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Abstract

Much of the justification for environmental rulemaking rests on estimates of the benefits to society of reduced mortality rates. Yet the literature providing estimates of the willingness to pay (WTP) for mortality risk reductions measures the value that healthy, prime-aged adults place on reducing their risk of dying, whereas the majority of statistical lives saved by environmental programs, according to epidemiological studies, appear to be the lives of older people and people with chronically impaired health.

This paper provides an empirical assessment of the effects of age and baseline health on WTP for mortality risk reductions by reporting the results of two contingent valuation surveys designed to test the above hypotheses. One survey was administered in-person to residents of Hamilton, Ontario, and the other to a nationally representative sample of U.S. residents using the Internet. Both surveys elicited respondents' WTP for reductions in mortality risk of different magnitudes. Respondents were limited to persons aged 40 years and older, including those older than 60, to examine the impact of age on WTP. Extensive information was collected about each respondent's health status to see whether it systematically influenced WTP.

Our results provide weak support for the notion that WTP declines with age, but only after age 70. Specifically, in our Canadian sample, WTP declines by about 30% after age 70 compared with WTP at younger ages. There is no such statistically significant decline, however, in the U.S. sample. We similarly find no support for the idea that people who have cancer or chronic heart or lung disease are willing to pay less to reduce their risk of dying than people without these illnesses. If anything, people with these illnesses are willing to pay more.

Key Words: willingness to pay, mortality, contingent valuation, age, health status

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Contents

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I. Introduction

Much of the justification for environmental rulemaking rests on estimates of the benefits to society of reduced mortality rates. Reductions in risk of death are arguably the most important benefit underlying drinking water regulations, as well as regulations that govern air pollution and the disposal of hazardous waste. In two recent analyses of the benefits of the U.S. Clean Air Act (U.S. EPA 1997; U.S. EPA 1999), more than 80% of monetized benefits were attributed to reductions in premature mortality. Similarly, a high proportion of the monetized benefits of Canadian air quality regulations are attributable to reductions in premature mortality (Canada-Wide Standards Development Committee for PM and Ozone 1999).

In studies conducted in the United States and Canada, estimates of individuals' willingness to pay (WTP) for mortality risk reductions and the implied value of a statistical life (VSL) come from revealed preference studies, primarily studies of compensating wage differentials in the labor market, as well as stated preference (contingent valuation) studies.[1] The use of figures from these studies to value the lives saved by environmental programs is, however, problematic. Both types of studies have focused on measuring the value that healthy, prime-aged adults place on reducing their risk of dying, whereas the majority of statistical lives saved by environmental programs, according to epidemiological studies, appear to be the lives of older

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[1] The Environmental Protection Agency's official VSL is based on 26 studies, of which 21 are hedonic labor market studies and five are stated preference studies (U.S. EPA 1997, 1999).

people and people with chronically impaired health (Pope et al. 1995; Schwartz 1991; Schwartz 1993).

There are two reasons why older persons are likely to benefit disproportionately from reductions in pollution. First, epidemiological studies typically assume that the effects of a change in exposure are proportional to baseline mortality (Pope et al. 1995; Morales et al. 2000). Since persons over 65 account for three-quarters of all deaths in the United States and Canada, a larger proportion of statistical lives will be saved among the old than among the young. Second, some epidemiological studies have found larger changes in mortality rates for people over 64 than for younger people (Schwartz 1991, 1993). Epidemiological studies also suggest that persons with chronic heart or lung conditions are likely to benefit disproportionately from improvements in air quality (Schwartz 1991; Schwartz and Dockery 1992; Pope et al. 1995).

It has been conjectured that older people should be willing to pay less for a reduction in their risk of dying than younger people on the grounds that they have fewer expected life years remaining. Indeed, some economists have argued that the VSL should be converted to a value per statistical life year (VSLY), and that lives saved should be valued by multiplying remaining life expectancy by the VSLY (Moore and Viscusi 1988). This procedure assumes, implicitly, that each year of life is equally valuable, and that the VSL is strictly proportional to remaining life expectancy. Whether this approach is consistent with welfare economics, however, depends on how, empirically, WTP for a reduction in risk of death varies with age.

It has also been argued that people in ill health should be willing to pay less for a reduction in their risk of dying because their utility from an additional year of life is lower than that of healthy people. In the literature on quality-adjusted life years (QALYs), saving the life of a person with chronic bronchitis is less valuable than saving the life of a person in good health (Gold et al. 1996). This has been used as an argument for assigning a lower VSL to beneficiaries of air pollution control programs than the value the Environmental Protection Agency (EPA) currently uses (EOP Group, Inc. 1997). There is no empirical evidence, however, showing that people with chronic heart and lung disease would pay less than healthier individuals to reduce their risk of dying.

This paper provides an empirical assessment of the effects of age and baseline health on WTP for mortality risk reductions by reporting the results of two contingent valuation surveys designed to test the above hypotheses. One survey was administered to residents of Hamilton, Ontario, and the other to a nationally representative sample of U.S. residents. Both surveys elicited respondents' WTP for reductions in mortality risk of different magnitudes. Respondents were limited to persons aged 40 years and older, including those older than 60, to examine the impact of age on WTP. Extensive information was collected about each respondent's health status to see whether it systematically influenced WTP.

Our results provide weak support for the notion that WTP declines with age, but only after age 70. Specifically, in our Canadian sample, WTP declines by about 30% after age 70 compared with WTP at younger ages. There is no such statistically significant decline, however, in the U.S. sample. We similarly find no support for the idea that people who have cancer or chronic heart or lung disease are willing to pay less to reduce their risk of dying than people without these illnesses. If anything, people with these illnesses are willing to pay more.

The remainder of this paper is organized as follows. Section II discusses how age and health status might influence WTP in the context of a life-cycle model of WTP for reductions in mortality risk. The survey instrument and its administration are discussed in section III. Section IV describes the characteristics of our samples and summarizes their responses to the questionnaire. Section V presents econometric models of WTP, and section VI concludes.

II. How Should Age and Health Status Affect WTP for Mortality Risks?

In this section we discuss how age and health status should influence WTP for a change in mortality risk, in the context of the life-cycle consumption model with uncertain lifetime (Yaari 1965). Several authors (Shepard and Zeckhauser 1982; Cropper and Sussman 1990) have used this model to derive an expression for an individual's WTP for a reduction in his risk of death. We summarize these results here and discuss their implications for the effects of age and health status on WTP.

