WILLINGNESS TO PAY FOR MORTALITY RISK REDUCTIONS: DOES LATENCY MATTER?

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Abstract:

Using results from two contingent valuation surveys conducted in Canada and the U.S., we explore the effect of a latency period on willingness to pay (WTP) for reduced mortality risk using both structural and reduced form approaches. We find that delaying the time at which the risk reduction occurs by 10 to 30 years reduces WTP by more than half for respondents in both samples aged 40 to 60 years. Additionally, we estimate implicit discount rates equal to 8% for Canada and 4.5% for the U.S. – both well within the range established previously in the literature.

Keywords: Value of a Statistical Life, mortality risks, benefit-cost analysis

Subject Areas: (11) Health, (62) Valuation, (58) Discounting.

For many environmental policies, such as those that seek to reduce exposure to carcinogens, the reduction in the risk of dying occurs many years after the initial investment in pollution reduction. To value the benefits of such policies it is necessary to ask people how much they would be willing to pay now for a reduction in risk that takes place in the future. Economic theory suggests that willingness to pay (WTP) for a future risk reduction should be less than WTP for an immediate risk reduction of the same size. This occurs for two reasons: (1) the individual may not be alive to enjoy the risk reduction and (2) if the individual is willing to substitute consumption for risk, the risk reduction should be discounted at the consumption rate of discount. A key question for policy is exactly how much WTP is reduced by a gap between the initiation of a program and time at which the risk reduction is delivered.

In a recent contingent valuation survey administered in Canada (Krupnick et al., 2002) and the U.S. (Alberini et al., forthcoming), we asked individual respondents how much they would be willing to pay today for a reduction in their risk of dying at age 70. In this paper, we use the responses to such payment questions to produce estimates of mean and median willingness to pay for the future risk reduction. Specifically, we present three sets of results: (1) a reduced-form model of WTP for the future risk reduction that examines how WTP varies with respondent age, income, health status, expected health status in the future, and self-assessed probability of survival until age 70; (2) a structural model that estimates the discount rate implicit in WTP responses; and (3) a comparison of WTP for the future risk reduction with WTP for a risk reduction of the same size that occurs today.

In our reduced-form model we find that WTP today for a risk reduction at age 70 is, as prescribed by economic theory, lower for persons who have a lower self-assessed chance of surviving to age 70 and lower for persons who believe their health will be worse at age 75 than it is today. In our structural model, which assumes (as predicted by the life-cycle model) that WTP today for a risk reduction at age 70 equals what the individual would pay for a current risk reduction at age 70 discounted to the present, we estimate the average discount rate at 8% for our Canada sample and 4.5% for our U.S. sample. These estimates are in line with those in Viscusi and Moore (1989) (1-14%), Horowitz and Carson (1990) (4.5%), and Johannesson and Johansson (1996) (0.3 and 1.3%). Most importantly for policy, we find that WTP today for a risk reduction at age 70 is, for persons aged 40-60, less than half of WTP for a current risk reduction.

The remainder of this paper is organized as follows. Section 1 presents the life-cycle model with uncertain lifetime and reviews its implications for willingness to pay for a reduction in the conditional probability of dying at any age. It also elaborates on our plan of analysis. Section 2 discusses the administration and structure of our survey. Section 3 presents our econometric models, and section 4 our results. We summarize our findings in section 5.

1. Theoretical Framework and Plan of Analysis

1.1 The Value of Mortality Risk Changes in the Life-Cycle Model

To provide a framework for our empirical work, in this section we derive WTP for a change in the conditional probability of dying (at any age) in the context of the life-cycle model with uncertain lifetime (Cropper and Sussman, 1990; Cropper and Freeman,

1991). The model assumes that at age j the individual chooses his future consumption stream to maximize expected lifetime utility,

$$V_j = \sum_{t=j}^{T} q_{j,t}(1+\delta)^{j-t} U_t(C_t) \tag{1}$$

where V_j is the present value of expected utility of lifetime consumption, $U_t(C_t)$ is utility of consumption at age t, $q_{j,t}$ is the probability that the individual survives to age t, given that he is alive at age j, and δ is the subjective rate of time preference. We assume that (1) is maximized subject to a budget constraint that allows the individual to invest in annuities and to borrow via life-insured loans (Yaari, 1965). This is equivalent to assuming that the present value of expected consumption equals the present value of expected earnings plus initial wealth,

$$\sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} C_t = \sum_{t=j}^{T} q_{j,t}(1+r)^{j-t} y_t + W_j \,, \tag{2}$$

where r is the riskless rate of interest, y_t is income at time t and and W_j is initial wealth.

