff } b_i^L \leq \mathrm{WTP}_i < b_i & \text{(“no-yes” response)} \\ D_{3i} = 1 \text{ iff } b_i \leq \mathrm{WTP}_i < b_i^H & \text{(“yes-no” response)} \\ D_{4i} = 1 \text{ iff } b_i^H \leq \mathrm{WTP}_i & \text{(“yes-yes” response)} \end{cases} \tag{13}$$

Let $F(x;\theta)$ denote the cumulative distribution function (CDF) for x with parameters θ, and our sample log-likelihood for the conventional model is then,

$$\begin{aligned} l(\theta) = \sum_{i=1}^{N} \{ & D_{1i} \ln[F(b_i^L;\theta)] + D_{2i} \ln[F(b_i;\theta) - F(b_i^L;\theta)] \\ & + D_{3i} \ln[F(b_i^H;\theta) - F(b_i;\theta)] + D_{4i} \ln[1 - F(b_i^H;\theta)]\}. \end{aligned} \tag{14}$$

Now, assuming that $x \geq 0$, the CDF of x in the mixture model will have the form,

$$G(x;\rho,\theta) = \begin{cases} \rho & \text{if} \quad x = 0 \\ \rho + (1-\rho)F(x;\theta) & \text{if} \quad x > 0 \end{cases} \tag{15}$$

i.e. $G(x;\rho,\theta)$ has a point mass ρ at $x = 0$.

The estimation of the mixture model depends on whether the analyst has information about which respondents that have a WTP equal to zero, information that can be obtained by asking a follow-up question to the "no-no" respondents. When this information is not available, ρ needs to be estimated and the log-likelihood is specified as follows,

$$\begin{aligned} l_1(\rho,\theta) = \sum_{i=1}^{N} \{ & D_{1i} \ln[\rho + (1-\rho)F(b_i^L;\theta)] + D_{2i} \ln[(1-\rho)(F(b_i;\theta) - F(b_i^L;\theta))] \\ & + D_{3i} \ln[(1-\rho)(F(b_i^H;\theta) - F(b_i;\theta))] + D_{4i} \ln[(1-\rho)(1 - F(b_i^H;\theta))]\}. \end{aligned} \tag{16}$$

When $x_i = 0$ is known to the analyst, $\rho = N_0/N$, where N_0 is the number of respondents with a WTP equal to zero. For the log-likelihood we then need to introduce a new indicator variable, D_{0i}, which is equal to 1 if WTP is equal to zero. The log-likelihood with full information is then specified by

$$\begin{aligned} l_2(\rho,\theta) = \sum_{i=1}^{N} \{ & D_{0i} \ln[\rho] + (D_{1i} - D_{0i}) \ln[(1-\rho)F(b_i^L;\theta)] + D_{2i} \ln[(1-\rho)(F(b_i;\theta) - F(b_i^L;\theta))] \\ & + D_{3i} \ln[(1-\rho)(F(b_i^H;\theta) - F(b_i;\theta))] + D_{4i} \ln[(1-\rho)(1 - F(b_i^H;\theta))]\} \end{aligned} \tag{17}$$

References

Alberini, A.: 1995, 'Efficiency vs Bias of Willingness-to-Pay Estimates: Bivaraite and Interval-Data Models'. *Journal of Environmental Economics and Management* **29**, 169–180.

Alberini, A., M. Cropper, A. Krupnick, and N. B. Simon: 2004, 'Does the Value of a Statistical Life Vary With the Age and Health Status?: Evidence from the USA and Canada'. *Journal of Environmental Economics and Management* **48**(1), 769–792.

Alberini, A., M. Cropper, A. Krupnick, and N. B. Simon: 2006a, 'Willingness to Pay for Mortality Risk Reductions: Does Latency Matter?'. *Journal of Risk and Uncertainty* **32**(3), 231–245.

Alberini, A., A. Hunt, and A. Markandya: 2006b, 'Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-Country Contingent Valuation Study'. *Environmental and Resource Economics* **33**(2), 251–264.

An, Y. and R. A. Ayala: 1996, 'A Mixture Model of Willingness to Pay Distributions'. Mimeo, Duke University, USA, and Central Bank, Ecuador.