In the life-cycle model, a person at the beginning of period j receives expected utility of V_j over the remainder of his lifetime.

$$(1)\ V_j = \sum_{t=j}^{T} q_{j,t}(1+\rho)^{j-t} u_t(C_t)$$

V_j is the present value of utility of consumption in each period, $u_t(C_t)$, times the probability that the individual survives to that period, $q_{j,t}$, discounted to the present at the subjective rate of time preference, ρ. V_j is maximized subject to initial wealth, W_j, and a budget constraint that reflects opportunities for borrowing and lending. The two cases usually considered are the case of actuarially fair annuities and the more realistic situation in which the individual can borrow and lend at the riskless rate r, but can never be a net borrower,

$$(2) \quad W_j + \sum_{t=j}^{T} (1+r)^{j-t} (M_t - C_t) \geq 0$$

The life-cycle model can be used to determine the amount of initial wealth that an individual would give up to reduce D_j, the probability that he dies during the current period. A reduction in D_j will increase the probability that the person survives to all future periods since, by definition, $q_{j,t}$ is the product of the probabilities that the individual does not die in all periods from j to t-1,

$$(3) q_{j,t} = (1-D_j)(1-D_{j+1}) \cdot \cdot \cdot \cdot (1-D_{t-1}).$$

The rate of substitution between D_j and W_j corresponds to the value of a statistical life for a person of age j, VSL_j,

$$(4) VSL_j = (\partial V_j/\partial D_j)/(\partial V_j/\partial W_j) = dW_j/dD_j .$$

The amount an individual is willing to pay for the change in D_j is, in turn, the product of the VSL_j and the size of the risk reduction,

$$(5) \qquad \mathrm{WTP_j} = (\mathrm{VSL_j})\mathrm{dD_j} .$$

If actuarially fair annuities are not available but the individual can borrow and lend at the rate r, VSL_j may be written as the product of the reciprocal of the probability that the individual survives the current period, $(1-D_j)^{-1}$, times the present value of expected utility of consumption from period j+1 onward, converted to dollars by dividing by the marginal utility of consumption, $\partial u_j/\partial C_j.$

$$(6) VSL_j = (1-D_j)^{-1} \sum_{t=j+1}^{T} q_{j,t} (1+r)^{j-t} \frac{u_t(C_t)}{\partial u_j / \partial C_j}$$

How should the VSL change with age j? The first term in (6), $(1-D_j)^{-1}$, unambiguously increases with age: As people age, their probability of surviving the current period falls, and for this reason, their WTP to reduce their risk of death should increase. How the present value of expected utility of consumption—the remainder of the equation—changes with age is ambiguous. If utility of consumption $u_t(C_t)$ were constant over time, then the present value of expected utility of consumption would be proportional to discounted remaining life expectancy, $\sum_{t=j+1}^{T} q_{j,t} (1+r)^{j-t}$. The latter unambiguously decreases with age (j) and motivates the hypothesis that WTP for mortality risk reductions should fall with age. In general, however, $u_t(C_t)$ is not constant, and the impact of age on WTP is therefore ambiguous.

If health status at age j, H_j, is treated as exogenous, it can easily be incorporated in equation (6).[2] If lower values of H_j signify poorer health, then the first term on the right-hand side of (6) will be higher the lower is H_j. Persons in poorer health presumably have smaller chances of surviving the current period and, for that reason, should be willing to pay more to reduce D_j. The impact of current health on the rest of the equation is, however, ambiguous. Even if discounted remaining life expectancy is lower for people with lower current health status, one can say little about their time pattern of consumption, or about the way in which health affects the marginal utility of consumption.

The implications of this section are that little can, in general, be said about the impact of current age (j) or current health status (H_j) on the value of mortality risk reductions. Older people and people in poorer health should have higher WTPs because their chance of surviving the current period is lower than that of younger, healthier individuals. Even though discounted remaining life expectancy should fall with age and current health status, it is discounted expected utility of consumption that matters in determining WTP, and the impact of age and health status on this term is ambiguous. The expression for the VSL and for WTP also suggests that it would be difficult empirically to estimate anything but a reduced-form relationship among WTP, age, and health status.

III. The Surveys

A. The Commodity Valued

The goal of our surveys is to estimate individuals' WTP for a reduction in their conditional probability of dying during the current period (D_j). Periods are treated as 10 years long.[3] After being told the baseline risk of death over the next 10 years for someone of their race and gender, individuals are asked whether they would purchase a product (not covered by health

[2] If health status were endogenous, one would have to examine the impact of a change in D_j on expenditures on health.

[3] In focus groups, individuals more readily accepted information about their risk of dying and changes in their risk of dying over a 10-year period than over shorter periods.

insurance) that would reduce this risk by either 1 in 1,000 (1 in 10,000 annually) or 5 in 1,000 (5 in 10,000 annually), at a stated price.[4] Payment for the commodity is to be made annually, over 10 years.

Both the baseline risk of death and the risk reductions are communicated graphically. Baseline risk of death over the next 10 years is represented by coloring in red the appropriate number of squares on a white grid containing 1,000 squares. Reductions in risk of death are shown by turning the appropriate number of red squares to blue.

B. The Structure of the Survey

Our survey begins with a series of questions about the respondent's health history and the health history of his family. This is followed by exercises that acquaint the respondent with the concept of risk and test his risk comprehension. Subjects are introduced to simple probability concepts using coin tosses and roulette wheels, working up to our standard risk communication device—a 1,000-square grid in which risks are represented using red squares. To test their comprehension, respondents are asked to compare grids for two hypothetical people (person A and person B) and to determine which of the two has the higher risk of death. They are also asked to select which person they would rather be. The baseline risk of death for a person of the respondent's age and gender is then presented both numerically and graphically.

It is sometimes argued that respondents in contingent valuation surveys find it difficult to report their WTP for a mortality risk reduction because they are not accustomed to trading income for reduced risks. To mitigate this problem, we first acquaint respondents with *quantitative* risk reductions resulting from medical tests and products that are likely to be familiar to the respondent (e.g., mammograms, colon cancer screening tests, medicine to reduce blood pressure). In doing so, we provide only qualitative cost information for each action or product ("inexpensive," "moderate," and "expensive").

This is followed by the WTP questions. Information about WTP is obtained through a combination of dichotomous choice payment questions with followups, and open-ended questions. Figure 1 shows the structure of each WTP question. Respondents are asked an initial

[4] We chose a risk reduction of this order of magnitude because risk changes valued in labor market studies are typically of this size, and risk reductions of comparable size are often delivered by environmental programs (e.g., air pollution control).

dichotomous choice question: would they pay for the product at a price randomly chosen from one of four predetermined values? (See Table 1 for bid values.) Those respondents who answered yes were asked whether they would pay a higher price, and those who answered no were asked whether they would pay a lower price. A final, open-ended question was asked of those respondents who gave "yes-yes" or "no-no" responses.

Each respondent was asked his WTP for two risk reductions. Respondents in Wave 1 of each survey were asked to value the 5-in-1,000 risk reduction first, whereas respondents in Wave 2 were asked to value the 1-in-1,000 risk reduction first. After each question, respondents were asked to indicate their degree of certainty about the WTP responses on a scale from 1 to 7. Because WTP can be affected by the respondent's understanding of risks and interpretation of the scenario, we included debriefing questions at the end of the questionnaire to identify respondents who had trouble comprehending the survey or who did not accept the risk reduction being valued. The survey ends with questions about the respondent's income, followed by Short Form 36 (SF-36), a questionnaire commonly used in medical research to measure mental and physical health status (Ware et al. 1997).

