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Perception of own death risk

An analysis of road-traffic and overall mortality risks

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Abstract Individuals' perception of their own road-traffic and overall mortality risks are examined in this paper. Perceived risk is compared with the objective risk of the respondents' peers, i.e. their own gender and age group, and the results suggest that individuals' risk perception of their own risk is biased. For road-traffic risk we obtain similar results to what have been found previously in the literature, overassessment and underassessment among low- and high-risk groups, respectively. For overall risk we find that all risk groups underestimate their risk. The results also indicate that men's risk bias is larger than women's.

Keywords Bayesian learning · Overall risk · Peers · Road-traffic risk

JEL Classification C21, D81, D83, I18

Individuals' perception of risk has been given a lot of attention in academic literature in recent decades (Slovic, 2000). There is plenty of empirical evidence that objective risk measurements, experts' risk estimates, and lay people's perceptions differ (Sunstein, 2002).[1] Whereas experts are often better informed and rely on sophisticated tools in order to evaluate hazards, lay people (who have been found to have difficulties judging small probabilities (Kahneman and Tversky, 1979; Kahneman et al., 1982)) are influenced to a larger extent by their own experience of the hazards, how they perceive the risk (dread, controllable, etc.), and media coverage, when forming their risk perceptions (Slovic, 1987).

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[1] What defines an objective risk measure is hard to determine, since "danger is real, but risk is socially constructed" (Slovic, 1999, p. 699). Frequencies of fatalities or the chance of fatality, i.e. the probability of death, are often used as measures of objective risk, and we follow this tradition. Thus, statistical risk defines objective risk in this paper.

A widely cited study on mortality risk comprehension is Lichtenstein et al. (1978), where it was shown that individuals overassessed small fatality risks and underassessed large fatality risks. The pattern found in Lichtenstein et al., also obtained in several other studies, has come to be regarded as an "established fact" (Morgan et al., 1983; Benjamin and Dougan, 1997; Viscusi et al., 1997; Hakes and Viscusi, 2004; Armantier, 2006). When Benjamin and Dougan (1997) reexamined the data in Lichtenstein et al., and controlled for age cohorts, they could not reject the hypothesis that the risk estimates were unbiased. Benjamin and Dougan (1997) suggested that individuals would be able to more accurately perceive the risk of their own age group, since this is the risk most relevant to them. This hypothesis was supported by the findings in Benjamin et al. (2001), where respondents were asked about mortality risks of the population and of their own age group, especially for larger risks. Armantier (2006) suggested, however, that the results obtained in Benjamin et al. (2001) were due to an anchoring effect and that the pattern in Lichtenstein et al. is a "salient and robust phenomenon" (p. 54). Armantier also found evidence, however, that individuals perceive the risk of their own age group more accurately, as was suggested by Benjamin and Dougan (1997).

Most of the previous literature has examined differences in average values between perceived and objective risks for accident groups. Hakes and Viscusi (2004) further contributed to the analysis of mortality risk perception by collecting extensive data on individuals' mortality risk perception, which enabled them to study how demographic factors influenced perception. They examined how individuals perceive the risk of the population (i.e. the "risk of others"). Our study further contributes to the literature by examining individuals' perception of their own mortality risk, using individual-level data, which (in line with Hakes and Viscusi) enables us to examine how socio-economic and demographic factors affect mortality risk perception and the corresponding bias. The analysis is done for two mortality risks, overall and road-traffic. Road-traffic risk is assumed to be more voluntary and controllable compared with overall risk.[2] Data on risk perception originates from a Swedish contingent valuation survey (Persson et al., 2001).

The aim of this study is fourfold, to examine if: (i) perceived risks differ from objective risks, (ii) the probability of underestimation varies in terms of demographic characteristics, (iii) there is any correlation between the magnitude of bias and individual characteristics, and (iv) the risk perception formation of own risk follows the pattern found in Lichtenstein et al. (1978), and whether it differs between road-traffic and overall mortality risks. Objective risk in this study is defined as the risk of the respondents' peers (their own gender and age group).

In the following section we present empirical findings from previous research on mortality risk perception, and briefly outline the *Bayesian learning model* for risk assessment. In Section 2 the data used is described and in Section 3 we discuss the empirical models. The results are shown in Section 4. We find that road mortality risk follows the same pattern found in Lichtenstein et al. (1978), that men are more likely to underestimate their own risk, and that there is a positive correlation between the perception of own health and a lower perception of own risk. Finally, Section 5 offers a summary and a discussion of the results, and some concluding remarks about the policy relevance of the findings in the study.

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[2] Road-traffic risk refers to all traffic risks individuals are faced with in the road environment, e.g. as pedestrians, bicyclists, users of public transports, car users, etc. Controllable risks are risks from hazardous activities which can be regarded as voluntary and where the individual by his/her actions can influence his/her risk exposure.

1 Risk perception

1.1 Empirical findings in the literature

The effect of *gender* on risk perception has been thoroughly examined. The results strongly imply that females perceive health and environmental risks as greater than males do (Viscusi, 1991; Savage, 1993; Liu and Hsieh, 1995; Davidson and Freudenberg, 1996; Antoñanzas et al., 2000; Dosman et al., 2001; Brown and Cotton, 2003; Lundborg and Lindgren, 2004; Lundborg and Andersson, 2006). That the gender difference in risk perception is biological was questioned by results in Flynn et al. (1994) and Finucane et al. (2000), who found that women have a higher risk perception than men, but more interestingly, that the group with the lowest perception of risks was white males, and that white females and non-white men had similar risk perceptions. Studies that examined whether the difference was a result of better informed men found that women experts also perceive risks to be higher compared with male experts (Barke et al., 1997; Slovic et al., 1997), and a study on American and Canadian environmental activists (who can be assumed to be better informed than the general public) showed that female activists perceived the risk to be higher than male activists (Steger and Witt, 1989). There is some evidence that women distrust new technology more than men (Davidson and Freudenberg, 1996), and this, together with the fact that men are often the main beneficiaries of hazardous activities, could explain part of the gender difference.