Consider now a program that alters D_k, the conditional probability of dying at age k, given that the individual survives to that age. Since $q_{j,t} = (1-D_j)(1-D_{j+1}) \ldots (1-D_{t-1})$, any program that alters D_k will necessarily alter the probability of surviving to all future ages. For small changes in D_k, willingness to pay may be written as the product of the rate at which the individual is willing to trade wealth W_j for a change in D_k, which we term $VSL_{j,k}$, times the size of the change in D_k,

$$WTP_{j,k} = -\frac{dV_j / dD_k}{dV_j / dW_j} dD_k \equiv VSL_{j,k} dD_k \,. \tag{3}$$

Applying the Envelope Theorem to the Lagrangian function formed by (1) and (2), the rate at which the individual substitutes current wealth for D_k may be written (Cropper and Sussman, 1990) as:

$$VSL_{j,k} = \frac{1}{1-D_k}\sum_{t=k+1}^{T} q_{j,t}\left[(1+\delta)^{j-t}U_t(C_t)\lambda_j^{-1} + (1+r)^{j-t}(y_t - C_t)\right]. \qquad (4)$$

Equation (4) says that the value of a change in the probability of dying at age *k* equals the loss in expected utility from age *k+1* onward, converted to dollars by dividing by the marginal utility of income (λ_j). Added to this is the effect of a change in D_k on the budget constraint. Cropper and Sussman (1990) show that, by substituting first-order conditions for utility maximization into (4) and rearranging terms, WTP at age *j* for a risk reduction at age *k* equals WTP for a current risk reduction at age *k* multiplied by the probability of surviving to age *k* and discounted to the present at the monetary rate of discount,

$$WTP_{j,k} = q_{j,k}(1+r)^{j-k}WTP_{k,k}.^{1} \qquad (5)$$

1.2 Plan of the Analysis

Our empirical work focuses on equation (5), and its goal is three-fold. First, as a test of internal validity of responses, we estimate a reduced-form version of (5) for persons for whom $40 \leq j \leq 60$ and $k = 70$. Equation (5) suggests that $WTP_{j,70}$ should be lower the lower is the probability of surviving to age 70 ($q_{j,70}$) and should increase with current age (*j*), holding $q_{j,70}$ constant. $WTP_{70,70}$ should be higher for wealthier respondents and may depend on the respondent's estimate of his health after age 70. The impact of other variables (e.g., education) on $WTP_{j,70}$ is, however, ambiguous.

Second, we then use equation (5) to estimate respondent discount rates (r). Because our survey elicits WTP for a current risk reduction (for persons of different ages) we can use models described elsewhere (Alberini et al. 2003) to estimate $WTP_{70,70}$ for each respondent. Given the respondent's estimate of $q_{j,70}$, we estimate a log-linear version of (5), where $(1+r)^{j-70}$ has been approximated by $\exp[r(j-70)]$ to obtain an estimate of the interest rate facing respondents:

$$\ln WTP_{j,70} = \ln WTP_{70,70} + \ln q_{j,70} + r \cdot (j - 70). \qquad (6)$$

On appending an error term equation (6) becomes a regression model where the discount rate can be estimated as the coefficient on (j – 70), the time until the risk reduction takes place, as long as the latter varies across respondents.

