Risk, price, and reimbursement

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Abstract: The article offers five hypotheses for the inverse relationship between risk and price in terms of first and second derivatives, establishing ranges of convexity, linearity, concavity. Negative price means reimbursement. Examples of risks are malfunction of a product or service, finite loss, severe injury, death, due to a variety of causes. For products with a probability of malfunction (risk) the relationship is empirically shown to be convex in a risk versus price diagram when paying for the product, and concave when enjoying reimbursement. This also holds for ticket prices for travel with a probability of death (risk), with transition from convexity to concavity for very low risk levels. The convexity result for probability of death stands in contrast to Viscusi and Zeckhauser's (2003) finding of a linear relationship. The value of life is estimated to be $\$1.02 \times 10^9$ by comparing subjects' willingness to pay for risky travel, and is estimated to be $\$2.08 \times 10^9$ based on subjects' requiring reimbursement $\$10^8$ to accept travel with death probability 4.8%. These values of life are larger than those usually reported in the literature. A possible reason may be that young students may be reluctant to place a value on life, and thus request an uncommonly large monetary amount to accept a small probability of death.

Keywords: risk; price; reimbursement; malfunction; finite loss; severe injury; death.

1 Introduction

The relationship between risk and price is inverse. This article provides five hypotheses to quantify the relationship in terms of first and second derivatives, establishing ranges of convexity, linearity, concavity. The hypotheses are tested empirically. Examples of risks are malfunction of a product or service, finite loss, severe injury, death, due to a variety of causes. Assume that a consumer or customer pays a price for a product. A product guaranteed to malfunction is worth nothing, a product guaranteed to function is worth a certain value, but the price for intermediate probabilities of malfunction cannot be determined on theoretical grounds. Such prices depend on consumers' risk attitudes. If a product sells for a price with a finite probability of malfunction (risk), a higher price gives a lower risk, and a lower price gives a higher risk. A sufficiently high price may eliminate the risk, but it is also possible that an infinite price does not eliminate the risk. Conversely, zero price may guarantee malfunction, but the consumer may also require negative price interpreted as reimbursement for large risks. A sufficiently high reimbursement may be sufficient if the product is guaranteed to malfunction, but it is also possible that an infinite reimbursement is not sufficient if the probability of malfunction is too high. This article quantifies these relationships empirically. A price can be a monetary amount paid by an agent, but can be any cost incurred, such as work exerted, inconvenience, and lost time. The article quantifies empirically how respondents make tradeoffs between risk, price, and re reimbursement.

We all carry out numerous tradeoffs on an hourly basis. Some of these require our explicit attention and extensive deliberation. Others have gradually worked their way into our habitual behaviour. Some have become so deeply entrenched that we rarely think of them as tradeoffs, and some we carry out unconsciously. This article focuses on those tradeoffs that not only require our explicit attention, but deep soul-searching for how we reconcile incompatible extreme concerns. We are forced to choose a price for malfunction or finite loss, and a value for human life due to a variety of different risks. We have to allocate investments to curb death from a variety of causes.

Some may perceive such tradeoffs as choices between the plague and cholera. Some prefer to avoid making the tradeoffs, and some prefer to let others make the tradeoffs for them. Society has set up procedures to make some tradeoff choices easier for us, or to give the appearance that we don't have to make the tradeoffs. Ticket prices for travel account for deep tradeoffs between risk and safety, driven by cultural tradition, political choices, profit motives where market forces play a role, etc. The consumer can sometimes but not always choose to refuse the travel, or can choose alternate travel. Time, price, and other constraints affect choices. Travel insurance is often offered. Purchase depends on price, marketing, consumer consciousness, etc. Again it is up to the consumer or individual to make the ultimate tradeoff. Whether each individual makes the tradeoff alone, or delegates the tradeoff to someone else, inevitably someone has to make the tradeoff. In cases where it is hard to pin down who makes the tradeoff, one may say that societal development as such proceeds in a manner so that tradeoffs are implicitly made.

The profiling between risk-price or price-reimbursement and its convex, linear or concave shapes brings to mind utility theory and functions. The relationship is as follows. Utility can be plotted as a function of risk. Ceteris paribus, utility decreases (convexly, linearly or concavely) when risk increases given that risk is undesirable (malfunction, etc.). Utility is commonly defined as benefit minus cost. A price paid is a cost, and a reimbursement earned is a benefit. Hence plotting price as a function of risk, as in this article, is the same as plotting minus utility as a function of risk, which means reversing the direction of the vertical axis. This article defines reimbursement as paying a negative price, plotted as negative values along the vertical price axis. Such reimbursement is equivalent to utility.

Section 2 verbalises, illustrates, and tests five hypotheses. Section 3 concludes.

2 Verbalising, illustrating and testing five hypotheses

This article delegates the authority of making tradeoffs to 90 students at the Universities of Stavanger and Bergen, Norway, who were surveyed with five questions March 9–May 29, 2004.[1] The questions and response are listed in the Appendix.