C. Administration of the Questionnaire

The Canadian survey was self-administered using a computer by a sample of 930 residents of Hamilton, Ontario. Subjects were recruited by telephone through random-digit dialing and asked to take the survey at a facility in downtown Hamilton.[5] The survey took place over five months in spring 1999.

The respondents in the U.S. survey were reached through a technology called Web-TV©, which involves attaching a special device (resembling a cable box) to a television. A remote control device or a keyboard enables the user to access the Internet, using the TV as a monitor. Knowledge Networks® recruited individuals to participate as panel members in exchange for the technology and free Internet access. The panel members were recruited by telephone using

[5] Because of the need to travel to a centralized facility, response rates were low. Of 17,841 residential phone contacts, 8,260 were "cooperative," but 4,917 households proved ineligible for age reasons. Among the 3,591 eligible households, 455 declined to participate because of mobility problems and 1,079 refused, stating that the incentive payment (C$35) was insufficient. 1,545 persons agreed to participate in the survey, but in fact only 930 (60%) kept their appointments. All persons who began the survey completed it. The response rate, calculated as the number of respondents successfully completing the study (930) divided by the number of eligible contacts (3,591), was thus 26%.

random-digit dialing and were representative of the U.S. population in gender, age, race, and income. Panel members were randomly selected to complete surveys.[6] Knowledge Networks® administered our survey to a selected sample of U.S. adults fitting our age profile in August 2000. 1,800 persons were contacted to take the survey, and within two days 1,200 of them (our target sample) had completed the survey.

IV. Sample Characteristics and Responses

A. Characteristics of the Respondents

The respondents in our Canadian and U.S. surveys were somewhat different, since they were sampled from different populations. In this section we describe our respondents, focusing on their age and health. Table 2 describes features of each sample other than health. It shows that both samples were well balanced in terms of gender, with each having slightly more women than men. Although respondents in the Canadian study were all Caucasian, the U.S. sample included blacks (11%) and Hispanics (8%).

In part because of the differing racial compositions, the baseline risks reported to the respondents were different in the two studies. The average baseline risk was 123 in 1,000 for the Canadian sample, and 187 in 1,000 for the U.S. sample. African Americans, included in the U.S. sample, typically have higher baseline risks—except when very old—compared with Caucasians. The U.S. sample also included respondents over 75, whereas the Canadian sample did not. When these elderly respondents and African Americans are excluded from the U.S. sample, baseline risks decline substantially and are comparable to those for the Canadian sample.

Average household incomes were similar in both studies, as were years of schooling (on average, about 13 years in both studies). The U.S. study recruited participants from areas that were classified as neither urban nor suburban (22%), but the Canadian study, by design, covered only residents of the urban and suburban area of Hamilton.

[6] More information about Knowledge Networks is available from the company's website: www.knowledgenetworks.com.

B. Respondents' Health

We obtained a variety of information about respondents' health. First, we asked respondents to rate their health as excellent, very good, good, fair or poor, compared with others the same age. We then asked them whether they had been diagnosed with various illnesses, including asthma, chronic bronchitis, emphysema, various heart ailments, cancer, high blood pressure, and stroke. We also inquired about time spent in the hospital. Finally, we administered all the questions from SF-36.

Table 3 displays descriptive statistics for the health status of the respondents. Because participants in the Canadian study had to be well enough to travel to a central facility to complete the questionnaire, this sample was likely to be relatively healthy. By contrast, respondents in the U.S. study participated from their homes, allowing the inclusion of less healthy individuals and persons with impaired mobility. The difference in health status across the samples is borne out in the table. A slightly higher percentage of respondents in the Hamilton sample described themselves as having good or excellent health relative to others the same age (57.2%) compared with the U.S. sample (53.1%). Furthermore, the fractions of the sample with various types of chronic illness were slightly higher in the United States.[7] Although 3.4% of the Hamilton respondents said they had been diagnosed with cancer (a figure in line with the area's official health statistics), 11% of the U.S. sample reported having been diagnosed with cancer.

C. Probability Comprehension and Acceptance of the Scenario

Valuing mortality risk reductions through direct questioning techniques requires that subjects understand probabilities and accept the WTP scenarios presented to them. This section summarizes respondents' comprehension of probabilities and reports the percentage of respondents who questioned the assumptions made in the survey. Respondents who failed our probability tests were dropped from the analysis. Responses to debriefing questions indicating

[7] The questions on chronic illness were asked differently in the two studies. Canadian respondents were asked, in a single question, whether they had ever been diagnosed with one or more of the following illnesses: asthma, bronchitis, or emphysema. Respondents in the U.S. study, however, were asked whether they had ever been diagnosed with each of the following illnesses in four separate questions (i) asthma, (ii) chronic bronchitis, (iii) emphysema, or (iv) other respiratory illnesses. Similarly, the respondents in Hamilton were asked whether they had been diagnosed with heart disease, whereas the subjects in the U.S. study were asked four questions—whether they had ever been diagnosed with (i) angina pectoris, (ii) coronary heart disease, or (iii) other heart disease, and (iv) whether they had ever had a heart attack.

that the respondent did not believe his baseline risk of death or had doubts about the effectiveness of the product were used to create dummy variables. In table A1, we show results from a test of whether people who questioned some aspect of the questionnaire had significantly different WTP from those who did not.

To test their comprehension of probabilities, we asked respondents several questions using side-by-side grids of squares to convey the chances of dying for two people, person A and person B. The first question, the *probability test* question, asks which of the two people has the higher probability of dying. The second question, the *probability choice* question, asks which of the two people the respondent would rather be. If respondents answer the probability test question incorrectly, another explanation of the concept is provided and the respondent is asked a second probability test question. Should respondents indicate a preference for the person with the higher risk in the choice question, they are asked to confirm their selection following an additional explanation of the grids.

Table 4 reports the results of the probability test and choice questions. The table shows that roughly 12% of the respondents answered the initial probability test incorrectly. However, following an explanation of the error, a much smaller portion provided an incorrect answer to the second probability test (1.1% in Canada and 1.8% in the United States). A similar proportion of respondents initially indicated a preference for the person with the higher risk in the probability choice question (11% in the United States and 13% in Canada). However, most of these respondents corrected their answers when asked the question a second time. Only 1.3% of each sample confirmed that they would prefer to be the person with the higher risk of death.

Combining the responses to the test and choice questions, about 3% of each sample answered the initial probability test question incorrectly *and* indicated a preference for the person with the higher chance of dying in the probability choice question. These respondents were removed from subsequent analyses.

In Table 5 we examine the acceptance of the risk-reducing product or action and the scenario presented in the questionnaire. Roughly 20% to 25% of the respondents did not believe the baseline risk figures that were presented to them. Most of these respondents thought that their own risks of death were lower than the questionnaire stated. Approximately one-third of the respondents in each sample had doubts about the effectiveness of the product or action, with a large fraction of these respondents stating that these doubts influenced their WTP for the product or action itself.

Some respondents worried about side effects of the product; others thought that the product would yield additional benefits. A larger proportion of Hamilton respondents were concerned about possible side effects and admitted thinking about other benefits of the product than people in the U.S. sample. In the U.S. study, respondents were asked about the kinds of additional benefits they had in mind. Their replies included additional benefits to themselves (40%), benefits to other people—such as family members—of their living longer (25%), and improved health for other people (26%).