Finally, we use the responses to WTP questions for current and future risk reductions to estimate $WTP_{j,k}/WTP_{j,j}$—i.e., to see by how much WTP is reduced when the risk valued occurs in the future. Equation (5) does not necessarily imply that $WTP_{j,j} > WTP_{j,k}$; however, if $WTP_{j,j} \geq WTP_{k,k}$—if WTP for a given risk reduction is no larger at age 70 than between ages 40 and 60—equation (5) indeed implies that $WTP_{j,j} > WTP_{j,k}$. The question of interest for policy is exactly what the ratio of $WTP_{j,k}/WTP_{j,j}$ is.

2. Survey Administration and Structure

Our survey instrument was administered in Canada in 1999 and in the U.S. in 2000.[2] In the Canada study, the questionnaire was self-administered by respondents using a computer at a centralized facility in Hamilton, Ontario. Study participants were recruited through random digit dialing. In the U.S., we drew a national sample from the

panel of consumers maintained by Knowledge Networks. The sample received and filled out the questionnaire via Web-TV.

The questionnaire began by asking the respondent to provide information about his or her self, including age, gender, health status. It also queried the respondent about the health status of family members (parents and siblings), and about the age of his or her parents. This was followed by a simple tutorial on probability, at the end of which respondents were introduced to the concept of risk of dying. To show risk and risk changes, we used a grid of 1,000 squares. White squares represent survival, while red squares represent death.

Respondents were subsequently told about their own risk of dying over the next 10 years (and shown this risk on the grid of squares), along with the most common causes of death for a person of their age and gender. When eliciting WTP for a risk reduction, it is important that respondents understand that it is possible to reduce risk through a number of actions (both medical and non-medical), but that doing so costs money. We described to the respondents common risk-reducing actions (such as exercise and medical screening or diagnostic tests), but, to avoid anchoring respondents to specific dollar figures, we simply told them whether these actions were "expensive," "inexpensive," or "moderately priced."

Respondents were asked to report information about their WTP for each of three risk reductions: (i) 5 in 1000 over the next 10 years, (ii) 1 in 1000 over the next 10 years, and (iii) 5 in 1000, but beginning at age 70 and taking place over the subsequent 10 years.[3] The latter question was asked only of respondent aged 60 and younger. We used the dichotomous choice approach ("Would you purchase a product that would deliver the

risk reduction in question at a stated price?) with a follow-up question. (See table A.1 in the Appendix for the exact bid values.)

Respondents were also asked to report their subjectively assessed life expectancy and probability of surviving until age 70. The survey ended with socio-demographic questions, debriefing questions, and questions from Short Form 36 (SF-36), a questionnaire widely used to assess health status and functionality in the medical literature.[4]

A total of 930 and 1135 respondents completed the survey in Canada and in the US, respectively. The WTP questions about the future risk reductions were answered by 650 persons in Canada and 699 in the US.[5] We exclude from the usable samples respondents who failed simple probability questions, which results in 638 respondents for the Canada study, and all 699 for the US study.[6]

3. Econometric Model

As indicated in section 1 we use two approaches to estimate $WTP_{j,70}$. The first is a reduced-form approach, where $WTP_{j,70}$ is assumed to follow the Weibull distribution with scale parameter $\sigma_i = \exp(\mathbf{x}_i\beta)$ and shape parameter θ (i.e, an accelerated life model). This is equivalent to the regression equation:

$$\log WTP^i_{j,70} = \mathbf{x}_i\beta + \varepsilon_i, \tag{7}$$

where *i* denotes the respondent, the error term follows the type I extreme value distribution with scale θ, and the vector of regressors **x** includes variables thought to influence WTP. Since information about willingness to pay was elicited using dichotomous choice questions with a follow-up, we form intervals around the

respondent's (unobserved) WTP amount, specify a double-bounded interval-data likelihood function, and estimate the parameters of equation (7) using the method of maximum likelihood.