Regarding *age* and risk perception, the empirical findings are mixed and seem to depend on the type of hazard. Savage found, e.g., that the risk perception for aviation, home fires, and automobiles was negatively related to age, whereas cancer risk was positively correlated with age. In a study by Dosman et al. (2001) on food-borne risk, the perception of risk increased with age, whereas Dickie and Gerking (1996) found the opposite for skin-cancer risk.

Two attributes which seem to reduce individual perception of risk are *income* and *education* (Savage, 1993; Dosman et al., 2001). This could be explained by the fact that people with a high income are able to buy safer products, and thereby actually expose themselves to less risk. One plausible explanation why individuals with higher education are less concerned about risks is that they trust themselves to a higher degree to be able to determine their own actual risk exposure. Better educated individuals are also expected to have more accurate risk beliefs (Hakes and Viscusi, 2004). Two other attributes of interest to this study, and for which there are some empirical findings, are the number of *children* in the household and personal *negative experience* of the activity. The results imply that both the presence of children (Dosman et al., 2001; Davidson and Freudenberg, 1996) and sickness (accident) experience from the hazardous activity (Dickie and Gerking, 1996; Matthews and Moran, 1986) increase the risk perception.

According to Weinstein (1989), there is robust and widespread evidence of an optimism bias for risks to oneself, a bias which is greater for low probability hazards and for “hazards judged to be controllable by personal action” (p. 1232). Individuals have also been found to perceive voluntary risks to be less “troublesome” (Sunstein, 2002, p. 67), which can result in a lower risk perception of such risks. Regarding optimism bias and driving, the empirical evidence implies an optimism bias for both men and women, larger for men than for women (DeJoy, 1992), and larger for younger male drivers than for older male drivers (Matthews and Moran, 1986; Glendon et al., 1996).

1.2 Bayesian learning model

The overestimation of small risks and underestimation of large risks found in Lichtenstein et al. (1978) is in line with what we would expect, if individuals update their prior beliefs in a Bayesian fashion (Viscusi, 1989). Several studies have also shown that risk perception is updated in line with the *Bayesian learning model* (Viscusi, 1985; Smith and Johnson, 1988; Viscusi, 1991, 1992; Dickie and Gerking, 1996; Hakes and Viscusi, 1997; Gayer et al., 2000; Lundborg and Lindgren, 2002, 2004). Following Viscusi (1991), we assume that three sources of risk information, prior risk assessment (q), experience (a), and risk information (r), determine the individual's risk beliefs (p). Let λ_1 denote the information content associated with q, and λ_2 and λ_3 the information content associated with a and r, respectively. The learning process is assumed to follow a beta distribution and the functional form of the information sources that arise is

$$p = \frac{\lambda_1 q + \lambda_2 a + \lambda_3 r}{\lambda_1 + \lambda_2 + \lambda_3}. \tag{1}$$

Let $\theta_i = \lambda_i/(\lambda_1 + \lambda_2 + \lambda_3),\ \ i \in \{1, 2, 3\}$, then

$$p = \theta_1 q + \theta_2 a + \theta_3 r. \tag{2}$$

Experience is not only influenced by circumstances directly related to a risky activity. Individual attributes, such as gender and education, are also assumed to influence the individual's experience of the risky activity. Risk information in the third term can be information presented to the individual, in school or through campaigns, or any other risk information that the individual gathers and processes himself.

The *Bayesian learning model* can be used to predict how new information/experience and changes in the information content associated with information/experience will affect the individual's risk perception. For instance, if we differentiate Eq. (1) with respect to λ_3 we can see how the individual's perceived risk is affected by a change in the informational content associated with risk information,

$$\frac{\partial p}{\partial \lambda_3} = \frac{\lambda_1(r - q) + \lambda_2(r - a)}{(\lambda_1 + \lambda_2 + \lambda_3)^2}, \tag{3}$$

and, thus,

$$\frac{\partial p}{\partial \lambda_3} > 0 \quad \text{if } r > \frac{\lambda_1 q + \lambda_2 a}{\lambda_1 + \lambda_2}. \tag{4}$$

Equation (4) states that if the individual's experience of the risk and prior beliefs are lower than the risk information, then the perceived risk will increase as a result of the individual assigning more weight to the risk information. In a similar manner, the effect of a change in weight assigned to experience can be analyzed. Figure 1 illustrates the basic concept of the updating process and how it can explain the observed overestimation of smaller risks and underestimation of larger risks. When given information or gaining experience, individuals

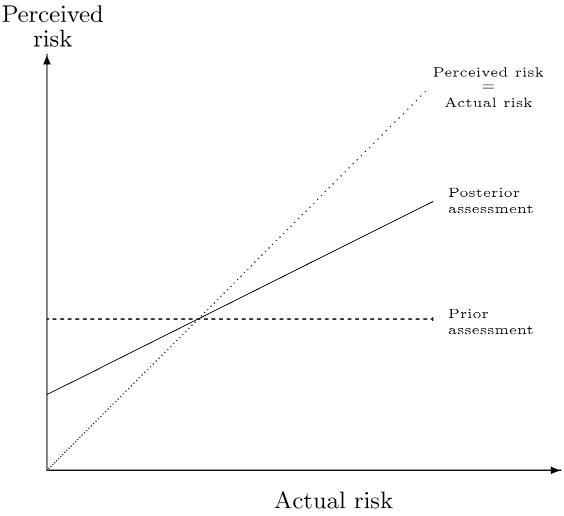

Fig. 1 Nature of updating process. Source: Viscusi (1992)

update their prior risk beliefs (the horizontal line), which will result in a more accurate risk perception (the unbroken line). In prior literature the model has been used for estimates of population risk ("risk of others") for different hazardous activities. In this study we employ it for the individuals' own mortality risk.