In Hamilton, 26% of the respondents noted that they did not consider whether they could afford the product or action when answering the payment question. In the United States, the fraction of the sample reporting such a behavior was even higher (37%). As discussed in Krupnick et al. (2002), these responses were common among people who were not willing to pay anything for the product. We conclude that most of these respondents had already ruled out the purchase of the product or action, making the price irrelevant to their decision. Finally, about 14% of the respondents revealed that they had not understood that they would be required to make a payment every year for ten years in order to receive the product and secure its risk-reducing benefits.

V. Willingness to Pay Results

A. Validity of WTP Responses

Before we examine the impact of age and health on WTP, it is important to establish criteria that WTP responses must satisfy for consistency with economic theory. We use three such criteria. First, the percentage of respondents answering "yes" to the initial payment question must decline with the dollar amount presented to the respondents. Second, respondents should be willing to pay more for a larger risk reduction. Third, under the assumptions in section II, willingness to pay should be proportional to the size of the risk reduction.[8]

To see whether the first criterion is met, we use only the responses to the initial payment question. Figures 2 and 3 show clearly that the first requirement is easily met in both studies: the percentage of "yes" responses clearly declines with the bid amounts used for the initial payment

[8] Equation (4) implies that WTP equals the rate at which an individual is willing to trade wealth for risk (VSL_j), multiplied by the size of the risk reduction. For small variations in D_j, VSL_j should remain constant.

questions. For the 5-in-1,000 risk reduction (wave 1), about 73% of the respondents are willing to pay the lowest bid amounts used (C$100 in the Hamilton study and $70 in the U.S. study). Smaller proportions are willing to pay the highest bid amounts (26% in Canada and 35% in the United States). A similar reaction to the 1-in-1,000 risk reduction (wave 2) is also found in both countries. The fraction of the sample willing to pay for the 1-in-1,000 risk reduction declines from 49% (for C$100) to 20% (C$1,100) in Canada, and from 44% (for $70) to 13% ($725) in the United States.

Furthermore, the percentages of respondents willing to pay for the 1-in-1,000 risk reduction are smaller than those for the 5-in-1,000 risk reduction at all bid levels. We therefore expect that when a formal estimate of mean WTP is obtained, WTP for the two risk reductions will be found to be significantly different.

B. External Scope Tests

To test whether WTP increases in proportion to the size of the risk reduction, we utilize the responses to the initial payment questions as well as the subsequent round of followups, fit a formal statistical model of WTP, and use the latter to produce estimates of mean WTP for the specified risk reductions.

A crucial decision is whether to use the open-ended responses that follow the first and second dichotomous choice questions. In both surveys, subjects answering no to both sets of dichotomous choice questions were asked whether they would pay anything at all for the product. As is often the case in contingent valuation surveys, a relatively high proportion of respondents in both samples indicated that they were not willing to pay anything for the risk reduction.[9] However, in the analyses reported in this paper we elect not to use these responses or the open-ended WTP amounts reported by persons who answered yes to the initial and followup dichotomous choice question. Although positive WTP amounts reported on a continuous scale are easily accommodated within a maximum likelihood estimation framework, we were

[9] In Canada, 19.5% and 36.8% of the respondents indicated that they were not willing to pay anything at all for the 5-in-1,000 (wave 1) and 1-in-1,000 (wave 2) risk reductions, respectively. The corresponding U.S. figures are 22% and 37.7%.

dissatisfied with the performance of the models we devised to accommodate zero WTP responses.[10]

For these reasons we use only the responses to the two rounds of dichotomous choice questions. Our statistical model is an interval-data model based on the Weibull distribution and is estimated using the method of maximum likelihood. The log likelihood function of the responses is:

$$\log L = \sum_i \log\left[F(WTP_i^U;\theta,\sigma) - F(WTP_i^L;\theta,\sigma)\right] \quad (7)$$

where F(•;θ,σ) is the cdf of the Weibull distribution with shape parameter θ and scale σ ($F(y;\theta,\sigma) = 1 - \exp(-(y/\sigma)^\theta)$), and WTP^L and WTP^U are the lower and upper bounds of the interval around the respondent's WTP amount.

Estimates of median and mean *annual* WTP based on equation (7) without using covariates are reported in Table 6.[11,12] We exclude from our models those respondents who failed both the initial probability test and the probability choice questions described above, whether or

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[10] We have attempted two such models. In the first model, responses are treated as if they came from a discrete mixture with two components. The first component is a degenerate distribution where all respondents hold a value of zero for the risk reduction, and the second component is a well-behaved random variable (a Weibull) that takes only positive, real values. Unfortunately, the estimation routine experienced convergence problems for all but the simplest specifications. The second model is an interval-continuous data version of the "spike" model described by Kristrom (1997). In this case, the estimation routine converged without problems, but we were concerned about the restriction implicitly imposed in this model that the coefficients be the same for zero-WTP respondents and for respondents who hold positive WTP amounts. This restriction appears to be violated in our data, at least for the U.S. study: Probit models to explain zero responses fail to identify any significant predictors of such responses among age, income, education, and variables measuring health status. The only variable that was consistently significant in explaining zero WTP was a dummy variable indicating that the respondent did not consider whether he could afford the payments. As discussed elsewhere (Krupnick et al. 2000), we believe that most of these respondents had already ruled out the purchase of the product, making the price irrelevant to their decision.

[11] All figures are expressed in U.S. dollars, based on a purchasing power parity for US$1.25 per C$1.

[12] Mean WTP is computed as $\hat{\sigma} \cdot \Gamma(1/\hat{\theta} + 1)$, and median WTP is $\sigma \cdot (-\ln 0.5)^{1/\theta}$ where the hats denote estimates. To compute standard errors around mean WTP, we drew samples of 20,000 observations from a multivariate normal distribution centered on the estimated Weibull parameters with covariate matrix equal to the inverse of the information matrix of log likelihood (7). We used the values drawn from this distribution to compute 20,000 estimates of mean WTP. The standard deviation of this vector of artificially generated mean WTP values is the standard error of the estimate of mean WTP shown in Table 7.

not they subsequently corrected their answers (FLAG 1=1). We also exclude respondents in the U.S. sample over the age of 80.[13]

For both the Canadian and the U.S. samples, mean WTP and median WTP are significantly larger for a 5-in-1,000 risk reduction than for a 1-in-1,000 risk reduction, but neither mean WTP nor median WTP increases *in proportion* to the size of the risk reduction. Median WTP does, however, show more sensitivity to the size of the risk reduction than mean WTP: in both samples the ratio of median WTP for a 5-in-1,000 risk reduction to median WTP for a 1-in-1,000 risk reduction is larger than the corresponding ratio of mean WTPs.

The corresponding estimates of the value of a statistical life are shown in Table 7. These are calculated using the mean annual WTP (from Table 6) and dividing it by the *annual* risk reduction implied by the product or action described to the respondent.[14] Given the similarity of the WTP figures from the Canadian and U.S. studies, it is not surprising that the VSLs are also very similar.