To test internal validity in a reduced-form context, $\mathbf{x}_i$ includes age, gender, current and future health status of the respondent, education and income and the respondent's estimate of $q_{j,70}$. From equation (5) we expect the coefficients on $q_{j,70}$ and on age to be positive. To the extent that current income is correlated with wealth, it should increase $WTP_{j,70}$ and so, presumably, should a more optimistic estimate of the respondent's health state at age 75 (midway between the beginning (70) and ending age (80) of the risk change being valued).[7]

Our second estimation approach is a structural-form approach. To implement it, we begin with an interval-data maximum likelihood regression for WTP for the immediate 5 in 1000 risk reduction on income, gender, age group dummies, etc. based on the underlying equation:

$$\log WTP_{j,j}^{i} = \mathbf{x}_i \gamma + \eta_i \tag{8}$$

where η is a Type I Extreme value error term with scale τ. We use the maximum likelihood estimates $\hat{\gamma}$ and $\hat{\tau}$ to predict what each respondent's median WTP would be, if his or her age were 70. We denote this prediction as $PWTP_{70,70}$, and its logarithmic transformation as $\log PWTP_{70,70}$.

In the next step, we regress $\log WTP_{j,70}$ on *(j–70)* (*j* being current age), $\log PWTP_{70,70}$ and $\log q_{j,70}$, where $\log q_{j,70}$ is the respondent-reported probability of surviving until age 70. Following equation (6), we restrict the coefficients on

$\log PWTP_{70,70}$ and $\log q_{j,70}$ to be equal to one. The coefficient on (j–70) is the interest rate, r.

Clearly, this approach assumes that the interest rate r is constant over time and across individuals. In subsequent runs, we relax this assumption by allowing individuals with different characteristics to have different discount rates. Specifically, we posit that $r_i = \exp(\mathbf{z}_i \lambda)$, where $\mathbf{z}_i$ is a 1×k vector of individual characteristics. Data limitations do not allow us to discriminate between a linear discount rate or a hyperbolic one, but we do check whether the discount rate is affected by the time until the discounting takes place by including a dummy variable that takes on a value of one for respondents in the age group from 50 to 60 years.

4. Results

4.1. Reduced Form

Results from the reduced-form model with covariates are reported in Table 1. Column (A) refers to the data from the Canada study, column (B) to the WTP responses from the U.S. study, as does (C), except that it omits African Americans for ease of comparison with the Canada sample, which does not include this group.

[Insert Table 1]

Three main findings emerge from the reduced-form regressions of Table 1. First, individual characteristics like age, race, education and income are not important predictors of a person's WTP for the future risk reduction. (The only exception is gender in specification (C).) The only significant determinants of WTP are current health status, future health status and the subjective probability of surviving until age 70. As a

consequence of the relatively large number of regression coefficients that are individually insignificant, likelihood ratio tests of the null hypothesis that all slopes are zero fail to reject the null for model (A) and marginally reject it at the 5% level for models (B) and (C).[8]

Second, the signs of two coefficients are consistent with expectations. Specifically, the coefficient on the low-income dummy (bottom 25% of the income distribution), which takes on a value of one if income is less than $24,500, is negative, although insignificant, and the sign on the log of the probability of living until age 70 is positive (and significant at the 5% level in the U.S. study).

Moreover, respondents who expect that their health will become worse when they are older are willing to pay less: their WTP is about one-third lower than that of all other individuals in Canada, and about 27% lower for U.S. respondents. This seems reasonable, and in sharp contrast with the fact that the coefficient on CHRONIC, a dummy taking on a value if the respondent has a chronic respiratory or cardiovascular disease, or cancer, is *positive* (and significant, at least in the U.S. study). The presence of one such chronic illness raises WTP by 28 to 33%.

Third, many coefficients are very similar across the two studies. Indeed, a Wald test comparing columns (A) and (C) does not reject the null that the coefficients are the same across the two studies.

These similarities and the result of the Wald test prompted us to pool the data from the two studies, and estimate the following regression:

$$log\ WTP_i = \mathbf{x}_i \beta + CANADA_i \cdot \lambda + \varepsilon_i \ , \qquad (9)$$

where CANADA is a dummy denoting the study. The scale of the error term ε is allowed to vary across the two countries: $\theta_i = \theta_0 + CANADA_i \cdot \theta_1$.