2 Data

The data on road and overall mortality risk perception originates from a Swedish contingent-valuation (CVM) study (Persson et al., 2001). The main objective of the CVM-study was to elicit the respondents' willingness to pay (WTP) to reduce their road mortality risk, but the respondents were also asked to state their WTP to reduce overall mortality and morbidity risks.[3]

The CVM-study was conducted as a postal questionnaire that was distributed to 5,650 randomly selected individuals between 17–74 years of age in Sweden in 1998. About half of the respondents received questionnaires on mortality-risk ($N = 3,050$), whereas the other half received questionnaires on morbidity-risk. The response rate was close to 50 percent. No questions on probability comprehension were included in the survey. Instead, in order to exclude answers from respondents who either had not understood the scenario or had given protest answers, two exclusion criteria were adopted. Respondents were excluded if they had stated that: (i) their road or overall risk was higher than 50 percent, and (ii) their overall risk was lower than their road risk. Observations were automatically dropped if there were missing answers in any of the variables, which together with the exclusion criteria reduced the number of observations by 146 (criterion (ii) was the main reason for excluding respondents' answers), resulting in a final number for road and overall risks equal to 1,116 and 803, respectively.

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[3] For an analysis of WTP for a reduction in road mortality risk, see Persson et al. (2001) and Andersson (2007), and for an analysis of WTP for overall mortality risk, see Norinder et al. (2001).

Table 1 Description of dependent and explanatory variables

Variable name	Description	Mean	(Std. dev.)
Dependent variables			
Road mortality	Perception of own risk of a fatal road accident per 100,000.	8.79	(37.14)
Road bias	Difference between objective and perceived road risks, in absolute terms.	8.99	(36.14)
Road underassess	Binary variable coded as 1 if respondent's perceived risk perception lower than objective risk estimate for own age and gender group, and 0 otherwise.	0.67	(0.47)
Overall mortality	Perception of own risk of a fatality per 1,000.	2.51	(18.66)
Overall bias	Difference between objective and perceived overall risks, in absolute terms.	4.69	(17.90)
Overall underassess	Binary variable coded as 1 if respondent's perceived risk perception lower than objective risk estimate for own age and gender group, and 0 otherwise.	0.75	(0.43)
Explanatory variables			
Age	Binary variable coded as 1 if respondent in specified age group. Reference group, Age 45–54.	–	–
Health status	Stated health status on a 0–100 scale where 100 is best imaginable health state.	84.24	(16.11)
Male	Binary variable coded as 1 if male and 0 if female.	0.53	(0.50)
Income	Household income in Swedish thousand kronor, 1998 price level. (US\$1 = SEK7.95)	331.51	(174.02)
Annual mileage	Stated annual car driven kilometers (km), in thousand km.	13.41	(7.64)
University	Binary variable coded as 1 if respondent has a university degree.	0.35	(0.48)
Own accident	Binary variable, where 1 denotes that respondent has been involved in a road traffic accident.	0.16	(0.36)
Family accident	Binary variable, where 1 denotes that someone in the respondent's family has been involved in a road traffic accident.	0.02	(0.13)
Household 0–3	Number of household members 0–3 years of age.	0.13	(0.39)
Household 4–10	Number of household members 4–10 years of age.	0.28	(0.61)
Household 11–17	Number of household members 11–17 years of age.	0.26	(0.59)

N = 1,116 for all variables except Overall Risk, Overall Bias, and Overall Underassess where N = 803.

The CVM-study variables are presented in Table 1. The mean age of the respondents was 45, and the sample was well representative for the Swedish adult population at the time of the survey. Two exceptions were that: (i) the household income of the sample was ca. 30 percent higher compared with the Swedish population, and (ii) a larger share had a university degree, 35 compared with 24 percent.[4] To take account of this sample bias, sampling weights were employed in the regression analysis of underassessment and size of risk bias.[5] In order to obtain self-reported health status, respondents were asked to mark their health status on a 0–100 scale, 100 being the best imaginable health state. This measure of individual health,

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[4] For references see Andersson (2007).

[5] Sampling weights were not used in the analysis of risk formation, since STATA does not allow sampling weights in "Seemingly Unrelated Regressions-models."

i.e. the EuroQol health-thermometer (EuroQol Group, 1990), has proven to be successful in measuring health status (Brazier et al., 1999). The mean of *Health status* reported in this study is close to the mean found in an earlier Swedish study (Brooks et al., 1991).