We express risk $0 \leq r \leq 1$ as a probability between zero and one of an adverse event. The relationships between risk r and price p can be conceived of as contracts which the consumer or customer signs and which specify the price to be paid, interpreted as reimbursement if p is negative, for all possible risks.

The relationship between risk and price can take many forms, such as convexity, linearity, concavity, or combinations of these for subranges of risk and price. Furthermore, the forms of the relationship between risk and price differ for different risk activities. We now proceed, in Popper's (1963) sense, to set up those five hypotheses for the relationship between risk and price that we find most plausible. The hypotheses are tested empirically for different risk activities applying Questions 1–5 in the Appendix. The results are illustrated graphically in Figures 1–4. In the hypotheses ' means first derivative and '' means second derivative of p with respect to r.

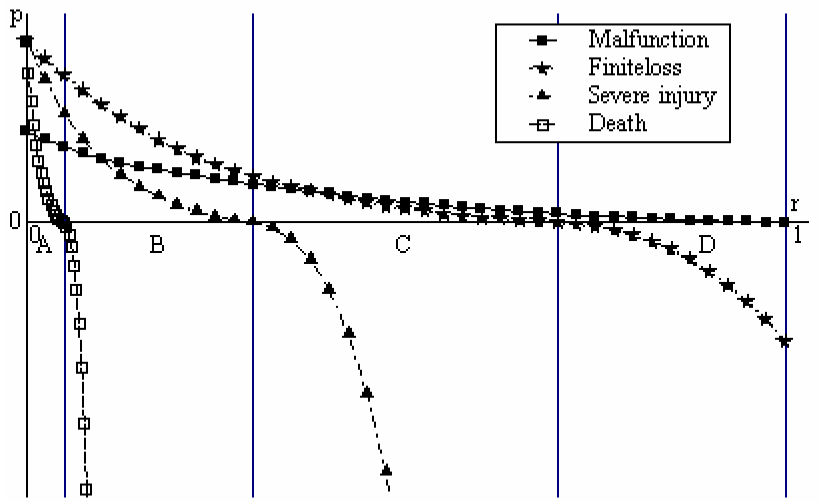
Hypothesis 1 $\quad p' < 0$ and $p'' > 0$ when $p > 0$ and $0 \leq r < 1$, and $p = 0$ when $r = 1$.

This hypothesis assumes convexly decreasing price as the risk increases, illustrated with the first curve in Figure 1 which expresses Malfunction e.g., of a product. Zero price corresponds to maximum risk $r = 1$. Hence the price never goes negative. When the adverse event is guaranteed, $r = 1$, the purchase is valueless and the price is zero, $p = 0$. As the adverse event becomes less likely, the price increases in an increasing manner reaching a finite level for $r = 0$ if the adverse event is removable, or an infinite level for $r = 0$ if the adverse event is not removable. An example of an adverse event which is 100% removable for a finite price is investment in alternative technology. A house of wood may burn down, but a house of brick cannot burn down since brick does not burn. A Cobb-Douglas function $u_{CD}(r, p) = p^{\alpha} r^{(1-\alpha)}$, $0 \leq \alpha \leq 1$, exemplifies Hypothesis 1 for $p > 0$ and $0 < r < 1$, limited by never reaching the axes $p = 0$ or $r = 0$ due to the multiplicative form. The additive form of the CES function $u_{CES}(r, p) = (ap^{\beta} + (1 - a)r^{\beta})^{1/\beta}$, $\beta \geq 0$, $0 \leq a \leq 1$, allows reaching the axes $p = 0$ or $r = 0$.

Hypothesis 2 $\quad p' < 0$ and $p'' > 0$ when $p > 0$ and $0 \leq r < r_{max} < 1$ and $p = 0$ when $r = r_{max}$

This hypothesis is equal to Hypothesis 1 except that zero prize does not correspond to risk $r = 1$, but instead to a risk $r_{max} < 1$ which is less than one. This is illustrated with regions ABC in the second curve in Figure 1, finite loss. The finite loss may be implied loss such as a malfunctioning bike causing a broken leg or a malfunctioning refrigerator causing loss of all content, an incompetent service causing loss of customer confidence, convenience loss, lost time, etc. Hypothesis 2 is also illustrated with regions AB in the third curve in Figure 1, severe injury, and with region A in the fourth curve in Figure 1, Death. For Hypothesis 2 the agent finds an adverse event with risk r_{max}, strictly less than one, unacceptable, and accordingly pays nothing for r_{max}. An example is an offer free of charge of parachuting from an airplane with an unreliable parachute. Most people will not not accept such a free offer except when the probability of failure is very low specified as $r = r_{max}$. As the risk decreases below $r = r_{max}$, the agent is hypothesised to accept paying a positive prize for the risky activity. Cobb-Douglas and CES functions exemplify also Hypothesis 2 except that there now is an upper bound below 1 on the risk where the axis $p = 0$ is reached.

