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THE WILLINGNESS TO PAY FOR MORTALITY RISK REDUCTIONS: A COMPARISON OF THE UNITED STATES AND CANADA

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Abstract

We present results for two contingent valuation surveys conducted in Hamilton, Canada and the US to elicit WTP for mortality risk reductions. We find similar Value of Statistical Life estimates across the two studies, ranging from USD 930,000 to USD 4.8 million (2000 US dollars). WTP increases with risk reduction size, but varies little with respondent age: individuals aged over 70 years hold WTP values approximately one-third lower than other respondents. Respondent health status has limited effect on WTP. These results provide little or no evidence for adjusting VSL estimates used in policy analyses for the affected population's age or health status.

JEL Classification: I18, Q28.

Keywords: value of a statistical life, mortality risks, benefit-cost analysis.

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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 many of the legislative mandates in both the United States (U.S.) and Canada, including the Safe Drinking Water Act, the Resource Conservation and Recovery Act and the Clean Air Act in the U.S. and the Environmental Protection Act in Canada. In two recent analyses of the benefits of U.S. air quality legislation, for example, over 80 percent of monetized benefits were attributed to reductions in premature mortality (USEPA 1997; USEPA 1999). Similarly, a high proportion of monetized benefits in Canadian regulations, including Regulations Respecting the Sulphur Content in Diesel Fuel, and Regulations Respecting the Sulphur Content in Gasoline, are attributable to reductions in premature mortality.

Existing 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, such as compensating wage, consumer behavior, and stated preference studies, including those employing contingent valuation methods. However, the use of figures from these studies to value the lives saved by environmental programs is problematic. Both types of studies have focused on measuring the value that prime-aged adults place on reducing their contemporaneous 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 (Pope et al., 1995; Schwartz 1991; Schwartz 1993). Furthermore, the reductions in mortality risks brought about by environmental policies tend to be experienced with a latency period – that is, a number of years after exposure.

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. Similar deductions have been made regarding the effect of health status on WTP for mortality risk reductions. It has 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. Alternatively, people in ill health may have higher baseline risk of death and would therefore be willing to pay more for a given risk change. Theory simply cannot predict exactly how WTP varies with age or health status. Economic theory does suggest, however, that WTP to reduce *future* health risks will be less than those experienced in the present. This theory holds even if payment for the future risk reduction is made in the present, due to discounting and the possibility that the subject will not live to experience the future benefit.

In spite of these limitations, the USEPA currently uses a central VSL estimate, based primarily on labor market studies, equal to approximately $6 million (1999 US$) for all ages, citing that there is little to no empirical evidence available to support age adjustments. 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 aged 65 years and over.[1] This adjustment factor is based on empirical estimates from Jones-Lee et al. (1985)—one of the only studies that shows the effects of age on WTP for mortality risk reductions. Neither agency currently makes adjustments based on health status.

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 answer the above speculations: one conducted in Hamilton, Ontario and the other in a nationwide survey of the U.S. In both surveys, respondents were asked about their WTP for several reductions in mortality risk that varied in magnitude and timing. Two of the mortality risk reductions were to take place over the next ten years, beginning immediately. A third mortality risk reduction was to take place beginning at age 70 over the course of ten years, whereas payments to secure the risk reduction would start immediately. WTP for immediate risk reductions can thus be compared with WTP for future risk reductions to assess the importance of

[1] Canadian dollars are converted to U.S. dollars using a purchasing power parity of 1.25C$ per 1US$.

the timing of the risk reduction. In all cases, the risk reduction is delivered by an abstract, private good (a product or action).

The questionnaire was self-administered by computer and included a probability tutorial, questions to test probability comprehension, and debriefing questions about the acceptance of the risk reduction scenario. A sample of residents of Hamilton, Ontario and a nationally representative sample of U.S. residents participated in the study. Respondents were limited to persons aged 40 years and older, including those older than 60, to examine the impact of age on WTP. We also collected extensive information about the respondent's health status to see if it systematically influences WTP.

The remainder of this paper is organized as follows. The survey instrument and its administration are discussed in section II. Section III presents the data, and section IV the results of econometric estimation of models of WTP. Section V concludes.