Before the respondents were asked about their perception of their own mortality risk, they were informed of the objective road and overall risks of a fifty-year-old individual in Sweden. In order to put the probabilities in perspective for the respondents, a grid consisting of 100,000 white squares was included in the questionnaire, where the number of squares corresponding to each risk had been blacked out. The respondents were first asked about their overall risk and the question was posed as:

> *In an average year the overall death risk for an individual in her/his 50s is 300 in 100,000. What do you think your own annual overall risk of dying will be in the following year? Your risk may be higher or lower than the average. Consider your present age and health status.*
>
> *I think that the risk is . . . . . . in 100,000.*

The question on road risk was only slightly altered:

> *In an average year the risk of dying in a traffic accident for an individual in her/his 50s is 5 in 100,000. What do you think your own annual risk of dying in a traffic accident will be? Your risk may be higher or lower than the average. Consider how often you are exposed to traffic, what distances you travel, your choice of transportation mode and how safely you drive.*
>
> *I think that the risk is . . . . . . in 100,000.*

3 Empirical models

In order to analyze our data we employed: (i) probit models to see what kinds of respondents are more likely to state that their own risk is lower than the objective risk of their peers, (ii) OLS regressions to obtain the magnitude of the risk bias (where bias is defined as the difference between perceived and objective risk), and (iii) seemingly unrelated regressions (SUR) to ascertain risk perception formation.[6]

Each respondent in Persson et al. (2001) answered two questions on fatality risk-perception. Individual characteristics are, therefore, identical in both risk formation regressions. Following Hakes and Viscusi (2004), we employed the natural logarithm to transform perceived and objective risks, and included a quadratic term to allow for non-linearity. Thus, the following regressions were estimated,

$$\begin{aligned} \ln(\mathit{Road\ Mortality}) &= \alpha_0 + \alpha_1 \ln(OR) + \alpha_2 \ln(OR)^2 + \mathbf{Z}\Gamma_1 + \varepsilon_1 \\ \ln(\mathit{Overall\ Mortality}) &= \delta_0 + \delta_1 \ln(OB) + \delta_2 \ln(OB)^2 + \mathbf{Z}\Gamma_2 + \varepsilon_2 \end{aligned} \tag{5}$$

where *OR* and *OB* are *Objective Road* and *Objective Overall* risks, $\mathbf{Z}$ and Γ_i denote vectors of individual characteristics and coefficient estimates, respectively, and ε_i the residuals, $i \in \{1, 2\}$. The SUR technique was employed, since in preliminary tests we could reject the hypothesis that the residuals in the regressions in Eq. (5) were uncorrelated. Three SUR models were estimated: (i) one with only objective risks as explanatory variables, (ii) one

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[6] For a description of the different models, see any econometric textbook, e.g. Wooldridge (2002).

Table 2 Geometric mean road mortality risk per 100,000 by sex and age groups

Age group	Objective risk[a]			Perceived risk					
	Female	Male	Overall	Female	N	Male	N	Overall	N
17–19[b]	4.99	16.20	10.72	3.55	19	6.18	11	4.35	30
20–24	4.21	15.81	10.13	3.88	41	4.55	33	4.16	74
25–34	2.13	10.80	6.56	2.75	97	3.60	120	3.19	217
35–44	2.60	5.82	4.24	3.39	106	2.61	119	2.95	225
45–54	1.93	8.61	5.31	3.62	116	3.52	125	3.57	241
55–64	3.40	10.87	7.13	3.22	82	3.22	109	3.22	191
65–74	5.41	12.83	8.85	3.95	48	4.25	61	4.12	109
Overall mean	3.08[c]	10.24[c]	6.68[c]	3.37	509	3.42	578	3.40	1,087
(95% C.I.)				(3.08 : 3.69)		(3.12 : 3.75)		(3.19 : 3.62)	
Wilcoxon rank-sum[d]: p-value = 0.80									

[a] Objective risk calculated on data from SCB and SIKA (1999), Table 1, and SCB (2000), Tables 60–61.

[b] Objective risk is for age group 18–19.

[c] Weighted by the size of the different age groups (SCB, 2000, Tables 60–61).

[d] H_0: Perceived (Female) = Perceived (Male).

where the coefficients for the household characteristics were constrained to be equal in both regressions, and (iii) one with unconstrained household characteristics. The unconstrained model is our preferred model. The constrained model was included to investigate the effect from an a priori assumption that individual risk formation is the same for both risks.

4 Results

4.1 Risk perception by age and gender

In Tables 2 and 3 objective and perceived risks are presented for different age groups and genders. As in previous studies of risk perception, we focus on geometric means (Hakes and Viscusi, 2004). Geometric means decrease the distorting effect of outliers among respondents' answers.[7] For road risk, we conclude that younger and older women underestimate their risk, whereas men in all age groups underestimate their risk. The geometric mean of perceived road risk for women as a group is not statistically significantly higher than the mean of the objective risk. Men have a higher perception of risk than women, but the difference is not statistically significant. When age groups are not divided according to gender, all age groups underestimate their risk exposure.

We find that most age groups, especially older respondents, underestimate their overall risk. We also find that both genders underestimate their risk. Mean perceived overall risk for each gender is equal up to the second decimal, and the estimates are again not significantly different. However, since men's objective risk is higher, the descriptive analysis indicates that the bias for men is larger.

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[7] Arithmetic means are presented in Table 8 in the appendix. The numbers of observations differ, since zero answers were dropped when the geometric means were estimated.