Figure 1 Risk r versus price p (see online version for colours)

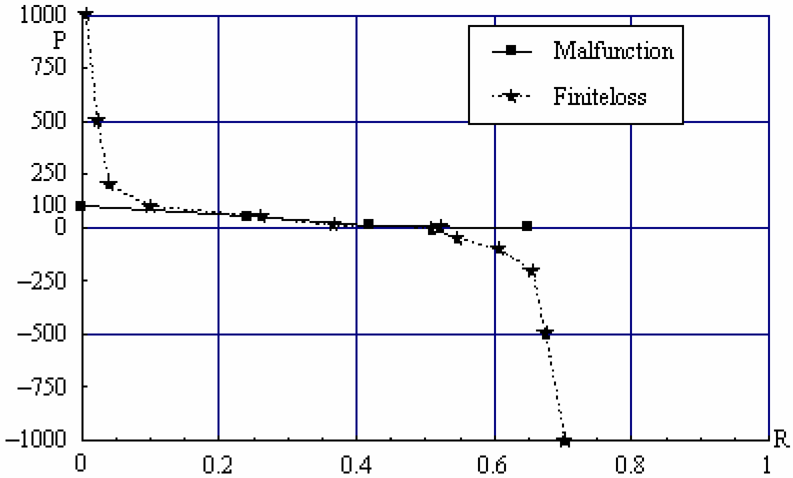


The tables following Questions 1–5 in the Appendix present the risks in the top row and the prices in the left column. The values in the tables are percentages, except the three right columns which present the expected value (E), standard deviation (Std) and number N of respondents.

Question 1 presents subjects with a price \$100 for a product, e.g., a mobile phone, guaranteed to function. Paying half the price \$50, they accept (on average) only a probability 0.24 of malfunction, referred to as risk. Paying \$10, they accept 0.42 risk. If they get the phone for free, they accept maximum 0.65 risk. These results support Hypothesis 2, and not Hypothesis 1, since subjects likely account for the additional work and inconvenience associated with purchasing, gathering information, and adapting to a new phone, as illustrated in Figure 2. Linear preferences P = 100–100 R, where P is price and R is risk, suggests the higher risks 0, 0.5, 0.9, 1 for the four payments. Subjects express preferences more akin to Cobb-Douglas preferences.

Hypothesis 3 $p' < 0$ and $p'' = 0$ when $p > 0$ and $0 \leq r < r_s \leq 1$.

Figure 2 Probability (risk) R of malfunction (Question 1) and finite loss (Questions 2–3) versus price P (see online version for colours)

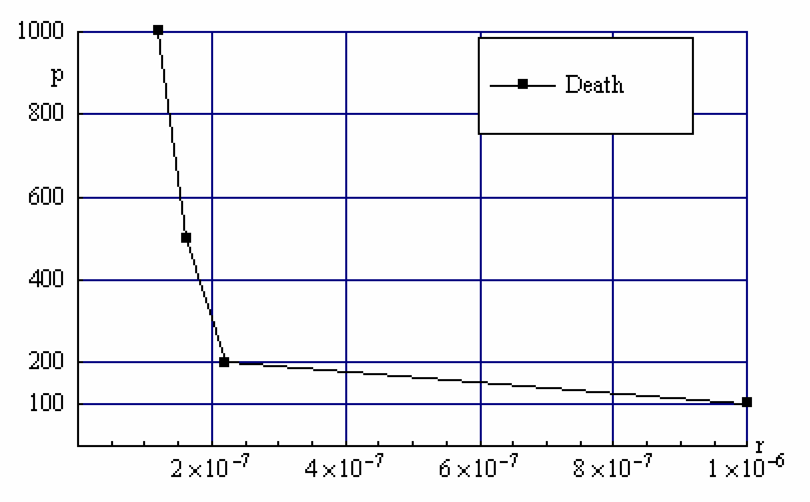


This hypothesis assumes linearly decreasing price as the risk increases. An analogy with Hypothesis 1 is that maximum risk $r_s = 1$ corresponds to zero price $p = 0$. An analogy with Hypothesis 2 is that maximum risk $r_s < 1$ corresponds to zero price $p = 0$. Viscusi and Zeckhauser (2003, p.115) suggest that Hypothesis 3 is valid when r_s is small. More specifically, they state that "for small probabilities" "the willingness to pay for the risk reduction should be a relatively invariant amount per unit risk reduction so that the willingness to pay to reach zero should be roughly double the value for reaching a 50% reduction". An example of Hypothesis 3 is when a person's willingness to pay for travel follows the curve $p = -cr + d$ where $c = 2 \times 10^8$ and $d = 300$ are positive constants. Assume the ticket costs $p = \$100$ which gives the death probability $r = 10^{-6}$. Using the formula, Hypothesis 3 applies when the person is willing to pay $p = \$200$ to enjoy the 50% lower death probability $r = 0.5 \times 10^{-6}$.