II. The Surveys

In both surveys, the questionnaire was self-administered on a computer, allowing us to avoid interviewer effects and to tailor the questionnaire specifically to the respondent using individual-specific risks and follow-up questions. The respondents were thus able to move through the survey at their own pace, listen to audio voice-overs, and were given extensive visual aids to increase comprehension and subject interest.

A. Presentation of Risks and Risk Changes

Understanding risks is essential if respondents are to report their WTP for a reduction in mortality risks. In our survey, respondents were given experience with graphical representations of risks of death (depicted by colored squares on a rectangular grid) and were tested for comprehension of probabilities before being asked WTP questions.

Subjects were 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 were represented using red squares. To test their comprehension, respondents were asked to compare grids for two hypothetical people (person A and person B) and to determine which of the two had the higher risk of death. They were also asked to select which of the two people they would rather be. The baseline risk of death for a person of the respondent's age and gender was then presented both numerically and graphically.

We asked respondents to value annual risk reductions on the order of 10^{-4} annually. Changes in risk of dying were depicted in side-by-side (before and after) representations of mortality risk, with the change in risk shown by changing the appropriate number of red squares to blue. 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).

Our grid represents the chances of dying (surviving) over a 10-year period with risks on the order of 10^{-3}, rather than a one-year reduction in risk of 10^{-4}. The use of a 10-year period makes it possible to represent risks using grids of 1,000 squares and to discuss risk changes of X in 1,000. In our questionnaire development, we found that respondents regarded grids with more squares (e.g., 10,000 or 100,000) or denominators greater than 1,000 as confusing, and tended to dismiss such small risk changes as insignificant. Furthermore, respondents in focus groups more readily accepted baseline risks and risk reductions described as occurring over longer periods, providing another compelling reason for using the 10-year risk reduction period.

B. Introducing Income-Risk Tradeoffs

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 off income for reduced risks. To mitigate this problem, we first acquainted respondents with *quantitative* risk reductions resulting from medical tests and products that were likely to be familiar to the respondent (e.g., mammograms, colon cancer screening tests, medicine to reduce blood pressure). In doing so, we provided only qualitative cost information for each action and product ("inexpensive," "moderate" and "expensive").

C. Willingness to Pay Questions

We asked respondents about their WTP for several reductions in their chances of dying from their baseline risk that varied in magnitude and timing. These included a 5-in-1,000 risk reduction over the next 10 years, a 1-in-1,000 risk reduction over the next 10 years, and a 5-in-1000 risk reduction beginning at age 70 from their baseline risk at age 70. The experimental design was the same in both countries and is shown in Table 1.

The survey was administered in each country in two waves with the only difference between the waves being the magnitude of the risk reduction the respondent was first asked to value. For the risk reductions that were contemporaneous to the payments, this design allowed the conduct of both internal and external scope tests of the WTP values. For the 5-in-1,000 risk reduction, it also allowed for internal scope tests on the WTP values for the contemporaneous versus the future risk reductions.

We argue elsewhere (Krupnick et al., forthcoming) that it is important that risk reductions be a private good. For this reason, the risk reduction mechanism described to respondents in our survey was an abstract product (not covered by health insurance) that reduces each respondent's *own* risk of dying.

Regarding the timing of payments, focus groups and one-on-one interviews suggested that payments for risk reductions should be made annually, over a ten-year period. We use graphs to convey the timing of the payments, as well as the relationship between the timing of payments and the timing of the risk reductions. This was especially important when eliciting WTP today for a future risk reduction.

Table 1. Survey Design

Group of Respondents	Initial Risk Reduction Valued	Second Risk Reduction Valued	Future Risk Reduction Valued
Wave 1	5 in 1,000	1 in 1,000	5 in 1,000
Wave 2	1 in 1,000	5 in 1,000	5 in 1,000

Table 2. Bid Structure in the Canada Mortality Risk Survey (1999 C$).

Group of Respondents	Initial Payment Question	Follow-up Question (if "Yes")	Follow-up Question (if "No")
I	100	225	50
II	225	750	100
III	750	1100	225
IV	1100	1500	750

Information about WTP was obtained through a combination of dichotomous choice payment questions with follow-ups, and open-ended questions. Table 2 provides the bid structure used in the Canadian survey. Essentially identical bids were used in the U.S. survey after conversion to U.S. dollars using purchasing power parity.