Andersson, H.: 2005, 'The Value of Safety as Revealed in the Swedish Car Market: An Application of the Hedonic Pricing Approach'. *Journal of Risk and Uncertainty* **30**(3), 211–239.

Andersson, H.: 2007, 'Willingness to Pay for Road Safety and Estimates of the Risk of Death: Evidence from a Swedish Contingent Valuation Study'. *Accident Analysis and Prevention* **39**(4), 853–865.

Andersson, H.: 2008, 'Willingness to Pay for Car Safety: Evidence from Sweden'. *Environmental and Resource Economics* **41**, 579–594.

Andersson, H.: 2011, 'Perception of Own Death Risk: An Assessment of Road-Trac Mortality Risk'. *Risk Analysis* **31**(7), 1069–1082.

Andersson, H. and M. Svensson: 2008, 'Cognitive Ability and Scale Bias in the Contingent Valuation Method'. *Environmental and Resource Economics* **39**(4), 481–495.

Andersson, H. and N. Treich: 2011, *Handbook in Transport Economics*, Chapt. The Value of a Statistical Life. Edward Elgar, Forthcoming.

Atkinson, S. E. and R. Halvorsen: 1990, 'The Valuation of Risks to Life: Evidence from the Market for Automobiles'. *Review of Economics and Statistics* **72**(1), 133–136.

Ayer, M., H. D. Brunk, G. M. Ewing, W. T. Reid, and E. Silverman: 1955, 'An Empirical Distribution Function for Sampling with Incomplete Information'. *Annals of Mathematical Statistics* **26**(4), 641–647.

Bateman, I. J., D. Burgess, W. G. Hutchinson, and D. I. Matthews: 2008, 'Learning design contingent valuation (LDCV): NOAA guidelines, preference learning and coherent arbitrariness'. *Journal of Environmental Economics and Management* **55**, 127–141.

Bateman, I. J., R. T. Carson, B. Day, M. Hanemann, N. Hanley, T. Hett, M. Jones-Lee, G. Loomes, S. Mourato, Özdemiroḡlu, D. W. Pearce, R. Sugden, and J. Swanson: 2002, *Economic Valuation with Stated Preference Techniques: A Manual*. Cheltenham, UK: Edward Elgar.

Beattie, J., J. Covey, P. Dolan, L. Hopkins, M. W. Jones-Lee, G. Loomes, N. Pidgeon, A. Robinson, and A. Spencer: 1998, 'On the Contingnent Valuation of Safety and the Safety of Contingent Valuation: Part 1 - Caveat Investigator'. *Journal of Risk and Uncertainty* **17**(1), 5–25.

Blumenschein, K., G. C. Blomquist, M. Johannesson, N. Horn, and P. Freeman: 2008, 'Eliciting Willingness to Pay without Bias: Evidence from a Field Experiment'. *Economic Journal* **118**(525), 114–137.

Boyle, K. J., F. R. Johnson, and D. W. McCollum: 1997, 'Anchoirng and Adjustment in single-Bounded, Contingnent Valuation Questions'. *American Journal of Agricultural Economics* **79**(5), 1495–1500.

Boyle, K. J., H. F. MacDonald, H. Cheng, and D. W. McCollum: 1998, ‘Bid Design and Yes Saying in Single-Bpunded, Dichotous-Choice Questions’. *Land Economics* **74**(1), 49–64.

Brooks, R. G., S. Jendteg, B. Lindgren, U. Persson, and S. Björk: 1991, ‘EuroQol: Health-Realted Quality of Life Measurement. Results of the Swedish Questionnaire Exercise’. *Health Policy* **18**, 37–48.

Cameron, T. A.: 1988, ‘A New Paradigm for Valuing Non-market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression’. *Journal of Environmental Economics and Management* **15**, 355–379.

Cameron, T. A.: 1991, ‘Cameron’s Censored Logistic Regression Model: Reply’. *Journal of Environmental Economics and Management* **20**, 303–304.