The VSL estimates for Canada range from $506,000 to $933,000, when computed using WTP for the 5-in-1,000 risk reduction, compared with $700,000 to $1.54 million for the United States. When based on WTP for the 1-in-1,000 risk reduction, the VSL estimates increase, exceeding $4 million. Because WTP is generally not proportional to the size of the risk change, VSL estimates are larger when calculated using WTP for the smaller risk change. Although the more generous VSL amounts for Canada appear in line with estimates used in policy assessments affecting elderly populations, they are well below the estimates used by EPA in its recent policy analyses.

Returning to the issue of sensitivity to scope, when we distinguish respondents by the degree of confidence they have in their answers, median WTP does, indeed, increase in proportion to the size of the risk reduction. This is shown in Table 8. After each WTP question, we asked respondents to indicate the level of certainty they had in their responses on a scale from 1 to 7. In Table 8, certainty levels of 6 and 7 are categorized as “more confident” and all other

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[13] We decided to exclude respondents older than 80 years because in our preliminary analyses of the relationship between WTP and age, we found that in the oldest age bracket (age 80 and older), this relationship appeared to be nonmonotonic and driven by a few responses implying relatively large WTP amounts. Since there were only 11 subjects in this age group, we deemed it safer to exclude these respondents from our analysis.

[14] Assuming that the respondents spread the risk reduction evenly over the 10 years, this approach overcomes the difficulty of having to choose a discount rate for the 10 annual payments.

certainty levels as "less confident." When attention is restricted to more confident respondents, the ratio between the median WTP amounts is 3.3 for Canada and 8.9 for the United States, with neither figure statistically different from 5. These results, however, should be interpreted with caution because of the large confidence intervals around the point estimates of the ratio between WTP for the two risk reductions.

C. The Impact of Age and Health on WTP

To examine the impact of age and health on WTP, we add covariates to the Weibull model. The life-cycle model presented in section II suggests that current wealth and a person's future income stream should influence his WTP for a reduction in risk of death. So should covariates that may alter the individual's estimate of his chances of surviving the next 10 years, $(1-D_j)$. These include, in addition to a person's own age and health, family health history, race, and gender. These same variables, of course, should influence estimates of future survival probabilities, so their net impact on WTP is uncertain.

We present results of interval-data Weibull regressions of WTP in Table 9 for the 5-in-1,000 risk reduction based on wave 1 for both the U.S. and the Canadian samples. The Weibull regressions assume that $WTP = \exp(x_i\beta)WTP_0^{1/\theta}$, where WTP_0 is WTP when all covariates are set to zero, which is distributed as a Weibull with shape parameter θ and scale 1. A log transformation produces the equation $\log WTP = \mathbf{x}_1\beta + (1/\theta)\varepsilon$, where $\varepsilon = \log WTP_0$ follows the type I extreme value distribution.

The first model presented in Table 9 examines the effects of age on WTP using a series of dummy variables to represent age groups 50 to 59, 60 to 69, and 70 and older. When these dummies are included on the right-hand side of the Weibull model, the coefficients of the 50–59 and 60–69 age group dummies are indistinguishable from the coefficient of the 40–49 age bracket (captured by the intercept). The coefficient of the oldest age bracket, however, is significantly lower for the Canadian sample, at the 10% level. This remains true when other covariates are included in the regression. No age effects are found using the U.S. sample.

Model 2 examines, in addition to age, the impacts of race, gender, income, and education on WTP. In the U.S. sample, income is measured as household income divided by number of persons in the household. Information about household size is not available for the Canadian sample. Instead, for the Canadian sample, the Weibull regression includes a dummy that takes on a value of one if the respondent's household income is below the first quartile. In both samples higher income increases WTP, although this effect is statistically significant only in the U.S.

sample. In the U.S. sample, blacks are willing to pay more for a 5-in-1,000 risk reduction than whites and Hispanics, possibly because they have higher baseline risks, whereas males are willing to pay less. Education does not have a statistically significant effect on WTP.

Model 3 examines the impact of family health history, health insurance coverage, and hospital admissions on WTP. These variables are insignificant in both samples, with two exceptions. Having a family history of chronic heart or lung disease increases WTP by 26% in the Canadian sample, and by 37% in the U.S. sample. More strikingly, in the United States, respondents who have been admitted to the hospital for a heart or lung condition within the last year or who have been admitted to an emergency room for one of these conditions within the last five years are willing to pay 63% more to reduce their risk of death than persons who have not had such hospital visits.[15]

In addition to recording hospital admissions, we measure respondents' health status by a series of dummy variables that indicate whether a respondent has ever been diagnosed with cardiovascular disease, chronic lung disease, high blood pressure, or cancer.[16] Because of correlations among these variables, we add the chronic health dummies one at a time to model 2 and to model 3 of Table 9.[17] These coefficients appear in Table 10. In the Canadian sample, none of the chronic health dummies are ever statistically significant. In the U.S. sample, the dummy variables for cancer and cardiovascular disease are never statistically significant; however, having blood pressure raises WTP by about one-third, even when family health history and hospitalization are controlled for. Having a chronic respiratory illness significantly raises WTP when the latter variables are omitted from the equation (model 2), but not when they are added (model 3). We conclude that having a chronic heart or lung condition certainly does not appear to reduce WTP for mortality risk reductions and may even increase WTP.

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[15] We note that the effects of age, race, gender, income, and family health history are, in general, robust to the inclusion of variables indicating whether the respondent questioned baseline risk figures or the assumptions of the WTP scenario. (The results of adding the debriefing variables to Model 3 are reported in Table A.1.) When significant, the coefficients on the debriefing variables are of the correct sign.

[16] We have chosen to focus on indicators of chronic illness rather than indicators of functional limitation, as measured by the indices from SF-36. The latter are often correlated with the former; however, it is the former that are used more often in epidemiological studies.

[17] We also tried interacting each health dummy with the emergency room–hospitalization variable, but these terms were never significant.

D. Conclusions and Implications for Policy

In this paper we have used contingent valuation to examine the effects of current age and health status on respondents' WTP for a product that would reduce their risk of death over the next 10 years. Economic theory is ambiguous about the impact of these variables on WTP to reduce risk of death. In general, WTP should be higher the lower an individual's chances of surviving the current period. It should also be higher the greater the present discounted value of lifetime utility conditional on surviving the current period. In a comparative static sense, being older and having a chronic heart or lung condition both reduce an individual's chances of surviving the current period and, for this reason, tend to raise WTP. Older individuals and persons with chronic diseases, however, have fewer life years to look forward to, assuming they survive the current period, and this should lower their WTP to reduce current risk of death.

Our empirical results suggest that with regard to health status, the former effect balances out the latter and may even dominate it: persons with chronic heart and lung disease are willing to pay at least as much to reduce their risk of dying as persons who do not have these diseases. In our U.S. sample, WTP is significantly greater (holding age, gender, and income constant) for persons who have been hospitalized for a chronic heart or lung condition within the last year and for persons who have high blood pressure. There are no statistically significant differences between the two groups in Canada.