Table 3 Geometric mean overall mortality risk per 1,000 by sex and age groups

Age group	Objective risk[a]			Perceived risk					
	Female	Male	Overall	Female	N	Male	N	Overall	N
17–19[b]	0.23	0.48	0.36	0.20	15	0.58	11	0.31	26
20–24	0.28	0.65	0.47	0.53	28	0.19	25	0.33	53
25–34	0.36	0.76	0.56	0.15	73	0.14	97	0.14	170
35–44	1.48	0.85	1.16	0.25	77	0.19	98	0.21	175
45–54	2.27	3.54	2.91	0.49	79	0.42	95	0.45	174
55–64	5.57	9.54	7.55	0.34	52	0.47	72	0.41	124
65–74	16.38	26.96	21.28	0.51	29	1.61	36	0.97	65
Overall mean	3.65[c]	5.66[c]	4.78[c]	0.30	353	0.30	434	0.30	787
(95% C.I.)				(0.24 : 0.38)		(0.24 : 0.37)		(0.26 : 0.35)	
Wilcoxon rank-sum[d]: p-value = 0.95									

[a] Objective risk based on statistics from 1995–1999 (SCB, 2001, Table 69).

[b] Objective risk is for age group 18–19.

[c] Weighted by the size of the different age groups (SCB, 2001, Table 69).

[d] H_0: Perceived (Female) = Perceived (Male).

4.2 Probability of underassessment

The results of the two probit models applied to the probability of underassessment of road and overall risks are presented in Table 4.[8] In column two, the marginal effects of belonging to the age groups 25–34, 55–64, and 65–74, are positive and statistically significant, which imply that individuals who belong to these age groups are more likely to underassess their road mortality risk compared with the age group 45–54 (i.e. the age group which was informed about its mortality risk in the survey). The marginal effect of *Male* is positive and statistically significant, implying that male respondents are more likely to state that their road risk is lower than the objective risk for their age and gender group. The variable *Annual Mileage* has a statistically significantly negative coefficient estimate, which implies that respondents who drive more are less likely to state that their own risk is lower than the objective risk.

Regarding overall risk, the coefficient estimates in column four reveal that, compared with the reference age group 45–54, younger respondents are less likely to underassess their mortality risk, whereas older respondents are more likely to. The result for *Male* is the same as for road risk. We now have a positive and a negative statistically significant marginal effect for *Health Status* and *Own accident*, respectively.

4.3 Magnitude of risk bias

The results of the OLS regressions on the magnitude of the bias are shown in Table 5. The upper half of the table contains the regression analysis of the respondents who stated that

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[8] The coefficient estimates in Table 4 denote marginal effects. Let $\Phi(\cdot)$, $\phi(\cdot)$, x, $\bar{x}$, and β, denote the standard cumulative normal distribution, normal density function, explanatory variables, mean value, and coefficients, respectively; then the marginal effects are calculated in *STATA* (StataCorp, 2001) as:

$$\frac{\partial \Phi(x\beta)}{\partial x_1} = \phi(\bar{x}\beta)\beta_1.$$

Table 4 Estimation results probit: Probability of underassessment of road and overall mortality risks

	Road mortality		Overall mortality	
Variable	Coeff	(Std. err.)	Coeff	(Std. err.)
Age 17–19	0.081	(0.095)	-0.417^{***}	(0.127)
Age 20–24	0.102	(0.065)	-0.388^{***}	(0.093)
Age 25–34	0.111^{**}	(0.048)	-0.141^{***}	(0.060)
Age 35–44	0.005	(0.052)	-0.150^{***}	(0.062)
Age 55–64	0.117^{**}	(0.043)	0.218^{***}	(0.029)
Age 65–74	0.211^{***}	(0.046)	0.160^{***}	(0.038)
Health Status[a]	0.078	(0.109)	0.516^{***}	(0.112)
Male	0.519^{***}	(0.031)	0.097^{***}	(0.035)
Income[a]	−0.018	(0.011)	−0.008	(0.011)
Annual Mileage	-0.007^{**}	(0.003)	0.001	(0.002)
University	0.009	(0.034)	0.026	(0.033)
Own Accident	−0.008	(0.049)	-0.087^{*}	(0.054)
Family Accident	0.207	(0.130)	0.090	(0.120)
Household 0–3	0.022	(0.047)	0.014	(0.038)
Household 4–10	0.053^{*}	(0.031)	−0.004	(0.026)
Household 11–17	0.031	(0.030)	$2 \cdot 10^{4}$	(0.027)
N	1,113		801	
$\tilde{R}^2$	0.25		0.18	

Dependent variables: 1 if Obj.risk > Sub.risk

Two-tailed test: *** significant at 1%, ** at 5% level, and * at 10%.

Coefficient estimates denote marginal effects, see footnote 8

Robust standard errors in parentheses.

$\tilde{R}^2$ denotes "pseudo- R^2" (Wooldridge, 2002, p. 465)

[a] Income and Health Status have been divided by 100 in the regressions.

their own risk was lower than the risk of their peers, and the lower half that of those who stated a higher or equal mortality risk.

Focusing on the results for those who underassessed their mortality risk, all age groups except 35–44 have a larger risk bias compared with the reference age group 45–54 for road risk. For overall risk, age groups younger than 45–54 have a smaller risk bias, whereas age groups older than 45–54 have a larger risk bias. Moreover, men have a larger risk bias for both risks, more healthy individuals a larger bias for road risk, drivers who drive more a smaller risk bias for road risk, and respondents with a university degree a smaller risk bias for overall risk. We also note that those individuals who have family members that have accident experience have a smaller risk bias concerning overall risk.

Regarding those who stated that their own risk was equal to or higher than their own age group, for road risk male respondents and those with a higher income have a larger risk bias, while more healthy respondents have a smaller bias. For overall risk, the only statistically significant coefficient estimates are for *Age 55–64* and *Age 65–74*. These estimates are positive and imply a higher risk bias for these age groups compared with the reference age group.