Question 4 lets a ticket price of \$100 for a travel (by plane, train, car, boat, etc.) correspond to a probability $R = 10^{-6}$ of death, referred to as risk. Subjects are willing to pay more, \$200, \$500, $\$10^3$, if they can enjoy the lower risks 0.221 R, 0.163 R, 0.121 R. Again, these risks at very small risk levels are convex supporting Hypothesis 2, shown in Figure 3. Subjects paying \$900 to decrease the death probability from R to 0.121 R means that $\$900/(10^{-6} - 0.121 \times 10^{-6}) = \$1.02 \times 10^9$ expresses the value of life. These results stand in contrast to Viscusi and Zeckhauser's (2003, p.115) finding which supports the linearity of Hypothesis 3. Testing ticket price increases customers would 'be willing to pay for screening measures that would decrease the probability of a terrorism attack on an airplane', they find that the mean customer is indifferent between the (risk, price) points (1, 1), (0.5, 1.2495), (10^{-6}/R, 1.3842), (10^{-7}/R, 1.5315), (0, 1.6943), where R is the current risk level.[2] A linear curve through the first two points reaches (0, 1.499), which is slightly below the fifth point.[3] This suggests slight convexity. A Cobb-Douglas function through the first three points gives $\alpha = 0.7568$ and $R = 2.75 \times 10^{-6}$.[4] Keeping $R = 2.75 \times 10^{-6}$, a CES function through the first, second, and fourth points gives $a = 3.54 \times 10^{-5}$, $\beta = 0.8581$.[5] The indifference curve crosses the vertical axis $r = 0$ for price p = 1.5560 P.[6] Minimising the sum of the squared differences between a linear curve through (1, 1) and the four last points gives $p/P = -0.61\ r/R + 1.61$, which crosses $p = 0$ for $r = 2.63$ R. The point (0, 1.61) is again below the fifth point, which suggests slight convexity. The upshot for the Viscusi and Zeckhauser (2003) data is that although slight convexity is involved, CES preferences or a linear risk versus price relationship more appropriately than Cobb-Douglas preferences describes the risk-price tradeoff for small risks.

Hypothesis 4 $p' < 0$ and $p'' < 0$ when $p < 0$ and $0 < r \leq 1$, and $p = 0$ when $r = 0$.

Figure 3 Probability (risk) r of death versus positive price p (see online version for colours)



This hypothesis assumes concavely decreasing price as the risk increases, which for negative price means convexly increasing reimbursement as the risk increases. When the adverse event is guaranteed not to occur, $r = 0$, the agent enjoys no reimbursement, $p = 0$. As the adverse event becomes more likely, the reimbursement increases in an increasing manner reaching a finite level for $r = 1$ if the agent accepts a guaranteed adverse event, or an infinite level if the agent does not accept a guaranteed adverse event regardless of reimbursement. An example is a person's willingness to accept hazardous waste to be deposited in his back yard, e.g., from a neighbouring community or someone seeking to get rid of the waste. When the waste is not deposited, the agent suffers no risk and enjoys no reimbursement, $r = p = 0$. As the waste increases in magnitude and degree of danger, the person requests convexly increasing reimbursement. If the waste is nuclear, the person may not accept it regardless of reimbursement.

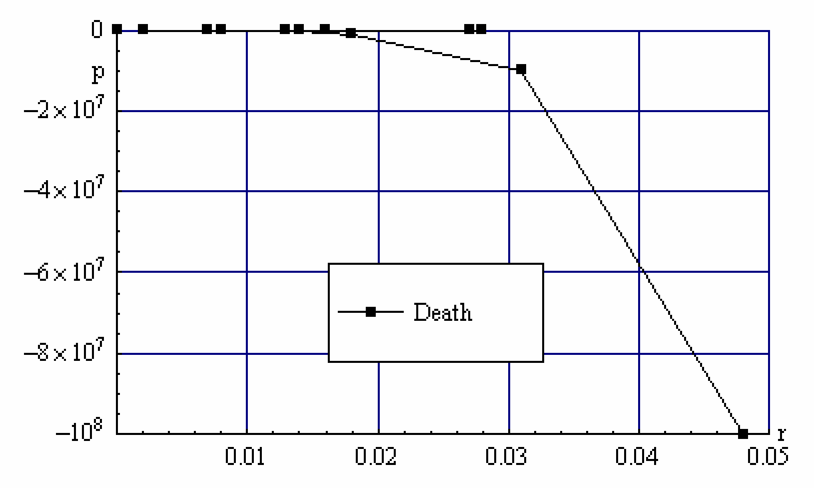
Hypothesis 5 $p' < 0$ and $p'' < 0$ when $p < 0$ and $0 < r_{min} < r \leq 1$, and $p = 0$ when $r = r_{min}$