As regards age, respondents in our Canadian sample who were 70 years of age or older were willing to pay about one-third less than their younger counterparts to reduce their risk of dying over the next 10 years. There was, however, no statistically significant impact of age on WTP in the U.S. sample.

Our results thus support current practice with regard to treatment of age and health status in both the United States and Canada. EPA currently uses a central VSL estimate, based primarily on labor market studies, equal to approximately $6 million (1999 US$) for all ages. In contrast, Health Canada employs age-adjusted VSL estimates in its economic assessments, applying a VSL of C$5 million (or US$4 million) to exposed populations under 65 years of age and using an adjustment factor of 0.75 for populations 65 years and older.[18] Neither agency currently makes adjustments based on health status.

[18] These adjustments are based on Jones-Lee et al. (1985).

These results stand in sharp contrast to the way in which age and health status are treated in evaluating medical interventions. We believe the comparison is relevant, since it is sometimes suggested that a similar approach be used in benefit-cost analyses of health and safety regulations (U.S. Food and Drug Administration 1999). The standard approach in the medical literature is to measure life-saving benefits in terms of Quality Adjusted Life Years Saved (QALYs). This assumes that the value of lives saved is strictly proportional to remaining life expectancy, and that the value of saving a life-year is less for a person with a chronic disease, such as chronic bronchitis, than for a healthy person, with the exact equivalence determined by QALY weights. Our results do not support either of these assumptions. There is no evidence that the VSL should be equally apportioned over remaining life expectancy, or that the VSL is systematically lower for persons with chronic illness.

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Figure 1: Structure of Payment Questions

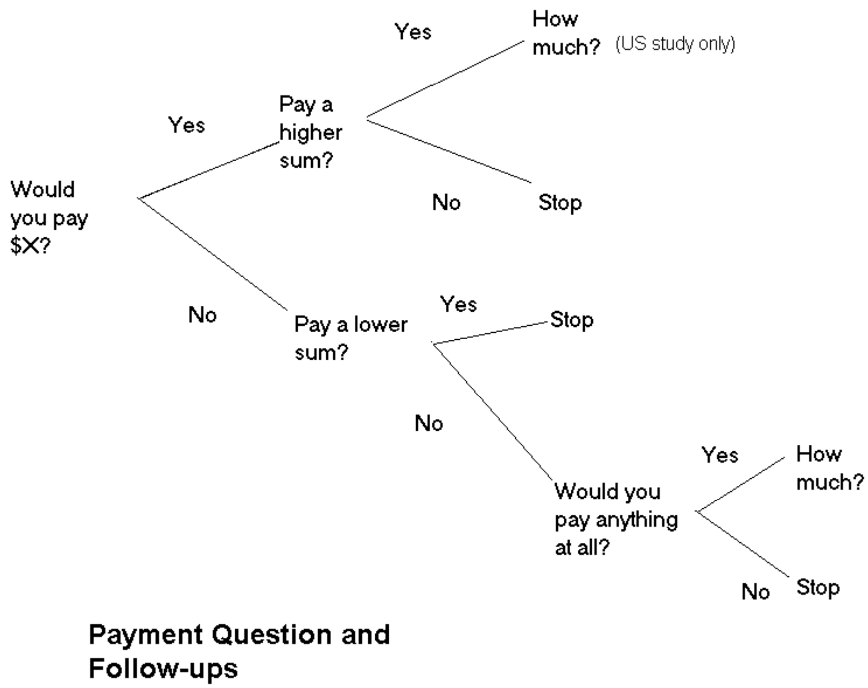

Figure 2.

Percentage of "Yes" Responses by Bid Value: Canadian Study

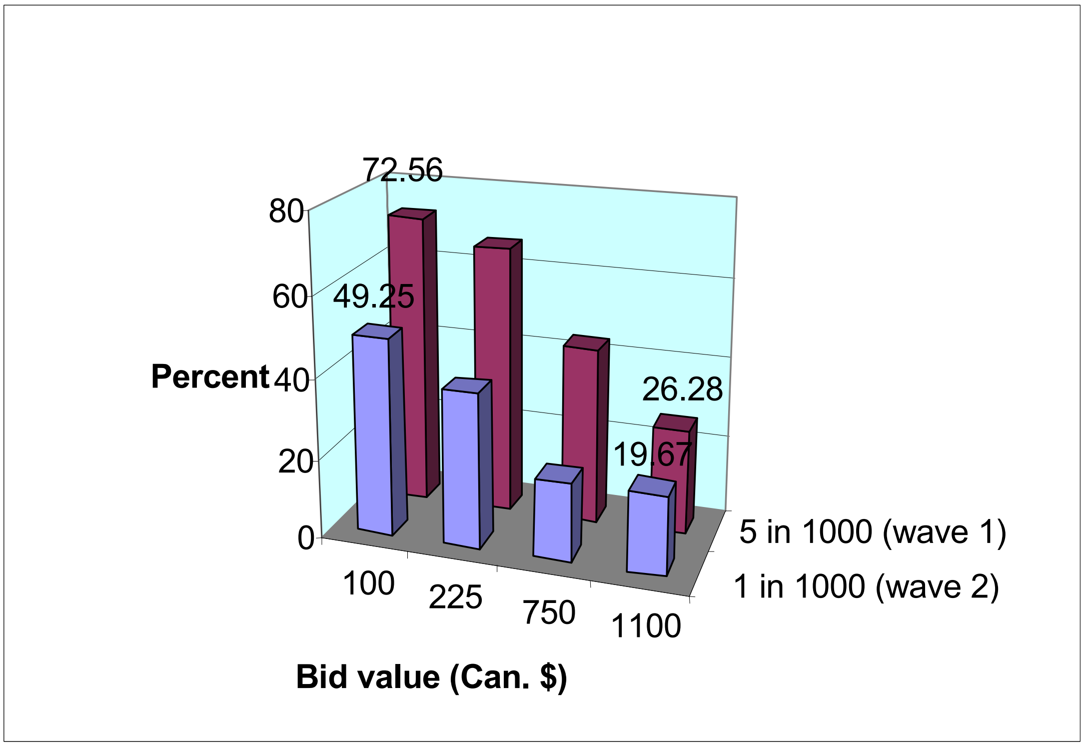

Figure 3.