Cameron, T. A. and M. D. James: 1987, ‘Estimating Willingness to Pay from Survey Data: An Alternative Pre-Test-Market Evaluaiton Procedure’. *Journal of Marketing Research* **24**, 389–395.

Carson, R. T., M. B. Conaway, W. M. Haneman, J. A. Krosnick, and S. Presser: 2004, *Valuing Oil Spill Prevention: A Case Study of California’s Central Coast*, Vol. 5 of *The Economics of Non-Market Goods and Resources*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Carson, R. T. and W. M. Hanemann: 2005, *Handbook of Environmental Economics: Valuing Environmental Changes*, Vol. 2 of *Handbook in Economics*, Chapt. Contingent Valuation, pp. 821–936. Amsterdam, the Netherlands: North-Holland, first edition.

Corso, P. S., J. K. Hammitt, and J. D. Graham: 2001, ‘Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation’. *Journal of Risk and Uncertainty* **23**(2), 165–184.

Dreyfus, M. K. and W. K. Viscusi: 1995, ‘Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency’. *Journal of Law and Economics* **38**(1), 79–105.

Eeckhoudt, L. R. and J. K. Hammitt: 2001, ‘Background Risks and the Value of a Statistical Life’. *Journal of Risk and Uncertainty* **23**(3), 261–279.

Evans, M. F. and V. K. Smith: 2006, ‘Do we really understand the age-VSL relationship?’. *Resource and Energy Economics* **28**(3), 242–261.

Green, D., K. E. Jacowitz, D. Kahneman, and D. McFadden: 1998, ‘Referendum contingent valuation anchoring and willingness to pay for public goods’. *Resource and Energy Economics* **20**(2), 85–116.

Haab, T. C.: 1999, ‘Nonparticipation or Misspecification? The Impacts of Nonparticipation on Dicotomous Choice Contingent Valuation’. *Environmental and Resource Economics* **14**, 443–461.

Haab, T. C. and K. E. McConnell: 2003, *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*. Cheltenham, UK: Edward Elgar.

Hammitt, J. K.: 2000, ‘Evaluating Contingent Valuation of Environmental Health Risks: The Proportionality Test’. *AERE (Association of Environmental and Resource Economics) Newsletter* **20**(1), 14–19.

Hammitt, J. K.: 2002, ‘QALYs Versus WTP’. *Risk Analysis* **22**(5), 985–1001.

Hammitt, J. K. and J. D. Graham: 1999, ‘Willingness to Pay for Health Protection: Inadequate Sensitivity to Probability?’. *Journal of Risk and Uncertainty* **18**(1), 33–62.

Hammitt, J. K. and K. Haninger: 2007, ‘Willingness to Pay for Food Safety: Sensitivity to Duration and Severity of Illness’. *American Journal of Agricultural Economics* **89**(5), 1170–1175.

Hammitt, J. K. and L. A. Robinson: 2011, ‘The Income Elasticity of the Value per Statistical Life: Transfering Estimates between High and Low Income Populations’. *Journal of Benefit-Cost Analysis* **2**(1), Article 1.

Hanemann, M. W., J. Loomis, and B. Kanninen: 1991, 'Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation'. *American Journal of Agricultural Economics* **73**(4), 1255–1263.

Hanemann, W. M.: 1984, 'Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses'. *American Journal of Agricultural Economics* **66**(3), 332–341.

Herriges, J. A. and J. F. Shogren: 1996, 'Starting Point Bias in Dichotous Choice Valuation with Follow-Up Questioning'. *Journal of Environmental Economics and Management* **30**, 112–131.

Hultkrantz, L., G. Lindberg, and C. Andersson: 2006, 'The Value of Improved Road Safety'. *Journal of Risk and Uncertainty* **32**(2), 151–170.

Irwin, J. R., P. Sloviv, S. Lichtenstein, and G. H. McClelland: 1993, 'Preference Reversals and the Measurement of Environmental Values'. *Journal of Risk and Uncertainty* **6**, 5–18.

Johannesson, M., P.-O. Johansson, and K.-G. Lövgren: 1997, 'On the Value of Changes in Life Expectancy: Blips Versus Parametric Changes'. *Journal of Risk and Uncertainty* **15**(3), 221–239.