This hypothesis is equal to Hypothesis 4 except that zero prize (zero reimbursement) does not correspond to risk 0, but instead to a risk r_{min} which is larger than zero. The agent accepts the adverse event with risk r_{min}, strictly above zero, acceptable without reimbursement, but requests reimbursement for higher risks. Hypothesis 5 is illustrated with region D in the second curve in Figure 1, Finite loss, reaching finite reimbursement when r = 1. Hypothesis 5 is also illustrated with regions CD in the third curve in Figure 1, severe injury, and regions BCD in the fourth curve in Figure 1, death. The two latter curves reach infinite reimbursement for r < 1. The curves proceed quickly toward negative p values requesting substantial reimbursement to accept the added risk. An example of Hypothesis 5 is the risk of living and going about one's daily activities. At zero reimbursement the risk is not zero since even living in a quiet countryside may cause one to get run over by a car or bicycle when walking to work, or one can fall out of bed while sleeping and break a leg. If one chooses a risky occupation (e.g., fighter pilot), work in risky environments (e.g., a war zone), and accept living in a house without security and no bodyguards, one may require substantial reimbursement in the form of high salary and low costs to accept the high risk. An example of an adverse event which cannot be removed regardless of price is probability of death (risk) for car driving. The most expensive and secure car combined with extensive driving experience and all imaginable precautions are not sufficient to eliminate the probability of death since factors outside one's control, such as human errors by other drivers who cannot be paid not to drive, influence the risk.

Question 2 assumes that a mobile phone priced at \$100 gives a probability 0.1 of finite loss, referred to as risk. Paying more, \$200, \$500, $\$10^3$, subjects require the lower risks 0.040, 0.023, 0.006 which form a convex curve as in Hypothesis 2. For payments as high as $\$10^3$, subjects require in response to Question 3 an almost riskless phone. Reimbursing subjects from \$0 to $\$10^3$ for finite loss, subjects accept risks ranging from 0.521 to 0.703, expressing concavity as in Hypothesis 5. The curves are convex when paying for a product, and concave when enjoying reimbursement.

Question 5 decreases the ticket price below \$100. Reimbursing subjects from \$50 to $\$10^8$, subjects accept risks changing concavely from 0.002 to 0.048. The mean respondent accepts a death probability of 4.8% when presented with more money, $\$10^8$, than most people make in a life time. This gives a value of life $\$2.08 \times 10^9$.[7] When offered less money, $\$10^7$, the mean respondent accepts a death probability of 3.1% which gives a lower value of life $\$3.23 \times 10^8$. The results are shown as a concave curve supporting Hypothesis 5, in Figure 4. The convexity for payment and concavity for reimbursement in Figure 2 are mirrored by similar convexity and concavity in Figures 3 and 4. The standard deviations are smaller than the expected values for Figures 2 and 3, aside from the large payment $\$10^3$ in Question 2 and \$500 and $\$10^3$ in Question 4. The reverse is the case for the entire range of prices from \$50 to $\$10^8$ in Figure 4, where the standard deviations are considerable. Presenting respondents with 17 tradeoff options in the range from $\$10^3$ to $-\$10^8$, in addition to the comparison standard \$100 for risk $R = 10^{-6}$ is done to hopefully make it easier for respondents to develop a possibly coherent or rational view of the tradeoffs along this continuum, rather than evaluating one tradeoff in isolation. Observe in this regard Kunreuther et al.'s (2001, p.103) argument that "it appears that one needs to present comparison scenarios that are located on the probability scale to evoke people's own feelings of risk". Further, 'fairly rich context information must be available for people to be able to judge differences between low probabilities'. This is attempted accomplished in the introduction to each question presented to respondents. Nevertheless, respondents exhibit considerable uncertainty when evaluating something as basic as reimbursement for increased probability of death, as illustrated by the standard deviation in the results.[8, 9]

Figure 4 Probability (risk) r of death versus negative price p (reimbursement) (see online version for colours)



A person's profile is affected by the severity (probability multiplied with impact) of the risky outcomes. This article defines risk as a probability that an event with a certain impact occurs. The correlation between the decision maker's profile and the risk severity scale stemming from the hypotheses is as follows. Five examples of events with specified impact are malfunction of a product or service, finite loss, minor injury, severe injury, death. A person can specify how he is indifferent between combinations of probability and impact for each of these events.[10] In Question 1 the person pays \$100 for a phone that malfunctions with probability 0.1, which gives severity \$10. He pays \$10 if the phone malfunctions with probability 0.42, which gives severity \$4.2. In Question 2 the person pays \$1000 for a phone that malfunctions with probability 0.006, which gives severity \$6.

For each degree of severity (probability multiplied with impact) each person can specify how much he is willing to pay to decrease the severity, and how much reimbursement he requires to accept increased severity. In Question 3 the person requires \$1000 reimbursement if a phone malfunctions with probability 0.703. This can be perceived as a lottery with expected value \$703 if one subtracts the inconvenience of a malfunctioning phone. In Question 4 the person pays \$900 to decrease the death probability of travel from 10^{-6} to 0.121×10^{-6}, which gives a value of life $\$1.02 \times 10^9$. In Question 5 the person requires $\$10^8$ reimbursement if the death probability of travel is 0.048 which gives a value of life $\$2.08 \times 10^9$.