Percentage of "Yes" Responses by Bid Value: U.S. Study

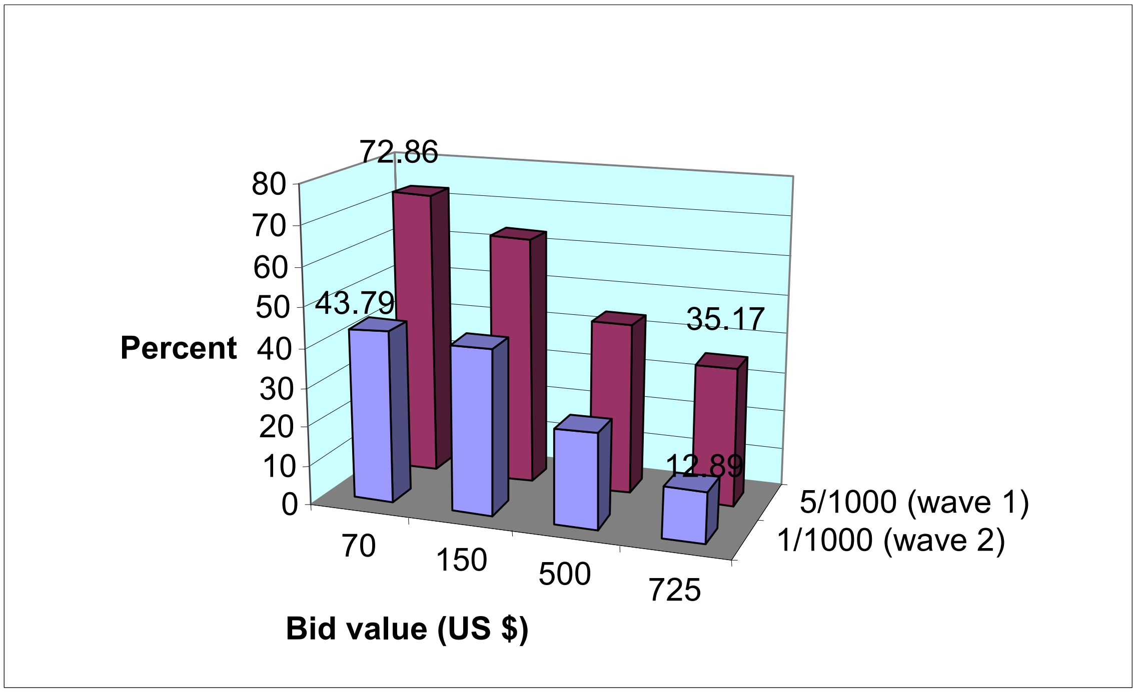

Table 1.

Bid Structure in the Canada Mortality Risk Survey (1999 C$).*

Group of respondents	*Initial payment question*	*Followup question (if "yes")*	*Followup question (if "no")*
I	100	225	50
II	225	750	100
III	750	1100	225
IV	1100	1500	750

Note: * Similar bid values were used in the U.S. survey after conversion to U.S. dollars using purchasing power parity.

Table 2.

Comparison across Canadian and U.S. Mortality Risk Studies:

Characteristics of Respondents

Characteristic	*Sample average or percentage of sample*	
	Canada	*United States*
Age	54.2 years	54.4 years
Male	48%	47%
Racial and ethnic composition		
African American	—	11%
Hispanic	—	8%
White	100%	82%
Baseline risk of dying over the next 10 years		
Entire sample	123	187
African American	—	174
No African American Or persons older than 75	—	147
Household characteristics		
Annual household income (US $)		
Mean	$46,800	$53,000
Median	$50,000	$55,000
Years of schooling	13.7	13.0
Married	—	72%
Household size	—	2.6
Number of adults in the household	—	2.2
Percent urban/suburban in county of residence	100%	78%

Table 3.

Comparison of Respondent Health Status

Across the Canada and U.S. Studies

Health Condition	Sample mean or percent: Canada	United States	
Has asthma	14 %	16 %	10 %
Has bronchitis			7 %*
Has emphysema			4 %
Has angina pectoris	(heart disease) 10 %	21 %	8 %
Has had a myocardial infarction (heart attack)			8 %
Has coronary disease			7 %
Has had a stroke	--	4 %	
Has been diagnosed with cancer	3 %	11 %	
ER visit in last 5 years or hospitalization in last year for ongoing heart or lung problems	12%	12%	
Has family history of cancer	49%	52%	
Has family history of chronic illness (excluding cancer)	79%	50%	
Has no medical insurance*	31%	6%	
General health score from SF-36	70	67	
Physical functioning score from SF-36	81	78	
Vitality score from SF-36	63	59	
Role-emotional score from SF-36	81	87	
Mental health score from SF-36	76	77	
Rates own health as good or excellent, relative to others of the same age	57 %	53 %	

* chronic bronchitis

* "No medical insurance" is defined in Canadian sample as "no supplemental insurance coverage."

Table 4.

Comparison across Canadian and U.S. Mortality Risk Studies: Probability Comprehension

	Percentage of the sample	
	Canada	*United States*
Probability test questions answered incorrectly		
1st probability test question	11.6	12.2
2nd probability test question (FLAG 4)	1.1	1.8
Indicates preference for individual with higher risk of death in		
1st probability choice question	13.0	10.8
Followup confirmation question (FLAG 5)	1.3	1.3
Other indicators of probability comprehension		
Fails both probability test and choice questions (FLAG 1)	2.6	3.7
Claims to understand probability poorly (FLAG 6)	7.0	16.2

Table 5. Comparison across Canada and U.S. Studies

Acceptance of the Product and Scenario

	Percentage of the sample	
	Canada	*United States*
Did not believe the risk figures (FLAG 7)	19.7	24.5
Thought own risks were higher	15.9*	20.5*
Thought own risks were lower	84.1*	79.5*
Doubts effectiveness of the product or action (FLAG 8)	30.6	33.5
Doubts about effectiveness influenced WTP (FLAG 9)	19.7	21.1
Thought about possible side effects of the product (FLAG10)	25.0	15.4
Thought of other benefits of the product (FLAG 11)	48.7	36.6
Other benefits to self	—	39.7**
Benefits to other people of living longer	—	25.2**
Improved health for other people	—	25.7**
Did not consider whether he could afford the product or action (FLAG 15)	26.0	37.4
Did not understand the timing of the payments (FLAG 16)	13.0	14.0

* Percentage of respondents who did not believe the risk figures.
** Percentage of respondents who thought of other benefits of the product.

Table 6.

Mean and Median WTP for Reduced Mortality Risk (U.S. dollars*)

	Canada		*United States*	
	Median WTP	*Mean WTP*	*Median WTP*	*Mean WTP*
5-in-1,000 risk reduction (wave 1)	253 (17.1) n=616	466 (33.6) n=616	350 (28.7) n=556	770 (86.9) n=556
1-in-1,000 risk reduction (wave 2)	131 (18.2) n=292	370 (48.6) n=292	111 (14.0) n=548	483 (74.0) n=548
Are the WTP figures for risk reductions of different sizes…				
Significantly different? Wald Test p-value	Yes 23.74 <0.0001	Yes ***2.65*** ***0.10***	Yes 56.10 <0.0001	Yes 6.32 0.01
Proportional to the size of the risk reduction?	No (ratio=1.9)	No (ratio=1.3)	No (ratio=3.2)	No (ratio=1.6)
Wald Test	19.0	***32.0***	7.3	18.7
p-value	< 0.0001	< 0.0001	0.007	< 0.0001

Notes: Standard errors in parentheses. Estimates based on cleaned data (respondents with FLAG 1=1 deleted). U.S. sample excludes people older than 80 years of age.

* In U.S. dollars, using purchasing power parity of C$1.25 per US$1.

Table 7.