Johannesson, M., P.-O. Johansson, and R. M. O'Connor: 1996, 'The Value of Private Safety Versus the Value of Public Safety'. *Journal of Risk and Uncertainty* **13**(3), 263–275.

Johansson, P.-O.: 2001, 'Is there a Meaningful Definition of the Value of a Statistical Life?'. *Journal of Health Economcis* **20**(1), 131–139.

Johansson, P.-O.: 2002, 'On the Definition and Age-Dependency of the Value of a Statistical Life'. *Journal of Risk and Uncertainty* **25**(3), 251–263.

Jones-Lee, M. W.: 1974, 'The Value of Changes in the Probability of Death or Injury'. *Journal of Political Economy* **82**(4), 835–849.

Jones-Lee, M. W., M. Hammerton, and P. Philips: 1985, 'The Value of Safety: Results of a National Sample Survey'. *The Economic Journal* **95**(377), 49–72.

Kahneman, D. and A. Tversky: 1979, 'Prospect Theory: An Analysis of Decision Under Risk'. *Econometrica* **47**(2), 263–291.

Kanninen, B. J.: 1995, 'Bias in Discrete Response Contingent Valuation'. *Journal of Environmental Economics and Management* **28**, 114–125.

Koltowska-Häggström, M., B. Jonsson, D. Isacson, and K. Bingefors: 2007, 'Using EQ-5D To Derive Utilities For The Quality Of Life - Assessment Of Growth Hormone Deficiency In Adults (QoL-AGHDA)'. *Value in Health* **10**(1), 73–81.

Krupnick, A.: 2007, 'Mortality Risk Valuation and Age: Stated Preference Evidence'. *Review of Environmental Economics and Policy* **1**(2), 261–282.

Krupnick, A., A. Alberini, M. Cropper, N. B. Simon, B. O'Brian, R. Goeree, and M. Heintselman: 2002, 'Age, Health and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuatoin Survey of Ontario Residents'. *Journal of Risk and Uncertainty* **24**(2), 161–186.

Krupnick, A., S. Hoffmann, B. Larsen, X. Peng, R. Tao, and C. Yan: 2006, 'The willingness to pay for mortality risk reductions in Shanghai and Chongqing, China'. Technical report, Resources for the Future, Washington, DC, US.

Morris, J. and J. K. Hammitt: 2001, 'Using Life Expectancy to Communicate Benefits of Health Care Programs in Contingent Valuation Studies'. *Medical Decision Making* **21**(6), 468–478.

NOAA: 1993, 'Report of the NOAA Panel on Contingent Valuation'. Federal Register 58, Arrow, K, Solow, R, Portney, P, Leamer, E, Radner, R, and Schuman, H.

Patterson, D. A. and J. W. Duffield: 1991, 'Comment on Cameron's Censored Logistic Regression Model for Referendum Data'. *Journal of Environmental Economics and Management* **20**, 275–283.

Persson, U., A. Norinder, K. Hjalte, and K. Gralén: 2001, 'The Value of a Statistical Life in Transport: Findings from a new Contingent Valuation Study in Sweden'. *Journal of Risk and Uncertainty* **23**(2), 121–134.

Pratt, J. W. and R. J. Zeckhauser: 1996, 'Willingness to Pay and the Distribution of Risk and Wealth'. *Journal of Political Economy* **104**(4), 747–763.

Roach, B., K. J. Boyle, and M. Welsh: 2002, 'Testing Bid Design Effects in Multiple-Bounded, Contingent-Valuation Questions'. *Land Economics* **78**(1), 121–131.

Rosen, S.: 1974, 'Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition'. *Journal of Political Economy* **82**(1), 34–55.

Rosen, S.: 1988, 'The Value of Changes in Life Expectancy'. *Journal of Risk and Uncertainty* **1**(3), 285–304.

Rydenstam, K.: 2008, 'Mer jämställt i Norden än i öriga Europa?'. SCB:s tidskrift Välfärd, Nr 1.

Shepard, D. S. and R. J. Zeckhauser: 1984, 'Survival Versus Consumption'. *Management Science* **30**(4), 423–439.