3 Conclusions

The article quantifies in five hypotheses, with empirical testing, the inverse relationship between risk and price in terms of first and second derivatives, establishing ranges of convexity, linearity, concavity. Examples of risks are malfunction of a product or service, finite loss, severe injury, death, due to a variety of causes. Examples of price interpretations when price is positive are any cost incurred, such as monetary amounts paid, work exerted, inconvenience, lost time. Negative prices are interpreted as reimbursement which may be any benefit enjoyed. The article finds empirical support for the result that for products with a probability of malfunction (risk) the relationship is convex in a risk versus price diagram when paying for the product (Hypothesis 3), and concave when enjoying reimbursement (Hypothesis 5). This also holds for ticket prices for travel with a probability of death (risk), with transition from convexity to concavity for very low risk levels. The convexity result for probability of death stands in contrast to Viscusi and Zeckhauser's (2003) finding of a linear relationship (Hypothesis 3). The value of life is estimated to $\$1.02 \times 10^9$ by comparing subjects' willingness to pay for risky travel (Question 4), and is estimated to $\$2.08 \times 10^9$ based on subjects' requiring reimbursement $\$10^8$ to accept travel with death probability 4.8% (Question 5). These values of life are larger than those usually reported in the literature. A possible reason may be that young students may be reluctant to place a value on life, and thus request an uncommonly large monetary amount to accept a small probability of death.

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Notes

1 Norway is socially democratic, outside the EU, mostly Lutheran Christian, Caucasian, and its 4.6 million population is relatively homogenous. Fifty-one subjects were asked nine additional personal characteristics questions.

   1 97.9% are white, 2.1% are not white
   2 93.7% are Norwegian, 6.3% are not Norwegian
   3 88% are students more than 50% of the time, 12% are students less than 50% of the time
   4 80% are 20–29 years, 12% are 30–39 years, 8% are 40–49 years
   5 84% are males, 16% are females
   6 their financial situation compared with all students at the university are much better than average 18%, better than average 40%, average 32%, worse than average 10%, much worse than average 0%
   7 with respect to psychological behaviour (e.g., gambling or stock market investment), 4% are very risk seeking, 30% are moderately risk seeking, 30% are risk neutral, 34% are moderately risk averse, 2% are very risk averse
   8 with respect to physical behaviour (e.g., ice climbing, white water kajaking, paragliding, martial arts (e.g., karate), boxing), the corresponding percentages are 6, 26, 38, 18, 12

9 their preference for the 11 Norwegian political parties are Arbeiderpartiet 6%, Fremskrittspartiet 16%, Fridemokratene 0%, Høyre 28%, Miljøpartiet De Grønne 2%, Kristelig Folkeparti 6%, Norges Kommunistiske Parti 0%, Rød Valgallianse 4%, Senterpartiet 4%, Sosialistisk Venstreparti 12%, Venstre 2%, no preference 20%.

2 Regarding the fifth point, although it is rational for a consumer to specify a maximum finite price if the risk gets reduced to zero, this event constitutes wishful thinking and cannot be realised in praxis. A zero tolerance principle for crime, or a zero vision for accidents (Elvik, 1999), are other examples which are operative when interpreted as desirable objectives. Zero risk $r = 0$ is impossible since, first, hitherto unknown technology may be applied that passes undetected through screening measures. Second, an airplane may be subject to terrorism through corrupting the crew, maintenance, and service personnel and procedures. Third, an airplane can be shot down with a missile or some other weapon. Fourth, a mid-air (James Bond style) hijacking cannot be ruled out.

3 That is, $p/P = -0.499\ r/R + 1.499$, specifying zero risk $r = 0$ for price $p = 1.499$ P, and a price zero $p = 0$ for risk $r/R = 3.004$.

4 The curve proceeds to (10^{-7}/R, 2.9010 P), which is almost twice the price increase suggested by the fourth point, and further to (infinity, 0). The consumer is willing to double the risk to $r = 2$ R if the price reduces to $p = 0.8003$ P.

5 Solving through the first three points gives $a = -1.71 \times 10^{-7}$, $\beta = 1.14355$, where negative a is not acceptable. $a < 0$ implies that all prices p impact the utility negatively while all risks r impact the utility positively, and conversely when $a > 1$. Solving through the first four points for general R gives $a = 3.65 \times 10^{-5}$, $\beta = 0.8804$, $R = 3.91 \times 10^{-6}$.

6 The consumer is willing to double the risk to $r = 2$ R if the price reduces to $p = 0.5479$P, and accepts risk $r = 3.7301\ R = 1.026 \times 10^{-5}$ if the price gets reduced to zero $p = 0$. Hence the consumer has to get the ticket for free to accept this risk level, and will have to get paid to accept higher risk levels. The CES function does not accept negative price p since imaginary values may follow.