Respondents were asked to indicate their degree of uncertainty about the WTP respondents 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.

D. Administration of the Questionnaire

The Canadian survey was self-administered using the computer by a sample of 930 residents of Hamilton, Ontario. Subjects were recruited by telephone through random-digit dialling and asked to take the survey at a facility in downtown Hamilton.[2] The survey took place over five months in the spring of 1999.

The respondents in the U.S. survey were reached through a technology called Web-TV© that involves attaching a special device (resembling a cable box) to one's television. The user can use a remote control device or a keyboard to access and negotiate the Internet using the TV as a monitor. Knowledge Networks® recruits individuals to participate as panel members in exchange for the technology and free internet access. The panel members are originally contacted and recruited using telephone contacts originated through random-digit dialling, and is representative of the U.S. population for gender, age, race and income. Panel members are then randomly selected to occasionally complete surveys.[3] Knowledge Networks® administered our survey to a pre-selected sample of U.S. adults fitting our age profile in August 2000. Of the 1,800 persons originally contacted to complete our survey, approximately 1,200 actually did so.

III. The Data

A. Characteristics of the Respondents.

Because the U.S. and Canadian samples were recruited in different ways, it is important to compare the characteristics of the respondents. Table 3 shows that both samples were well balanced in terms of gender, with only a slight prevalence of women. While the Canadian study recruited almost exclusively whites, the U.S. sample does include blacks (11 percent) and Hispanics (8 percent).

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[2] Because of the need to travel to a centralized facility, response rates were low. Out 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, bringing our response rate to 26 percent. The response rate is calculated as the number of respondents successfully completing the study (930) divided by the number of eligible contacts (3,591).

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

Table 3.
Comparison across Canada and US mortality risk studies:
Characteristics of Respondents

Characteristic	**Sample average or percent of sample**	
	CANADA	**U.S.**
Male	48 percent	47 percent
Racial and Ethnic Composition:		
• African-American	--	11 percent
• Hispanic	--	8 percent
• White	100 percent	82 percent
Baseline risk of dying over the next 10 years:		
• Entire Sample	123	187
• African-American	--	174
• No African-Amer. Or persons older then 75	--	147
Household characteristics:		
Annual household income (US $) Mean Median	$46,800 $50,000	$53,000 $55,000
Years of schooling	13.7	13.0
Married	--	72 percent
Household size	--	2.6
Number of adults in the household	--	2.2
Percent urban/suburban in county of residence	100 percent	78 percent

In part because of the differing racial compositions, the baseline risks of the respondents are different in the two studies. The average baseline risk is 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 to Caucasians. Another difference between the two samples is inclusion of persons older than 75 years of age in the U.S. sample. When these African Americans and persons older than 75 years of age are excluded from the U.S. sample, the average baseline risk for the U.S. is not statistically different from that of the Hamilton sample.

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

B. Respondent Health

Information about respondent health status was obtained in a number of ways. First, we asked respondents to rate their health as excellent, very good, good, fair or poor, compared to others the same age. We then asked them directly whether they had been diagnosed with various illnesses, including asthma, chronic bronchitis, emphysema, various heart ailments, cancer, high blood pressure, and stroke. Finally, we administered all of the questions from Short Form 36 (SF-36), a questionnaire commonly used in medical research (Ware et al., 1997). Responses to the SF-36 questions are summarized using index scores for physical and psychological well-being and have been shown to correlate well with the severity of various chronic diseases (Bousquet et al., 1994).