4.4 Risk formation

Tables 6 and 7 present the results from the SUR models. In *SUR 1* of Table 6, if the respondents perceive their risk to be equal to that of their age and gender group, the slope coefficient

Table 5 Estimation results OLS: Risk bias on road and overall mortality risks

	Road mortality		Overall mortality	
Variable	Coeff	(Std. Err.)	Coeff	(Std. Err.)
	Respondents who stated Sub.risk $<$ Obj.risk			
Age 17–19	4.262***	(0.672)	−1.536***	(0.279)
Age 20–24	4.522***	(0.610)	−1.814***	(0.228)
Age 25–34	1.799***	(0.372)	−1.616***	(0.151)
Age 35–44	−1.266***	(0.320)	−1.203***	(0.173)
Age 55–64	2.311***	(0.296)	4.298***	(0.196)
Age 65–74	3.402***	(0.383)	17.916***	(0.630)
Health Status	0.022***	(0.006)	−0.001	(0.006)
Male	5.673***	(0.203)	1.927***	(0.190)
Income	$-2 \cdot 10^{-4}$	(0.001)	0.001*	$(5 \cdot 10^{-4})$
Annual Mileage	−0.045***	(0.016)	−0.016	(0.010)
University	−0.038	(0.199)	−0.345*	(0.183)
Own accident	−0.091	(0.289)	−0.103	(0.250)
Family accident	1.276	(1.327)	−0.914***	(0.300)
Household 0–3	−0.126	(0.298)	−0.105	(0.114)
Household 4–10	−0.059	(0.174)	−0.066	(0.086)
Household 11–17	0.577***	(0.188)	0.193**	(0.094)
Intercept	−4.126	(2.748)	2.926***	(0.697)
N	741		608	
R^2	0.60		0.91	
	Respondents who stated Sub.risk $\geq$ Obj.risk			
Age 17–19	−22.761	(15.503)	−0.405	(2.568)
Age 20–24	4.843	(10.943)	3.468	(3.022)
Age 25–34	−9.640	(9.681)	−3.131	(2.488)
Age 35–44	−20.814	(15.530)	−2.067	(2.688)
Age 55–64	−12.318*	(6.917)	57.826***	(7.749)
Age 65–74	25.779	(35.003)	150.949**	(75.333)
Health Status	−0.565*	(0.329)	−0.005	(0.137)
Male	30.592**	(13.707)	6.146	(4.654)
Income	0.044*	(0.023)	−0.002	(0.005)
Annual Mileage	0.129	(0.405)	−0.041	(0.255)
University	−10.031	(6.179)	2.613	(5.356)
Own accident	−8.269	(6.609)	7.815	(7.447)
Family accident	12.992	(13.828)	2.680	(3.251)
Household 0–3	−4.093	(3.753)	1.198	(1.595)
Household 4–10	6.300	(9.821)	2.252	(2.035)
Household 11–17	6.318	(9.467)	0.301	(0.983)
Intercept	24.804	(23.746)	−6.319	(13.906)
N	372		193	
R^2	0.12		0.51	

Dependent variables: Absolute risk bias, i.e. |Obj. risk − Sub. risk|.

Two-tailed test: *** significant at 1% level, ** at 5% level, * at 10% level.

Robust standard errors in parentheses.

Table 6 Estimation results SUR: Risk perception formation bivariate and constrained covariates

	SUR 1		SUR 2	
Variable	Coeff	(Std. err.)	Coeff	(Std. err.)
Road mortality				
ln(Objective Road)	−0.497	(0.321)	−0.310	(0.364)
ln(Objective Road)^2	0.187*	(0.098)	0.156	(0.110)
Intercept	1.447***	(0.230)	2.723***	(0.668)
Overall mortality				
ln(Objective Overall)	−0.664	(0.429)	−0.678	(0.432)
ln(Objective Overall)^2	0.094**	(0.039)	0.096**	(0.039)
Intercept	4.180***	(1.132)	5.671***	(1.314)
Household characteristics[a]				
Age 17–19	–	–	0.071	(0.246)
Age 20–24	–	–	0.190	(0.188)
Age 25–34	–	–	−0.200	(0.133)
Age 35–44	–	–	−0.053	(0.134)
Age 55–64	–	–	−0.277**	(0.139)
Age 65–74	–	–	−0.090	(0.180)
Health Status	–	–	−0.010***	(0.003)
Male	–	–	−0.247*	(0.135)
Income	–	–	$4 \cdot 10^{-4}$	$(3 \cdot 10^{-4})$
Annual Mileage	–	–	0.011*	(0.006)
University	–	–	−0.060	(0.086)
Own Accident	–	–	0.033	(0.106)
Family Accident	–	–	−0.329	(0.298)
Household 0–3	–	–	−0.065	(0.107)
Household 4–10	–	–	−0.118	(0.072)
Household 11–17	–	–	−0.115	(0.071)
	Road 1	Overall 1	Road2	Overall 2
R^2	0.01	0.05	0.05	0.09
N	784		784	

Dependent variables, natural logarithm of road and overall risks.

Two-tailed test: *** significant at 1%, ** at 5% level, and * at 10%.

Objective road and overall risks are from Tables 2 and 3, respectively.

Both risks per 100,000 in SUR.

H_0: ln(Objective Risk) = 1, rejected at 1% level for both risks in both regressions.

Bresusch-Pagan test of independence of residuals rejected at 1% level in both regressions.