Results from this specification are reported in Table 2. They confirm that many individual characteristics, such as income, education, and age, are not important determinants of WTP, although the low-income dummy has the expected negative association with WTP. The coefficient on gender is now significant at the 5% level, implying that males hold lower WTP values: all else the same, men's WTP figures are 10% lower than those of women.

[Insert Table 2]

Table 2 also confirms that WTP for the future risk reduction is significantly lower if (all else the same) the respondent believes that in the future his health will deteriorate relative to the present. Specifically, respondents who believe their health at age 75 will be worse than it is now hold WTP values that are 18% less than the values of all other respondents. WTP is over 50% greater if the respondent currently has a chronic illness. As before, the WTP for the future risk reduction increases with the (logarithmic transformation of) the subjective probability of surviving to age 70, but this effect is weak.

4.2. Structural Form

We estimate the structural form using only respondents in wave 1.[9] Assuming that the discount rate is constant for all respondents and all ages, we estimate the discount rate to be 8% in the Canada study and 4.5% in the U.S. study. The discount rates are estimated very precisely: the standard errors around the estimates are 0.7% and 0.55%, respectively.

Results from the structural-form model with covariates are displayed in Table 3. Since the sample size is smaller when attention is restricted to wave 1 respondents, we pool the data from the two studies, but exclude U.S. African Americans. Coefficients are often large, and so are the standard errors, implying that results should be interpreted with caution. For example, the coefficient on the chronic illness dummy is equal to -0.59, and significant at the 10% level, implying that persons with these illnesses have discount rates that are 45% lower than those of respondents without chronic illnesses. At the same time, the discount rate of low-income respondents is 43% greater than that of the other respondents, but this effect is not statistically significant. Older respondents have higher discount rates: those in the age group between 50 and 59 have a discount rate that is 51% greater than that of younger respondents, the p-value of the coefficient being about 0.09.

[Insert Table 3]

We attempted to estimate a function where the discount rate is a linear function of age (and hence of the time until the discounting takes place, which is 70 minus current age), but this model behaved poorly, as did the model with hyperbolic discounting. These results are probably due to the insufficient variation in the time until the risk reduction occurs. We also attempted to control for the country of the study, but the model behaved very poorly when the Canada dummy was included. Models that included chronic illness variables in a more disaggregate form experienced the same problem. This suggests that the regression results for the structural form with covariates are not very robust, and should be interpreted with caution.

We end by comparing mean and median WTP for a future risk reduction, estimated using all respondents but with no covariates, with mean and median WTP for a

current reduction, estimated using the same respondents. These results appear in Table 4. We have previously argued that it is likely that WTP for a future risk reduction should be less than WTP for a risk reduction that starts immediately. This is borne out by the data. The ratio of mean $WTP_{j,k}$ to mean $WTP_{j,j}$ for $40 \leq j \leq 60$ and $k = 70$ is 0.44 in the Canadian sample and 0.48 in the U.S. sample. This suggests that a latency period of 10 to 30 years, experienced late in life, significantly reduces WTP for a reduction in risk of dying.

[Insert Table 4]

Table 4 also translates the WTP estimates into VSL estimates by dividing the WTP by 5/10,000. Mean VSLs derived from WTP estimates for the future risk reductions for this 40-60 age group range from $533,000 for Canada to $700,000 for the U.S. As is generally the case with estimates from CV surveys, the median VSLs are lower still.

5. Conclusions

This paper reports the results of a contingent valuation survey that elicits WTP for current and future mortality risk reductions. The survey questionnaire was self-administered by respondents in Canada and the US using a computerized format.

We examine the responses to the payment questions for the future risk reduction using both reduced form and structural form approaches. Using a reduced-form approach, we find that WTP for a risk reduction at age 70 relates to the respondent's expectations about his or her future health status.

Using a structural-form approach, we estimate the implicit discount rates to be 8% in Canada and 4.5% in the U.S. The discount rate appears to depend on age and health status, but inference should be made with caution. Our estimates of the discount rate are in line with previous estimates of the discount rate in risk reduction tradeoffs, which range from 0.3% (Johannesson and Johansson, 1996) to 14% (Viscusi and Moore, 1989).