Table 4 displays descriptive statistics for the health status of the respondents. Because participants in the Canada study had to be well enough to travel to a centralized facility in order to complete the questionnaire, this sample is 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 percent) compared to the U.S. sample (53.1 percent). Furthermore, the fractions of the sample with various types of chronic illness are slightly higher in the US.[4] While 3.4 percent of the

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

Table 4.
Comparison of Respondent Health Status Across the Canada and U.S. Studies

<table>
<tr><th rowspan="2">Health Condition</th><th colspan="3">Sample mean or percent</th></tr>
<tr><th>CANADA</th><th colspan="2">US</th></tr>
<tr><td>Has asthma</td><td rowspan="3">14 %</td><td rowspan="3">16 %</td><td>10 %</td></tr>
<tr><td>Has bronchitis</td><td>7 %*</td></tr>
<tr><td>Has emphysema</td><td>4 %</td></tr>
<tr><td>Has angina pectoris</td><td rowspan="3">(heart disease)
10 %</td><td rowspan="3">21 %</td><td>8 %</td></tr>
<tr><td>Has had a myocardial infarction (heart attack)</td><td>8 %</td></tr>
<tr><td>Coronary disease</td><td>7 %</td></tr>
<tr><td>Has had a stroke</td><td>--</td><td colspan="2">4 %</td></tr>
<tr><td>Has been diagnosed with cancer</td><td>3 %</td><td colspan="2">11 %</td></tr>
<tr><td>General health score from SF-36</td><td>70</td><td colspan="2">67</td></tr>
<tr><td>Physical functioning score from SF-36</td><td>81</td><td colspan="2">78</td></tr>
<tr><td>Vitality score from SF-36</td><td>63</td><td colspan="2">59</td></tr>
<tr><td>Role-emotional score from SF-36</td><td>81</td><td colspan="2">87</td></tr>
<tr><td>Mental health score from SF-36</td><td>76</td><td colspan="2">77</td></tr>
<tr><td>Rates own health as good or excellent, relative to others of the same age</td><td>57 %</td><td colspan="2">53 %</td></tr>
</table>

* chronic bronchitis

Hamilton respondents said that they had or had had cancer (a figure that is in line with the area's official health statistics), 11 percent of the U.S. study reported to have been diagnosed with cancer. Of the latter, about 80 percent were receiving or had received treatment. Despite these differences in self-reported illness, the health index scores created using the responses to the SF-36 questions are very similar.

C. Probability Comprehension and Acceptance of the Scenario.

Valuing mortality risk reductions through direct questioning techniques requires that the subjects understand risks. To test their comprehension of probabilities, we asked our respondents several questions relying on side-by-side grids of squares to convey the chances of dying for two people -- person A and person B – as noted earlier. The first question, which we refer to as the *probability test* question, asks simply 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

Table 5.
Comparison across Canada and U.S. Mortality Risk Studies:
Probability Comprehension

	Percent of the sample	
	CANADA	**U.S.**
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
• Follow-up "confirmation" question (FLAG5)	1.3	1.3
Other indicators of probability comprehension:		
• Fails both probability test and choice questions (FLAG1)	2.6	3.7
• Claims to understand probability poorly (FLAG6)	7.0	16.2

respondent would rather be. If respondents answer the probability test question incorrectly, another brief explanation of the concept is provided and the respondent is asked a second probability test question. Furthermore, should respondents indicate a preference for the person with the higher risk in the choice question, they are asked to confirm their selection following another brief explanation of grids.

Table 5 reports the results of the probability test and choice questions as well as other indicators of probability comprehension. The table shows that roughly 12 percent of the respondents answered the initial probability test incorrectly. However, following the brief explanation of the error, a much smaller portion provided an incorrect answer to the second probability test (1.1 percent in Canada and 1.8 percent in the U.S.). Likewise, a similar proportion initially indicated a preference for the person with the higher risk in the probability choice question (11 percent in the U.S. and 13 percent in Canada). However, most of these respondents, as before, corrected their answer when prompted, with only 1.3 percent of the samples confirming that they would prefer to be the person with the higher risk of death.

Combining the responses to the test and choice questions, around three percent 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. Interestingly, most of these respondents were among those who admitted having a poor understanding of the concept of probability in debriefing questions at the end of the survey. Notably, the fraction of the sample that so assessed their comprehension of probabilities is more than twice as large in the U.S. study as in the Canada study.

In table 6 we examine the acceptance of the risk-reducing product/action and the scenario presented in the questionnaire. Roughly 20 to 25 percent of the respondents did not believe the baseline risk figures that were presented to them. Most of the respondents who disputed such figures 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/action with a large fraction of these respondents stating that these doubts influenced their WTP for the product/action itself.