[a] Coefficient estimates constrained to be equal in both regressions.

for *ln(Objective)* will be one, and the intercept and the slope coefficient for *ln(Objective)*^{2} will be zero. The results suggest, however, that the slope coefficients for *ln(objective)* are different from one, and that *ln(Objective)*^{2} and the intercepts are different from zero. These differences are statistically significant for both road and overall risks. The results for road risk imply that: (i) individuals at low risk overassess their risk (women 25–54), (ii) individuals at a higher risk than $3.1 \cdot 10^{-5}$ underassess their risk (men and younger and older women), (iii) we do not have a monotonic relationship between perceived and objective road risks, and (iv)

Table 7 Estimation results unconstrained SUR: Risk perception formation unconstrained covariates

	Road mortality		Overall mortality	
Variable	Coeff.	(Std. err.)	Coeff.	(Std. err.)
ln(Objective Risk)	-0.193	(0.388)	-1.931^{**}	(0.912)
ln(Objective Risk)^2	0.199^{*}	(0.117)	0.226^{**}	(0.092)
Age 17–19	-0.132	(0.300)	-0.035	(0.766)
Age 20–24	0.020	(0.242)	0.050	(0.641)
Age 25–34	-0.213	(0.139)	-0.688	(0.531)
Age 35–44	0.008	(0.137)	-0.255	(0.377)
Age 55–64	-0.341^{**}	(0.159)	-0.960^{**}	(0.452)
Age 65–74	-0.221	(0.233)	-1.573	(0.982)
Health status	-0.008^{***}	(0.002)	-0.030^{***}	(0.005)
Male	-0.582^{*}	(0.316)	-0.081	(0.183)
Income	$4 \cdot 10^{-4*}$	$(3 \cdot 10^{-4})$	$3 \cdot 10^{-4}$	$(5 \cdot 10^{-4})$
Annual Mileage	0.012^{**}	(0.006)	-0.004	(0.010)
University	-0.077	(0.085)	0.130	(0.156)
Own Accident	0.022	(0.105)	0.184	(0.193)
Family Accident	-0.300	(0.294)	-0.610	(0.541)
Household 0–3	-0.075	(0.105)	0.116	(0.194)
Household 4–10	-0.124^{*}	(0.071)	-0.026	(0.131)
Household 11–17	-0.120^{*}	(0.070)	-0.112	(0.129)
Intercept	2.388^{***}	(0.670)	11.131^{***}	(2.769)
R^2	0.05		0.13	

Dependent variables, natural logarithm of road and overall risks.

$N = 784$.

Two-tailed test: *** significant at 1%, ** at 5% level, and * at 10%.

Objective road and overall risks are from Tables 2 and 3, respectively.

Both risks per 100,000 in SUR.

H$_0$: ln(Objective Risk) = 1, rejected at 1% level in both regressions.

Bresusch-Pagan test of independence of residuals rejected at 1% level.

For household attributes, test of $\alpha_{\text{Road}} = \delta_{\text{Overall}}$, F-statistic = 0.59.

the partial derivative ranges from -0.25 to 0.55.[9] For risk levels lower than $3.8 \cdot 10^{-5}$, an increase in objective risk results in a decrease in perceived risk. For overall risk we find that: (i) perceived risk is lower than objective risk for all objective risk levels, (ii) the relationship between perceived and objective risks is again non-monotonic, and (iii) the partial derivative ranges from -0.08 to 0.82. Thus, individuals at higher risk incorporate more of the risk information than those at lower risk. For instance, those at the highest road risk incorporate about half of the risk information compared with 0.13 at the mean, while those at the highest overall risk incorporate 0.82 of the information compared with 0.31 at the mean.

In *SUR 2*, household attributes are assumed to influence risk perception for road and overall risks in the same manner. Whereas both coefficient estimates for objective road risk are statistically insignificant, we again find a convex relationship between *ln(Perceived Overall)* and *ln(Objective Overall)*. Among household attributes; *Age 55–64*, *Health Status*, and *Male*, have negative coefficient estimates, whereas *Annual Mileage* has a positive estimate. The

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[9] $\frac{\partial \ln(\text{Perceived})}{\partial \ln(\text{Objective})} = \alpha_1 + 2\alpha_2 \ln(\text{Objective})$.

coefficient estimate for *Male*, e.g., indicates that men perceive the risk at a certain level to be 28 percent lower than women.

In the SUR model in Table 7, individual characteristics are allowed to influence road and overall mortality differently, and the coefficient estimates for household attributes are, therefore, unconstrained. We again find a convex relationship between perceived and objective risks. Perceived road risk is lower for men, declines with number of children aged 4–17, and increases with income. The correlation between self-reported health status and risk perception is negative for both risks. The test of differences in coefficient estimates of the household attributes showed that only *Health Status* and *Annual Mileage* were statistically significantly different at the 10 percent level, and that the null hypothesis of the same household slope parameters in both regressions could not be rejected.

5 Discussion and concluding remarks

We have examined individuals' perception of their own road-traffic and overall mortality risk, and found the expected pattern for road mortality risk, i.e. that low-risk groups overassessed their risk and that high-risk groups underassessed theirs. This pattern has not been found for overall mortality risk, however, where all risk groups underassessed their mortality risk. We can only speculate as to why our findings indicate that both low- and high-risk individuals underassess their overall mortality risk. A plausible explanation why older respondents reveal a quite large underassessment of overall mortality risk might be that there was a framing effect from the focus on road-traffic in the CVM-study. Such a framing effect cannot, however, explain why young respondents (who are at low objective overall mortality risk) also underestimate their risk. A framing effect would instead result in an overassessment among young respondents. Moreover, the risk formation regressions also show that the responsiveness of risk perception increases with the level of actual risk, i.e. the responsiveness is higher among high-risk groups. This is similar to the result found in Hakes and Viscusi (2004) for different hazardous activities. Since the slope remains below one in the relevant range, not all information about differences in risk levels is incorporated. Hence, since all groups underassess their overall mortality risk and since the slope is below zero, low-risk groups will perceive their risk more accurately.

