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Willingness to pay for reductions in health risks when probabilities are distorted

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Summary

We study the willingness to pay for reductions in health risks when people do not evaluate probabilities linearly, as is commonly assumed in elicitations of willingness to pay, but weight probabilities, as is commonly observed in empirical studies of decision under risk. We show that for the levels of baseline risk typically considered, probability weighting strongly affects willingness to pay estimates and may lead to unstable monetary valuations of health. Copyright © 2005 John Wiley & Sons, Ltd.

Keywords willingness to pay; health; probability weighting

Introduction

Cost benefit analyses of government programs that lead to reductions in risks to human health require estimates of the monetary value of health. To obtain such estimates, economists have sometimes used market data but more often contingent valuation and other stated-preference methods. The common approach in these studies is to analyze people's behavior under the assumption that expected utility holds. Empirical evidence abounds, however, that people violate expected utility in systematic ways [1,2]. Assuming expected utility in the face of such violations may lead to biased risk valuations and, consequently, to biased policy recommendations. There appears to be a need to derive valuation formulas for changes in mortality risks that take into account the fact that people deviate from expected utility.

An important reason why people deviate from expected utility is that they do not evaluate probabilities linearly, but distort probabilities. Many studies show the importance of probability weighting in risky choice, both for decisions involving money [3–7] and for health and life and death decisions [8]. There is also growing evidence that probability weighting is important in explaining a variety of field data [9]. A formal theory of probability weighting is rank-dependent utility [10,11].

The aim of this note is to analyze the effect of probability weighting on the willingness to pay for reductions in health risks. We show that for the range of probabilities commonly considered in empirical elicitations of willingness to pay, the introduction of probability weighting strongly affects the willingness to pay for reductions in health risks and might lead to unstable monetary valuations of health.

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In what follows, the next section derives the willingness to pay for reductions in health risks under rank-dependent utility. The following section discusses implications. The final section concludes.

WTP for reductions in health risks

Consider an individual who derives utility from income and health. Let us assume for simplicity, but without loss of generality, that there are two possible health states, either the individual is in good health or he has a health problem and is in less than good health. If he is in good health, his utility function over income is $U_g(y)$. We assume that U_g is increasing and concave, i.e. $U_g' > 0$ and $U_g'' < 0$. If the individual has a health problem his utility function over income is $U_h(y)$ with $U_h' \geq 0$ and $U_h'' \leq 0$. We further assume that for all income levels y, both the individual's utility of income and his marginal utility of income are higher in good health than in less than good health, i.e. for all y, $U_g(y) > U_h(y)$ and $U_g'(y) > U_h'(y)$. These assumptions are common in the literature [12,13]. The first assumption seems obvious. It says that for each level of income the individual prefers to be in good health rather than to have a health problem. Support for the second assumption was obtained by Viscusi and Evans [14] and Sloan *et al.* [15] who found that the marginal utility of income in good health exceeds the marginal utility of income in less than good health.

Let p_0 be the baseline probability of having a health problem. Consequently, $1 - p_0$ is the probability of being in good health. Let y_0 be the initial income level. The individual's rank-dependent utility is then

$$\mathrm{RDU}_0 = w(1-p_0)\cdot U_g(y_0) + (1 - w(1-p_0))\cdot U_h(y_0) \tag{1}$$

where w is the individual's *probability weighting function*, which has $w(0) = 0$, $w(1) = 1$, and which is nondecreasing, i.e. $w(p) \geq w(q)$ if and only if $p \geq q$. We further assume that w is twice differentiable.

Suppose that p_0 is changed into p_1. Let v be the compensating variation in y_0 such that

$$w(1-p_1)\cdot U_g(y_0 - v) + (1 - w(1-p_1))\cdot U_h(y_0 - v) = \mathrm{RDU}_0 \tag{2}$$

The willingness to pay for reductions in the probability of a health problem is equal to

$$\mathrm{WTP}_{\mathrm{RDU}} = -\left.\frac{\mathrm{d}v}{\mathrm{d}p}\right|_{p=p_0} = \frac{w'(1-p_0)(U_g(y_0) - U_h(y_0))}{w(1-p_0)U_g'(y_0) + (1 - w(1-p_0))U_h'(y_0)} \tag{3}$$

Equation (3) is the central result of this note. If w is the identity function, i.e. for all $p \in [0,1]$, $w(p) = p$ and, thus, $w'(p) = 1$, then rank-dependent utility reduces to expected utility. Substituting $w(p) = p$ and $w'(p) = 1$ in Equation (3) gives the, well-known, willingness to pay for an expected utility maximizer

$$\mathrm{WTP}_{\mathrm{EU}} = -\left.\frac{\mathrm{d}v}{\mathrm{d}p}\right|_{p=p_0} = \frac{U_g(y_0) - U_h(y_0)}{(1-p_0)U_g'(y_0) + p_0 U_h'(y_0)} \tag{4}$$

If we substitute death for the state less than perfect health in (3) and (4) we obtain the expressions for the value of a statistical life under RDU and EU, respectively.