Finally, we note that for respondents aged 40 to 60, WTP today for a risk reduction occurring at age 70 is less than half of WTP for a current risk reduction of the same size. Delaying the time at which the risk reduction occurs significantly reduces WTP, at least for respondents in the 40 to 60 age group.

What are the policy implications of this finding? In its primary analysis of the benefits of reducing the maximum contaminant level (MCL) of arsenic in drinking water from 50 ppb to 10 ppb, the USEPA (2000) did not discount the value of a statistical life used to value the reduction in lung and bladder cancers that were predicted to occur as a result of the rule, even though there is likely to be a cessation lag between the reduction in exposure and the reduction in cancers.[10] The study estimated that there would be between 21 and 30 fewer cancers per year from the reduction in exposure, starting immediately, and used a VSL of $6.1 million (1999 USD) to value each case. The resulting mortality benefits ($128-$183 million) accounted for over 90% of the monetized benefits of the rule. Total annual costs were estimated to be $205.6 million, implying that the upper bound estimate of benefits was approximately equal to costs. Adjusting the $6.1 million VSL to reflect an average gap of 20 years between reduction in exposure and reduction in cancer would, according to the results reported above, cause the benefit-cost ratio to fall below one-half. Using the VSLs estimated in our study for

this valuation exercise would have even more dramatic effects in lowering benefits, as our VSL for the U.S. is almost a factor of 10 lower than that used by EPA.

The decision to reduce the MCL for arsenic is, of course, more complicated than the previous paragraph would suggest.[11] Our purpose in citing this example is to show that allowing for a gap between reduction in exposure and reduction in risk can indeed make a difference in a policy context.

Table 1. Interval-data reduced-form regressions. Weibull distribution of WTP.
(Standard errors in parentheses.)

Variable	(A) Canada (n=632)	(B) US (n=668)	(C) US, no Blacks (n=600)
Intercept	4.7777**	5.3234**	5.1902**
	(0.933)	(0.539)	(0.591)
Wave 1	-0.2206	-0.1253	-0.1166
	(0.203)	(0.129)	(0.137)
Age 50 to 59	0.1067	0.0089	0.0129
	(0.199)	(0.134)	(0.143)
Male	-0.1038	-0.1378^	-0.2103
	(0.194)	(0.129)	(0.138)
Black		0.3715	
		(0.225)	
Education	-0.0030	-0.0175	-0.0203
	(0.041)	(0.0283)	(0.0296)
Bottom 25% of distribution of income (dummy)	-0.2726	-0.1789	-0.1327
	(0.245)	(0.157)	(0.164)
Health75worse	-0.4382**	-0.3013*	-0.3028*
	(0.199)	(0.132)	(0.140)
Log CHANCE70	0.0927	0.1735*	0.2243*
	(0.160)	(0.086)	(0.098)
Chronic	0.2929	0.2542*	0.2588^
	(0.210)	(0.135)	(0.143)
Scale parameter	0.4752**	0.7262**	0.7207**
	(0.029)	(0.041)	(0.043)

* = significant at the 5% level. ** = significant at the 1% level.

Table 2. Interval-data reduced form regressions.
Pooled samples, Weibull distribution of WTP with country-specific shape parameter (African Americans excluded from the sample).

Variable	Coefficient	Standard error
Constant	4.0165	0.560
Wave 1	-0.1375	0.116
Age 50 to 59	0.0845	0.111
Male	-0.2302*	0.114
Education	-0.0058	0.024
Bottom 25% of the distribution of income	-0.1160	0.138
Health75worse	-0.1944^	0.114
Log chance70	0.1541	0.095
Chronic illness	0.4173**	0.116
Canada	-0.8922**	0.137
Weibull shape: θ_0	1.1488**	0.066
Weibull shape: θ_1	0.1968*	0.085

^ = significant at the 10% level. * = significant at the 5% level; ** = significant at the 1% level.