Considering road-traffic risk as more controllable than overall risk, our results and the patterns found are not what we expected. Based on previous findings in the literature, we thought that it would be more likely that all respondents would underestimate the risk of road-traffic, since individuals: (i) can influence road risk by personal skills, and (ii) to a larger extent than overall risk can choose not to be exposed to road risk. The variable, which could be expected to be a proxy for driving skills, *Annual Mileage*, revealed that those who drove more were less likely to state that their own risk was lower than the objective risk. Among those who did state that they were safer than their peers, *Annual Mileage* was negatively correlated with the size of risk bias. This might be a result of the wording of the questions, where the respondents were asked to consider (among other things) "distance of travel" when they were asked to state their own road-traffic risk. Thus, those who drive more consider themselves to be more exposed to risk than those who drive less, which is why *Annual mileage* here might be a proxy for risk exposure rather than skill or experience.

We did not find any difference between men and women, when we compared mean estimates of their risk perception. However, when answers were divided on the basis of age group and gender, we found that male drivers underestimate their risk and that younger and older female drivers also underestimate theirs. When using multivariate regression analysis, we found, as expected, that men perceived the risks as lower than women and that they were also more likely to underestimate the risks. Further, the results also imply that women are more accurate in their risk perception. We expected that the age group (45–54), that received information about its own objective risk in the CVM-study, would have the smallest risk bias. A surprising result was, therefore, that several age groups among those who underassessed their risk had a significantly lower risk bias. We did not find any support for our expectations in the group that overassessed their risk, either. Some coefficient estimates were positive, others negative, most of them statistically insignificant.

The only statistically significant correlation between having a university degree and risk perception was a negative correlation for those who stated that their own overall mortality risk was lower than the objective risk. Thus, the results in this study do not imply any strong relationship between higher education and risk perception. Respondents in better health perceive both road and overall mortality risks as lower and are also more likely to underassess their overall risk. Since people in better health ought to have a lower overall risk than those in worse health, a lower perception of overall risk and a higher likelihood of stating that their risk is lower than that of their peers might not reflect any risk bias. That health status is a good predictor of longevity has been shown by, e.g., Smith et al. (2001).

The results of this study are of relevance to both policy making and the study of risky behavior. This study contributes knowledge on how individuals perceive their own risk, not only how they perceive risk for the population at large which prior studies have examined. Since individuals' perception of their own risk influences their behavior and their optimal tradeoffs between risk reductions and other consumption (i.e. benefit measures), this knowledge is important. Without it there is a chance that hazards are not prioritized in an optimal way, with too much focus and resources allocated to some specific risks and other hazards not given the proper attention (Tengs et al., 1995; Gayer et al., 2000).

Appendix: Arithmetic means

Table 8 Arithmetic mean of road-traffic and overall mortality risks by sex and age groups

Age group	Objective risk[a]			Perceived risk					
	Female	Male	Overall	Female	N	Male	N	Overall	N
				Road mortality					
17–19[b]	4.99	16.20	10.72	9.68	19	9.86	11	9.75	30
20–24	4.21	15.81	10.13	9.26	41	21.18	36	14.83	77
25–34	2.13	10.80	6.56	4.30	97	10.21	121	7.58	218
35–44	2.60	5.82	4.24	8.63	110	4.12	122	6.26	232
45–54	1.93	8.61	5.31	9.94	118	14.42	126	12.25	244
55–64	3.40	10.87	7.13	3.90	85	5.50	115	4.82	200
65–74	5.41	12.83	8.85	14.98	49	8.83	66	11.45	115
Overall mean	3.08[c]	10.24[c]	6.68[c]	8.03	519	9.45	597	8.79	1,116
(Std. Dev.)				(31.65)		(41.34)		(37.14)	
				Overall mortality					
17–19[b]	0.23	0.48	0.36	0.74	15	1.09	11	0.88	26
20–24	0.28	0.65	0.47	4.59	28	1.07	27	2.86	55
25–34	0.36	0.76	0.56	0.68	73	0.66	98	0.67	171
35–44	1.48	0.85	1.16	0.90	80	1.65	100	1.32	180
45–54	2.27	3.54	2.91	1.52	80	1.42	96	1.47	176

Continued on next page

Table 8 (*Continued.*)

Age group	Objective risk[a]			Perceived risk					
	Female	Male	Overall	Female	N	Male	N	Overall	N
55–64	5.57	9.54	7.55	3.34	54	1.61	74	2.34	128
65–74	16.38	26.96	21.28	2.46	30	22.99	37	13.80	67
Overall mean	3.65[d]	5.66[d]	4.78[d]	1.77	360	3.11	443	2.51	803
(Std. Dev.)				(7.21)		(24.26)		(18.66)	

Road mortality per 100,000 and overall mortality per 1,000.

H_0: Perceived (Female) = Perceived (Male) not rejected for either risk. (Wilcoxon rank-sum: p-value. equal to 0.91 and 0.97 for road-traffic and overall mortality risk, respectively.)

[a] Objective road risk calculated on data from SCB and SIKA (1999, Table 1), and SCB (2000), Tables 60–61, whereas objective overall risk is based on statistics from 1995–1999 (SCB, 2001, Table 69).

[b] Objective risk is for age group 18–19.

[c] Weighted by the size of the different age groups (SCB, 2000, Tables 60–61)

[d] Weighted by the size of the different age groups (SCB, 2001, Table 69).

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