Furthermore, a larger proportion of the Hamilton respondents voiced concern about possible side effects of the product/action compared to the U.S. sample (25 percent and 15 percent respectively), and admitted thinking about other benefits of the product (49 percent versus 37 percent). In the U.S. study, respondents were probed further about the kinds of additional benefits they had in mind. Other benefits for these respondents included additional benefits to themselves (40 percent), benefits to other people—such as family members—of their living longer (25 percent) and improved health for other people (26 percent).

In Hamilton, 26 percent of the respondents noted that they did not consider whether they could afford the product/action when answering the payment question. In the U.S., the fraction of the sample reporting such a behavior was even higher (37 percent). As discussed in Krupnick et al. (forthcoming), these responses were common among people that were not willing to pay anything for the product. We conclude that most of these respondents had already ruled out the

Table 6. Comparison across Canada and US studies: Acceptance of the Product and Scenario

	Percent of the sample	
	CANADA	**US**
Did not believe the risk figures (FLAG7)	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 /action (FLAG8)	30.6	33.5
• Doubts about effectiveness influenced WTP (FLAG9)	19.7	21.1
Thought about possible side effects of the product (FLAG10)	25.0	15.4
Thought of other benefits of the product (FLAG11)	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/action (FLAG15)	26.0	37.4
Did not understand the timing of the payments (FLAG16)	13.0	14.0

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

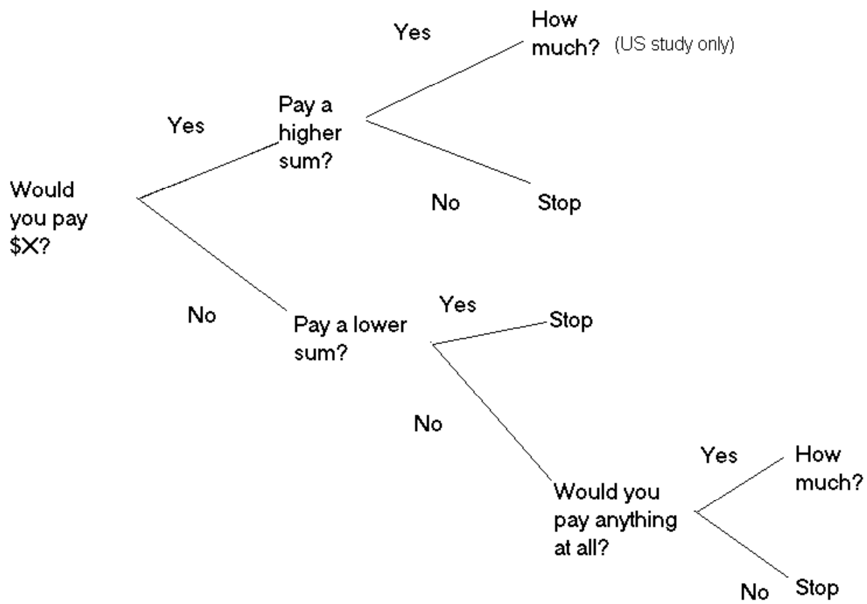
purchase the product/action making the price irrelevant to their decision. Finally, about 14 percent of the respondents revealed that they had not understood that they would be required to make a payment every year for 10 years in order to receive the product and secure its risk-reducing benefits.

IV. Willingness to Pay Results

A. Responses to the payment questions and WTP figures

For each risk reduction to be valued, respondents were asked a minimum of two questions. Respondents were asked an initial dichotomous choice question querying them about a dollar amount randomly chosen from four pre-determined values (see Table 2). Those respondents who answered in the affirmative were queried about their willingness to pay a higher dollar amount, while those who declined were given a lower dollar amount. A final open-ended question was asked of those respondents who gave "yes-yes" or "no-no" responses. The structure of the payment question is shown in Figure 1.

Figure 1: Structure of Payment Questions



Payment Question and Follow-ups

As is often the case with this type of valuation approach, a relatively high proportion of respondents in both samples indicated that they were not willing to pay anything for the product/action we described. Using probit models, we attempted to identify determinants of the zero WTP responses. In the right-hand side of our probit equations, we included variables known to influence baseline risks, including the respondent's gender, age, and race (for the U.S. study only), as well as income, and education. We also included dummy variables capturing perceptions of the risk figures and interpretations of the risk-reducing scenario, in addition to other variables measuring health status.