7 See Viscusi (1998) for other methods of determining the value of life, e.g. choices between professions offering different salaries linked to different risks, and costs of cigarette smoking linked to death risks.

8 The risks 0.027, 0.016, 0.028, 0.008 accepted for the prices \$50, \$10, \$0, –\$10 are due to a few respondents not exhibiting economic rationality. Removing the entries in the upper right part of the table for Question 5 gives risk levels between 0.002 and 0.221R. The entries are kept to illustrate respondent uncertainty.

9 See Kunreuther et al. (2002) for a review of "the state of the art of research on individual decision making in high-stakes, low probability settings", and "a proposed agenda for future research" that "focuses on how the process and outcomes of high-stakes decision making might be improved".

10 For example, the person may be indifferent between breaking a finger with probability 0.01 and breaking a foot with probability 0.0001.

Appendix

1 Consider the tradeoff between price and probability of malfunction (risk) for a product, for example a mobile phone. The price is US\$100, and the phone is guaranteed to function for one year. You are also offered the same phone for a cheaper price, but with a probability of malfunction expressed with a number R between zero and one. As the price decreases below \$100, the probability of malfunction increases above R = 0. For example, R = 0.1 means a 10% probability of malfunction during the first year. If the malfunction occurs, the phone cannot be repaired and becomes useless. Price changes affect probability of malfunction, and

nothing else. For the price specified in the row in the following matrix, which maximum risk R of malfunction specified in the column (choose the risk closest to your preference) do you accept?

		Probability of malfunction													
		1	*0.9*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*	*0.3*	*0.2*	*0.1*	*0*	*E*	*Std*	*N*
Price to pay	$50	1.26	-	2.51	4.96	-	14.83	1.25	8.61	20.94	23.44	22.19	0.24	0.23	81
	$10	2.64	9.12	2.58	5.22	5.16	23.35	5.16	14.28	16.87	5.22	10.38	0.42	0.27	77
	$0	33.32	9.00	7.71	3.86	2.55	14.11	7.70	6.41	3.85	2.55	8.95	0.65	0.34	78

2 Many products have an inevitable probability of malfunction. Assume that the mobile phone priced at $100 gives a risk R = 0.1 of malfunction, which means a probability 10% of malfunction, during the first year of use. If the malfunction occurs, the phone cannot be repaired and becomes useless. If the price increases above $100, the probability of malfunction decreases below R = 0.1, thus giving a probability below 10% of malfunction. Your maximum phone budget is $1000. Given that price $100 corresponds to risk R = 0.1 of malfunction, for the price specified in the row in the following matrix, which maximum risk R of malfunction specified in the column do you accept?

		Probability of malfunction												
		0.09	*0.08*	*0.07*	*0.06*	*0.05*	*0.04*	*0.03*	*0.02*	*0.01*	*0*	*E*	*Std*	*N*
Price to pay	$200	10.00	6.25	6.24	2.54	22.49	7.46	7.52	13.76	7.46	16.26	0.040	0.029	80
	$500	2.60	1.31	1.30	2.60	14.09	2.60	5.15	23.04	24.28	23.02	0.023	0.022	78
	$\$10^3$	2.64	-	-	-	1.32	-	2.64	1.32	23.33	68.75	0.006	0.016	77

3 Conversely, if the price decreases below $100, the probability of malfunction increases above R = 0.1. Given that a price of $100 corresponds to risk R = 0.1 of malfunction, for the price specified in the row in the following matrix, which maximum probability of malfunction specified in the column (choose the ratio closest to your preference), do you accept? The negative prices mean that you get reimbursed for the malfunction. That is, the phone company compensates you if the phone malfunctions, acknowledging the inconvenience, lost time, etc. for you of malfunction.

		Probability of malfunction												
		0.15	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*	*1*	*E*	*Std*	*N*
Price to pay	$50	44.02	25.34	11.96	2.65	9.31	-	4.00	1.35	1.36	-	0.261	0.172	75
	$10	28.34	13.48	16.23	9.48	16.17	2.75	4.06	1.38	6.75	1.37	0.367	0.232	74
	$0	17.07	11.85	10.51	6.56	18.41	1.34	5.28	2.67	7.90	18.41	0.521	0.315	76
	–$10	15.99	10.69	13.33	9.32	13.33	7.96	2.65	4.02	6.66	16.05	0.508	0.303	75
	–$50	9.50	10.82	10.82	10.81	18.88	4.06	4.06	9.44	4.06	17.57	0.546	0.293	74
	–$100	9.44	5.38	8.07	10.81	16.25	8.12	5.44	4.07	10.81	21.63	0.607	0.296	74
	–$200	8.34	1.42	16.63	5.58	8.34	9.69	5.58	4.18	6.93	33.31	0.655	0.310	72
	–$500	9.56	5.51	5.51	8.17	10.97	4.12	6.84	5.51	9.56	34.26	0.675	0.313	73
	$-\$10^3$	14.86	1.38	4.05	6.74	9.49	1.37	6.74	4.06	9.48	41.83	0.703	0.327	74