Table 3. Structural Form results. $r=\exp(\mathbf{z}_i\gamma)$

	Coefficient	Standard error
Constant	-2.7212**	0.184
Male	-0.1677	0.227
Chronic	-0.5897^	0.307
Bottom 25% distribution of income	0.3570	0.264
Age 50 to 59 years	0.4131^	0.245
θ	2.7630**	0.134

^ = significant at the 10% level. * = significant at the 5% level; ** = significant at the 1% level.

Table 4. Mean and Median WTP and VSLs for present v. future risk reductions.
Weibull interval-data model with no covariates.
All Figures in 2000 US dollars (PPP conversion from the Canadian dollar). Cleaned samples, 40-60 year-olds.

	Canada		US	
	Current risk reduction*	Future risk reduction	Current risk reduction*	Future risk reduction
Mean WTP (standard error)	609 (59.02)	265 (32.85)	727 (53.12)	348 (25.29)
Mean VSL ($million)	1.22	0.53	1.45	0.70
Median WTP (standard error)	317 (26.71)	55 (7.73)	395 (27.69)	167 (13.86)
Median VSL ($million)	0.63	0.11	0.79	0.33

* wave 1 only. N= 438 for Canada, N = 361 for the US.

Appendix.

Table A.1. Bid design by country.

	Initial bid	If yes	If no
US (2000 US dollars)	70	150	30
	150	500	70
	500	725	150
	725	1000	500
Canada (1999 Canadian dollars)	100	225	50
	225	750	100
	750	1100	225
	1100	1500	750

Notes:

[1] Equation (5) of course holds for $VSL_{j,k}$ and $VSL_{k,k}$ as well.

[2] The survey instruments we used in our Canada and U.S. studies were almost identical, except for currency and baseline risk adjustments, and the fact that U.S. respondents were asked more detailed questions about their own health status, and the health status and ages of family members. For more information, see Alberini et al. (forthcoming).

[3] People were randomly assigned to one of two subsamples, "wave 1" and "wave 2." The two subsamples received identical questionnaires, except for the order in which the risk reductions to be valued were presented to the respondents. In wave 2, the order of (i) and (ii) was reversed, but the future risk reduction was the third commodity to be valued in both subsamples.

[4] The SF-36 questions were given to respondents in a pencil-and-paper questionnaire in the Canada study, but were included in the web-TV questionnaire in the US study. The SF-36 questions were asked at the end of both surveys.

[5] We remind the reader that the questions about WTP for the future risk reduction were asked of individuals up to 60 years of age.

[6] Following the probability tutorial, respondents were asked to identify which of two grids represented the individual with the higher risk and which of the two they personally would rather be. Individuals who answered these questions incorrectly were deleted from the sample used in this paper.

[7] As a special case, we also consider a simple version of the model that includes only the intercept in the right-hand side of equation (7). We use this model without covariates to estimate mean and median WTP, which we discuss in section V.B. Mean WTP is $\sigma \cdot \Gamma(1/\theta + 1)$, where $\Gamma(\bullet)$ is the gamma function, and median WTP is $\sigma \cdot [-\ln(0.5)]^{1/\theta}$.

[8] The likelihood ratio test of the null hypothesis that all slope coefficients are zero are 10.38 for model (A), 20.02 for specification (B), and 18.46 for specification (C).

[9] We choose to do so because our procedure relies on predicting willingness to pay for a 5 in 1000 risk reduction at age 70 for respondents who are currently between 40 and 60 years old. But willingness to pay for an immediate risk reduction is sensitive to the order in which the risk reductions were valued by the respondents in the survey. To be conservative, when we estimate models of willingness to pay for the 5 in 1000 risk change, we restrict attention to the responses from those respondents who valued the 5 in 1000 risk reduction first.

[10] In evaluating the health benefits of a reduction in exposure to a carcinogen, the *cessation-lag* matters, i.e., the time between cessation of exposure and the reduction in risk.

[11] The USEPA Science Advisory Board (USEPA, 2001) criticized the benefits analysis for assuming a zero cessation lag, but also noted that no attempt was made to quantify other health benefits, in spite of a rich epidemiological literature.