SIKA: 2008, 'Samhällsekonomiska kalkylprinciper och kalkylvärden för transportsektorn'. SIKA PM 2008:3, SIKA (Swedish Institute for Transport and Communications Analysis).

Sundström, K. and H. Andersson: 2009, 'Swedish Consumers' Willingness to Pay for Food Safety - a Contingent Valuation Study on Salmonella Risk'. SLI - Working Paper 2009:1, Swedish Institute for Food and Agricultural Economics (SLI), Lund, Sweden, Forthcoming.

Turnbull, B. W.: 1976, 'The Empirical Distribution Function with Arbitrarily Grouped, Censored, and Truncated Data'. *Journal of the Royal Statistical Society* **38**(B), 290–295.

Tversky, A., P. Slovic, and D. Kahneman: 1990, 'The Causes of Preference Reversal'. *American Economic Review* **80**(1), 204–217.

Tversky, A. and R. H. Thaler: 1990, 'Anomalies: Preference Reversals'. *Journal of Economic Perspectives* **4**(2), 201–211.

Viscusi, W. K.: 1998, *Rational Risk Policy*. New York, NY, USA: Oxford University Press.

Viscusi, W. K. and J. E. Aldy: 2003, 'The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World'. *Journal of Risk and Uncertainty* **27**(1), 5–76.

Weinstein, M. C., D. S. Shepard, and J. S. Pliskin: 1980, 'The Economic Value of Changing Mortality Probabilities: A Decision-Theoretic Approach'. *Quarterly Journal of Economics* **94**(2), 373–396.

Werner, M.: 1999, 'Allowing for Zeros in Dichotomous-Choice Contingent Valuaiton Models'. *Journal of Business & Economic Statistics* **17**(4), 479–486.

Table 1: The effect on WTP from time framing

	$p = 3/1000$		$p = 10/1000$	
T	$i = 0.00$	$i = 0.04$	$i = 0.00$	$i = 0.04$
5	0.982	0.910	0.941	0.872
10	0.960	0.810	0.869	0.736
20	0.916	0.650	0.736	0.527

Values refer to $\Gamma(T)$ in Eq. (8).

Table 2: Baseline risks, risk reductions, and bid levels

	Annual	**Monthly**
Baseline risk: Initial	9, 11	8, 10
Final	3, 5	3, 5
$\Rightarrow \Delta p$	4, 6, 8	3, 5, 7
Bid levels	200, 1 500, 12 000, 24 000	20, 120, 1 000, 2 000

Risk per 100,000 and 1,000,000 in annual and monthly scenario, respectively..

Table 3: Summary statistics

Variable	Description	Survey Mean	Survey Std. Dev.	Survey N	Sweden Mean
Income	Net monthly household income.	25,718	1,3347	735	22,639
Age	Age of respondent.	46.936	15.309	745	44.7[c]
Health	Respondent's self-reported health status.	89.133	11.986	707	NA[d]
Female	Dummy coded as one if female.	0.596	0.491	743	49.6[c]
Elementary	Dummy coded as one if highest finished education level.	0.194	0.396	736	0.17
Secondary	- " -	0.444	0.497	736	0.48
University	- " -	0.361	0.481	736	0.35
Household	Household size.	2.851	3.125	707	2.1
Driving licence	Dummy coded as one if respondent has a driving licence.	0.895	0.307	743	0.82
Access to car	Dummy coded as one if respondent has access to a car in his/her household.	0.898	0.303	723	0.74
Distance	Annual mileage by car (as driver and/or passenger, 1 mile = 10 kilometers).	1,326	803	740	1,390
Own injury	Dummy coded as one if respondent has been injured in a traffic accident.	0.077	0.267	739	NA
Household injury	Dummy coded as one if someone in respondent's household has been injured in a traffic accident.	0.106	0.308	728	NA
Risk Year[a]	Risk perception, annual scenario	71.167	1,102	330	7
Risk Month[a]	Risk perception, monthly scenario	41.799	534	357	6
Risk low[b]	Dummy coded as one if risk perception lower than objective risk.	0.464	0.499	687	NA
Risk high[b]	Dummy coded as one if risk perception higher than objective risk.	0.159	0.366	687	NA