Implied Estimates of the Value of a Statistical Life (US$)

Magnitude of risk change	*Canada*		*United States*	
	From median WTP	*From mean WTP*	*From median WTP*	*From mean WTP*
5 in 1,000	506,000	933,000	700,000	1,540,000
1 in 1,000	1,312,000	3,704,000	1,110,000	4,830,000

Note: VSLs are computed using on annual risk changes—that is, 5 in 10,000 and 1 in 10,000.

Table 8.

The Effect of Confidence on Median WTP for Reductions to Mortality Risk (US$)

Magnitude of risk reduction	*Canada median WTP*		*U.S. median WTP*	
	More confident	*Less confident*	*More confident*	*Less confident*
5 in 1,000 (wave 1)	414 (48.1) n=267	268 (36.2) n=349	205 (41.8) n=244	445 (36.1) n=311
1 in 1,000 (wave 2)	126 (29.4) n=139	136 (22.9) n=151	23 (9.4) n=298	236 (25.3) n=250
Are the WTP figures for risk reductions of different sizes…				
Significantly different? Wald Test p-value	Yes 25.95 <0.0001	Yes 9.51 0.002	Yes 18.04 <0.0001	Yes 22.48 <0.0001
Proportional to the size of the risk reduction? Wald Test p-value	Yes (ratio=3.3) 1.99 0.15	No (ratio=2.0) 11.8 0.0006	No (ratio=8.9) 2.04 0.15	No (ratio=1.9) 31.21 <0.0001

Note: Standard errors in parentheses. Estimates based on cleaned data (respondents with FLAG 1=1 deleted; respondents older than 80 excluded).

Table 9.

Weibull Interval-Data Regression Results for 5-in-1,000 Risk Reduction (Wave 1)

Variable	*Canada*			*United States*		
	Model 1	*Model 2*	*Model 3*	*Model 1*	*Model 2*	*Model 3*
Intercept (ages 40 to 49)	6.42** (0.10)	6.98** (0.36)	6.81** (0.38)	6.39** (0.13)	6.95** (0.50)	6.53** (0.54)
Ages 50 to 59	0.15 (0.16)	0.19 (0.16)	0.17 (0.16)	0.05 (0.21)	0.13 (0.23)	0.071 (0.23)
Ages 60 to 69	0.13 (0.17)	0.14 (0.17)	0.17 (0.17)	0.03 (0.22)	-0.07 (0.23)	-0.23 (0.23)
Age 70 and older	-0.34* (0.20)	-0.35* (0.21)	-0.33 (0.21)	-0.21 (0.23)	-0.17 (0.25)	-0.23 (0.26)
Male	—	-0.21* (0.13)	-0.19 (0.13)	—	-0.43** (0.17)	-0.45** (0.17)
Black	—	—	—	—	0.73** (0.36)	0.71** (0.36)
Bottom 25% of distribution of income (=1 if income < C$24,500)	—	-0.23 (0.15)	-0.23 (0.16)	—	—	—
Income per person	—	—	—	—	.000013** (6.39×10^{-6})	.000016** (6.58×10^{-6})
Education (years of schooling)	—	-0.03 (0.02)	-0.03 (0.02)	—	-0.05 (0.04)	-0.052 (0.038)
Family history of chronic illness (excluding cancer)	—	—	0.26* (0.16)	—	—	0.37* (0.22)
Family history of cancer	—	—	-0.06 (0.13)	—	—	0.02 (0.17)
ER visit in last five years or hospitalization in last year	—	—	-0.07 (0.19)	—	—	0.63** (0.28)
No insurance	—	—	-0.03 (0.15)	—	—	0.29 (0.28)
Scale parameter	1.27 (0.07)	1.27 (0.07)	1.26 (0.07)	1.44 (0.09)	1.41 (0.09)	1.37 (0.09)
Sample size	616	605	605	551	474	474

Notes: Standard errors in parentheses. ** indicates significance at the 5% level; * indicates significance at the 10% level. FLAG 1=1 deleted. U.S. sample excludes people older than 80 years of age.

Table 10. Effect of Adding Health Variables One at a Time to Previous Models

Characteristic	Canada		United States	
	Model 2 +	Model 3 +	Model 2 +	Model 3 +
CARDIO≅	0.16 (0.22)	0.19 (0.23)	0.19 (0.22)	-0.018 (0.25)
LUNGS	0.03 (0.16)	0.03 (0.16)	0.45** (0.23)	0.29 (0.23)
PRESSURE	0.14 (0.16)	0.11 (0.17)	0.38** (0.19)	0.35* (0.19)
CANCER	0.51 (0.36)	0.53 (0.36)	0.28 (0.31)	0.19 (0.31)

Note: ** indicates significance at the 5% level; * indicates significance at the 10% level. FLAG1=1 deleted. U.S. sample only includes people of ages no greater than 80 years.

≅ Definition of CARDIO: respondent has one or more of the following: angina pectoris, coronary disease, other heart diseases, and/or has had a myocardial infarction.

Table A1. The Effect of Acceptance of the Product and Scenario on Weibull Interval-Data Regression Results for 5 in 1,000 Risk Reduction (Wave 1)
(Standard Errors in Parentheses)

Variable	Canada	United States
Intercept (ages 40 to 49)	6.72** (0.40)	7.35** (0.59)
Ages 50 to 59	0.15 (0.15)	0.021 (0.23)
Ages 60 to 69	0.09 (0.17)	-0.32 (0.23)
Ages 70 and older	-0.37* (0.20)	-0.27 (0.26)
Male	-0.04 (0.13)	-0.44** (0.17)
Black	--	0.79** (0.36)
Bottom 25% of distribution of income (=1 if income < C$24,500)	-0.35** (0.16)	--
Income per Person	--	0.000017** ($6.62x10^{-6}$)
Education (Years of Schooling)	-0.03 (0.02)	-0.067* (0.039)
Family history of chronic illness (excluding cancer)	0.30** (0.15)	0.37* (0.22)
Family history of cancer	-0.08 (0.12)	-0.14 (0.17)
ER visit in last five years or hospitalization in last year	0.07 (0.19)	0.46* (0.27)
No Insurance	-0.09 (0.15)	0.24 (0.28)
Does not believe risk figures (dummy) (Flag7)	-0.10 (0.16)	-0.26 (0.21)
Does not believe the product would be effective (Flag8)	-0.24* (0.14)	-0.17 (0.18)
Thought there would be side effects (dummy) (Flag10)	0.09 (0.15)	-0.42 (0.22)
Other benefits (dummy) (Flag11)	0.57** (0.13)	-0.018 (0.19)
Did not consider if could afford payments (dummy) (Flag15)	-0.61** (0.14)	-0.94** (0.18)
Did not understand timing of payments (dummy) (Flag 16)	0.07 (0.19)	0.094 (0.24)
Scale parameter	1.22 (0.06)	1.34 (0.090)
Sample size	605	474

Note: ** indicates significance at the 5% level; * indicates significance at the 10% level. FLAG1=1 deleted. U.S. sample only includes people of ages no greater than 80 years.