A comparison between (3) and (4) shows the effect of probability weighting on willingness to pay. By assumption, $U_g' > U_h'$. The denominator in (3), therefore, exceeds the denominator in (4) if $w(1-p_0) > 1 - p_0$. That is, the denominator in (3) is larger than the denominator in (4) if the individual overweights the probability of being in good health or, alternatively put, when he is *optimistic at* p_0. Similarly, the denominator in (3) is smaller than the denominator in (4) when the individual is *pessimistic at* p_0, i.e. when he underweights the probability of being in good health.

The numerator in (3) is smaller than the numerator in (4) when $w'(p_0) < 1$, i.e. when the individual is relatively insensitive to changes in p_0 (where the benchmark is expected utility). The numerator in (3) exceeds the numerator in (4) when the individual is relatively sensitive to changes in p_0, i.e. when $w'(p_0) > 1$.

We, therefore, find that the introduction of probability weighting leads to an increase in the willingness to pay for reductions in health risks when the baseline risk of having a health problem p_0 is such that the individuals is pessimistic at p_0 and is relatively sensitive to changes in p_0. When the individual is optimistic at p_0 and relatively insensitive to changes in p_0, probability weighting decreases the willingness to pay for reductions in health risks.

Implications

Empirical studies show that the probability weighting function is inverse S-shaped, overweighting small probabilities and underweighting large probabilities [3,5,7,8]. This corresponds to a function that starts off concave and becomes convex for higher probabilities. The point $p \in (0,1)$ at which $w(p) = p$ typically lies between 0.30 and 0.40. People turn out to be especially sensitive to a change from something that is impossible to something that is possible, e.g. to a change from 0 to 0.05, and to a change from something that is possible to something that is certain, e.g. to a change from 0.95 to 1. They are less sensitive to changes from one possibility to another possibility, e.g. to a change from 0.55 to 0.60. That is, the slope of the probability weighting function, $w'(p)$, exceeds 1 near 0 and near 1 and is less than 1 for intermediate probabilities. These findings, in combination with what we derived in the previous section, therefore, suggest that probability weighting will lead to an increase in willingness to pay when the probability of having a health problem is low.

For example, if we use Prelec's [16] weighting function

$$w(p) = e^{-\gamma(-\ln p)^{\delta}} \tag{5}$$

the derivative of which is equal to

$$w'(p) = \frac{\gamma\delta(-\ln p)^{\delta-1}}{p} e^{-\gamma(-\ln p)^{\delta}} \tag{6}$$

and if we substitute the values for γ and δ obtained by Bleichrodt and Pinto [8], who elicited probability weighting in the health domain, then we have both $w'(p) > 1$ and $w(p) < p$ when p lies between 0.85 and 1. That is, if the baseline risk of having a health problem is less than 0.15 (15%) the introduction of probability weighting will lead to an increase in the willingness to pay for reductions in health risks.

In empirical studies the probability of illness or premature death is generally low, nearly always less than 0.01 (1%). Then the introduction of probability weighting can have a strong impact on willingness to pay, primarily because w' is high near 1. For example, if $p_0 = 0.005$ (0.5%) then the sensitivity to changes in probability is high, $w'(1 - p_0)$ is approximately 3.8 when we use Prelec's weighting function Equation (5) with the estimates of Bleichrodt and Pinto [8]. This estimate should be treated with caution because Bleichrodt and Pinto did not use probabilities as small as 0.005 to estimate γ and δ, but it illustrates the basic point that the impact of w' is likely to be strong near 1. Because $w(1) = 1$, the degree of pessimism is small when the probability of good health is close to one and underweighting of probabilities will, therefore, only exert a small upward pressure on willingness to pay.

The high values of $w'(1 - p_0)$ in empirical studies, which follow from the choice of low baseline risks, imply that obtained willingness to pay estimates can be unstable. For example, Equation (3) displays that small errors in the determination of the utility of income will have large effects on reported willingness to pay for low baseline risks, and ensuing high values of $w'(1 - p_0)$.

Another problem may arise if willingness to pay data are used to draw inferences about the shape of the utility function. Equations (3) and (4) show that falsely assuming expected utility implies that effects that are caused by probability weighting will be attributed to utility curvature, leading to unreliable estimates of the utility function.

Equation (4) implies that the higher the level of baseline risk, the higher the willingness to pay under expected utility [13]. This follows from the assumption that the marginal utility of income is higher in good health than in less than good health at each income level. Smith and Desvousges [17] found, however, that willingness to pay decreased with the level of the baseline risk. Their findings can be explained by probability weighting. For the low probabilities they considered, $w'(1 - p_0)$ decreases in p_0 and this effect is larger than the increase in the denominator caused by the increase in p_0. Hence, Equation (3) predicts that the willingness to pay for reductions in health risks will decrease with the level of the baseline probability consistent with the findings of Smith and Desvousges [17].

Conclusion

The elicitation of willingness to pay is a descriptive exercise and, hence, is susceptible to the biases induced by violations of expected utility. In this note we have analyzed how probability weighting, one of the main causes for violations of expected utility, affects willingness to pay for health improvements. We showed that the effect of probability weighting can be large and may lead to unstable estimates of willingness to pay for the probabilities generally used in empirical elicitations of willingness to pay. We also showed that probability weighting can account for earlier findings on willingness to pay that were inconsistent with expected utility.

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