4 Consider the tradeoff between ticket price and probability of death (risk): Events in recent years reveal that travelling by plane, train, car, boat, crossing bridges, proceeding through tunnels, etc., cause death with a strictly positive probability. The probabilities vary considerably across modes of transportation. The probability of death from hijacking of a US carrier arriving to or departing from the US was
7.5 per billion over the 1970–2000 period [Viscusi and Zeckhauser, (2003), p.109, www.air-transport.org]. Examples of risks by airplane travel are hijacking, bombs, bullets, biological or chemical weapons, missiles, airplane failure due to technical or human errors, inappropriate scanning of luggage, passengers, crew, corrupted maintenance or service procedures, etc. There are slightly above 300 traffic related deaths in Norway per year. With a population of around 4.6 million, this gives a probability of death of around 1 per 15000. As a concrete example, assume that an agency offers a ticket price of $100 for a travel (e.g., airplane travel) where there is a statistical probability of death of 1 per 1 million, expressed as $R = 1/10^6$. If the entire Norwegian population of 4.6 million makes this travel once, the expected number of deaths is 4.6. Assume that the agency offers a variety of ticket prices for this travel, which affect probability of death, and nothing else. In an uncertain world, assume that you cannot refuse to make this travel, and that your maximum budget is $1000. If the price increases above $100, the probability of death decreases to a fraction of R. Given that a ticket price of $100 corresponds to risk R of death, for the price specified in the row in the following matrix, which maximum risk specified in the column, where $R = 1/10^6$ (choose the ratio closest to your preference), do you accept?

		Probability of death												
		R/2	*R/3*	*R/4*	*R/7*	*R/10*	*$R/10^2$*	*$R/10^3$*	*$R/10^4$*	*$R/10^5$*	*0*	*E*	*Std*	*N*
Price to pay	$200	30.08	9.57	5.51	13.68	5.51	2.78	5.45	4.12	6.84	16.46	0.221R	0.209R	73
	$500	13.12	6.56	17.09	14.47	11.86	3.95	1.34	7.90	7.90	15.81	0.163R	0.168R	76
	$\$10^3$	13.49	1.37	5.37	18.93	8.12	6.75	1.38	4.06	14.86	25.67	0.121R	0.169R	74

5 Conversely, if the price decreases below $100, the probability of death increases above R. Given that a ticket price of $100 corresponds to risk $R = 1/10^6$ of death, for the price specified in the row in the following matrix, which maximum risk specified in the column (choose the ratio closest to your preference), do you accept? The negative ticket prices mean that you get reimbursed for the travel, at the cost of accepting a higher risk R. You can get rich, but face a scenario reminiscent of Russian Roulette.

		Probability of death													
		2/10⁶													
		$2/10^6$	$3/10^6$	$4/10^6$	$7/10^6$	$1/10^5$	$1/10^4$	$1/10^3$	$1/10^2$	*1/10*	*1/2*	*9/10*	*E*	*Std*	*N*
Price to pay	$50	70.43	5.60	5.60	7.03	5.67	1.43	-	-	-	2.80	1.44	0.027	0.134	71
	$10	54.92	12.64	5.60	11.27	9.84	1.43	-	-	1.43	2.87	-	0.016	0.084	71
	$0	49.90	11.10	8.35	5.58	16.69	1.41	-	1.41	2.82	-	2.76	0.028	0.148	72
	–$10	52.85	5.91	8.84	5.84	14.68	4.41	2.99	2.99	-	1.49	-	0.008	0.061	68
	–$50	47.85	7.24	11.59	5.76	14.49	5.76	2.88	2.95	1.47	-	-	0.002	0.012	69
	–$100	46.37	5.76	10.13	10.12	15.96	5.83	-	4.36	1.48	-	-	0.002	0.012	69
	–$200	44.83	10.18	10.11	7.23	15.93	5.82	2.94	1.47	1.48	-	-	0.002	0.012	69
	–$500	40.81	8.46	15.50	7.04	15.50	9.83	-	1.43	-	1.44	-	0.007	0.059	71
	–$103	37.63	8.64	15.94	7.23	14.53	13.06	1.48	-	-	-	1.48	0.013	0.109	69
	–$104	34.75	12.99	8.72	14.54	10.19	10.11	7.23	-	-	-	1.48	0.013	0.109	69
	–$105	31.41	8.52	10.03	11.43	17.16	9.96	5.74	4.29	-	-	1.46	0.014	0.108	70
	–$106	25.72	8.58	4.28	17.15	11.42	11.42	11.41	4.28	4.28	-	1.45	0.018	0.109	70
	–$107	27.10	5.74	5.74	11.41	18.54	4.29	11.42	8.51	2.90	2.90	1.45	0.031	0.135	70
	–$108	27.54	4.35	4.35	10.13	17.36	8.71	2.95	13.01	7.24	-	4.35	0.048	0.184	69