In short, we found that very few of these variables had significant coefficients. Specifically, we found that our Canadian subjects were significantly more likely to have zero WTP if they also reported that they did not consider whether or not they could afford the payment when responding to the payment questions. Interestingly, Canadian respondents with high mental health scores from SF-36 were significantly less likely to have zero WTP. Because high mental health scores imply respondents with less psychological distress, we interpreted this finding as consistent with the notion that increasing one's chance of survival is highly valued when one has a rosier view of life. We were, therefore, surprised to find that, in our U.S. study, high mental health scores related *positively* to the likelihood of having zero WTP for a given risk reduction. U.S. males were also more likely to indicate zero WTP. Again, those respondents who also said they did not consider whether they could afford the payments were more likely to report zero willingness to pay.

Before we estimate a statistical model of WTP, it is important to establish criteria that the 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 certain assumptions willingness to pay should be near-proportional to the size of the risk reduction. To check if the first criterion is met, we use only the responses to the initial payment question. For the second and third requirements, on the other hand, we utilize the responses to the initial payment questions as well as the subsequent round of follow-ups, fit a formal statistical model of WTP, and use the latter to produce estimates of mean WTP for the specified risk reductions.[5]

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:

$$\log L = \sum_i \log\left[F(WTP_i^U;\theta,\sigma) - F(WTP_i^L;\theta,\sigma)\right] \tag{1}$$

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.

Figures 2 and 3 show clearly that the first requirement is easily met in both the Canada and U.S. studies: the percentage of "yes" responses clearly declines with the bid amounts used for the initial payment questions. For the 5 in 1,000 risk reduction (wave 1), around 73 percent 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). Comparatively smaller proportions are willing to pay the highest bid amounts (26 percent in Canada and 35 percent in the U.S.). 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 percent (for C$100) to 20 percent (C$1100) in Canada, and from 44 percent (for $70) to 13 percent ($725) in the U.S.

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

[5] In this paper, we therefore elect not to use the responses to the open-ended questions. In Canada, 19.5 and 36.8 percent of the respondents indicated that they were not willing to pay anything at all for the 5 in 1,000 and 1 in 1,000 risk reductions, respectively, from wave 1 and wave 2. The corresponding U.S. figures are 22.0 and 37.7 percent.

expect that, when a formal estimate of mean WTP is obtained, WTP for the two risk reductions will be found to be significantly different.

Estimates of median and mean *annual* WTP based on equation (1) without using covariates are reported in Table 7.[6,7] We exclude from our models those respondents who failed both the initial probability test and probability choice questions described above, whether or not they subsequently corrected their answers (FLAG1=1).

[6] All figures are expressed in US dollars, based on a purchasing power parity for 1.25 US dollars per Canadian dollar.

[7] 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 the use of the estimates. The compute standard errors around mean WTP, we drew samples of 20000 observations from a multivariate normal distribution centered on the estimated Weibull parameters and with covariate matrix equal to the inverse of the information matrix of log likelihood (1). We use the values drawn from this distribution to compute 20000 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 8.

Figure 2:

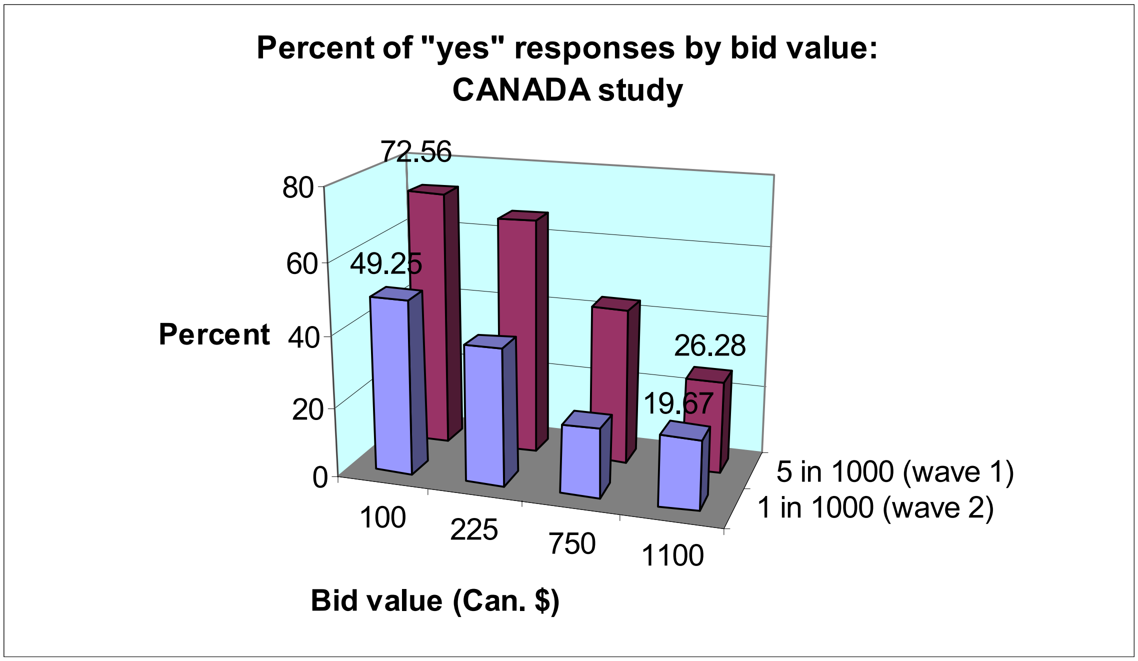


Figure 3:

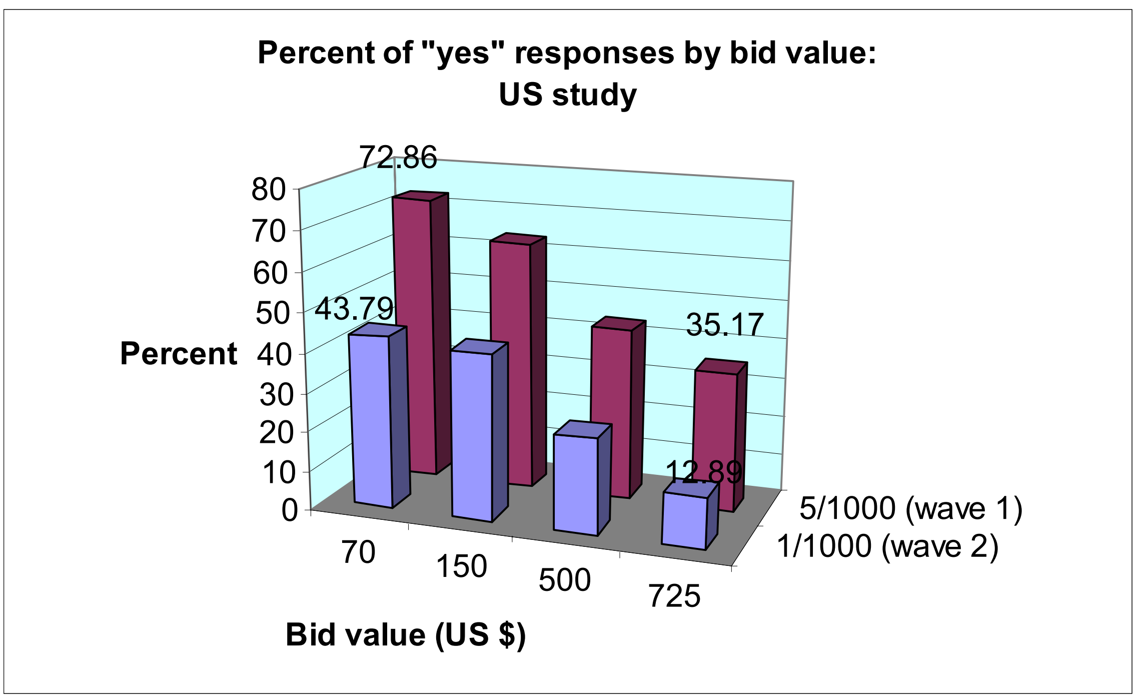


Table 7.
Mean and Median WTP for Reduced Mortality Risk (U.S. dollars*)

	Canada		U.S.	
	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 1000 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?	Yes	Yes	Yes	Yes
• Wald Test	23.74	2.65	56.10	6.32
• p-value	<0.0001	0.10	<0.0001	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 FLAG1=1 deleted). Sample from the U.S. excludes people older than 80 years of age.
* In U.S. dollars, using purchasing power parity of $1.25 Canadian per $1 US.