USD 1=SEK 7.38

a: Respondents informed in annual scenario that objective risk was 7 per 100,000 and in monthly scenario that risk was 6 per 1,000,000. Geometric means for annual and monthly scenario, 4.875 and 4.730.

b: Reference group, respondents who stated that their perceived risk was equal to the objective ($n = 340$).

c: Age group 18-74.

d: Mean estimates from three other Swedish studies using the same VAS measure, 84.14 (Andersson, 2007), 85 Koltowska-Häggström et al. (2007), and 85.37 (Brooks et al., 1991).

Table 4: Probability distribution of yes answers, Mean WTP and the VSL

Lower	Upper[a]	N	P(Yes)	N	P(Yes)	N	P(Yes)	VSL[e]
Annual[b]		$\Delta p = 4$		$\Delta p = 6$		$\Delta p = 8$		
0	200	26	0.96	73	0.79	18	0.78	
200	1500	20	0.40	41	0.37	20	0.40	
1500	12000	16	0.00	46	0.20	21	0.24	
12000	24000	17	0.12	37	0.24	22	0.09	
	Turnbull							
	E[WTP]		2,076[c]		5,514[c]		4,266	74.30
	95% CI		±1,235		±1,360		±1,626	(61.76 − 86.82)
Monthly[b]		$\Delta p = 3$		$\Delta p = 5$		$\Delta p = 7$		
0	20	25	0.68	55	0.75	28	0.75	
20	120	29	0.41	42	0.48	24	0.38	
12	1000	19	0.05	48	0.17	27	0.19	
1000	2000	31	0.10	38	0.03	29	0.07	
	Turnbull							
	E[WTP]		169[c]		202		264	43.89
	95% CI		±104		±66		±107	(36.15 − 51.64)
Time ratio[d]			1.02		2.27		1.35	1.69
	95% CI		0.93 − 1.12		2.21 − 2.34		1.27 − 1.43	(1.27 − 2.33)

a: *Upper* and *Lower* defines initial bid level in questionnaire and lower bound for estimation of Turnbull E[WTP]. For respondents answering yes to highest bid level, that level defines lower bound.

b: Risk per 100,000 and 1,000,000 in annual and monthly scenario, respectively.

c: Where probability vector not non-increasing, the pooled adjusted violators algorithm (Ayer et al., 1955) have been used prior to estimation of E[WTP].

d: Time ratio = $\frac{\text{WTP annual}}{12 \cdot \text{WTP monthly}}$

e: Weighted average of subsamples.

Table 5: Regressions results: SB format

Variable	**Model 1**	**Model 2**	**Model 3**
$\ln(\Delta p)$	0.362	0.789*	0.473
	(0.439)	(0.468)	(0.477)
Year[a]	0.257	0.297	0.331
	(0.242)	(0.256)	(0.261)
ln(Income)[b]		0.030	-0.009
		(0.232)	(0.245)
Female		0.601**	0.744***
		(0.262)	(0.270)
ln(Age)		-0.337	-0.402
		(0.384)	(0.397)
ln(Health)		-0.023	-0.382
		(0.911)	(0.904)
Secondary		0.834**	0.876**
		(0.402)	(0.437)
University		0.721*	0.871*
		(0.409)	(0.445)
Risk low			0.321
			(0.282)
Risk high			0.961**
			(0.402)
Distance 1[c]			2.762***
			(1.034)
Distance 2[c]			3.843***
			(1.125)
Own injury			-0.765
			(0.613)
Household injury			-0.473
			(0.481)
Intercept	6.952***	6.298	5.833
	(0.913)	(4.840)	(4.940)
σ	2.027	1.905	1.766
N	752	641	571
Pseudo-R^2	0.001	0.166	0.287

Significance levels : $*$: 10% $**$: 5% $***$: 1%

Standard errors in parentheses.

a: Dummy coded as one for "Annual scenario".

b: Income per consumption unit.

c: Dummies equal to one based on distance by car ($1 < 2$).

Reference group "I never drive or travel by car."