We estimate mean WTP for the 5 in 1,000 risk reduction from wave 1 of the Canada sample to be $466 (U.S. dollars), with a standard error around the mean of $33.6. Wave 2 of the Canada sample holds a mean WTP value of $370, with a standard error of $48.6.[8] A Wald test indicates that these two mean WTP figures are marginally statistically different (Wald statistic 2.65; p-value = 0.10), only just satisfying the so-called "scope test." Mean WTP, however, is not strictly proportional to the size of the risk reduction. The ratio of the mean WTP figures is 1.3, and not 5, and a Wald test clearly rejects the hypothesis of proportionality to the size of the risk reduction (Wald statistic 32.0, p-value < 0.0001).

A similar story holds for the U.S. sample. The mean WTP for the 5 in 1,000 risk change of $770 (s.e. $86.9) is statistically different from the mean WTP for the 1 in 1,000 risk reduction

[8] The estimates reported in table 7 are based on excluding from the sample failed both the initial probability test question and the probability choice question. We experimented with many other criteria for excluding respondents from the usable sample based on their explicit or stated poor comprehension of probability, but found that mean WTP changed very little.

of \$483 (s.e. \$74.0), with the Wald statistic equal to 6.32 (p=0.01). Once again the null hypothesis of proportionality of mean WTP with the size of the risk change is soundly rejected (Wald statistic 18.7, p-value < 0.0001).

Holding the risk reduction the same, the WTP figures for the Canada sample do not differ appreciably from the U.S. figures. The Wald statistics are 0.17 (p-value 0.67) for the 5 in 1,000 risk reduction, and 1.05 (p-value 0.30) for the smaller risk change.

Median WTP estimates are also reported in Table 7. While median WTP increases significantly with the size of the risk reduction, satisfying the scope test, the median WTP figures do not exhibit strict proportionality with size of the risk reduction. The ratio between the median WTP values for the two risk reduction, however, is greater than that for the mean WTP figures (1.9 in Canada and 3.2 in the US).

In Table 8, we examine the effects of respondent confidence on median WTP estimates. After querying respondents regarding their WTP for each risk reduction, we asked respondents to indicate the level of certainty they had in their responses on a scale from 1 to 7. This table is based on grouping respondents by how confident they felt about their WTP responses, categorizing certainty levels of 6 and 7 as "high confidence" and all other certainty levels as "low confidence."

As before, regardless of the stated degree of confidence expressed by the respondent, WTP estimates for the risk reductions of different magnitudes remained statistically significantly different, with the WTP for the large risk reduction substantially larger than that for the small reduction. Interestingly, when attention is restricted to those respondents who reported a high degree of certainty, the median WTP estimates for the two risk reductions are near-proportional. The ratio between the median WTP amounts is 1.99 for Canada and 8.99 for the US, and both figures are not statistically different from 5.

The estimates of implied Value of a Statistical Life (VSL) are displayed in Table 9. These are calculated using the mean annual WTP (from Table 7), and dividing it by the *annual*

Table 8.
The Effect of Confidence on Median WTP for Reductions to Mortality Risk (U.S.$)

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 FLAG1=1 deleted; respondents older than 80 excluded).

Table 9.
Implied Estimates of the Value of a Statistical Life
(U.S. $)

Magnitude of Risk Change	Canada		U.S.	
	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 computed using on annual risk changes, i.e. 5 in 10,000 and 1 in 10,000

risk reduction implied by the product/action described to the respondent.[9] Given the similarity of the WTP figures from the Canada and U.S. studies, it is not surprising that the VSLs are also very similar across the two studies.

[9] 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.

The VSL estimates for Canada range from \$506,000 and \$933,000, when computed using WTP for the 5 in 1,000 risk reduction, compared to \$700,000 and \$1.54 million for the U.S. When based on WTP for the 1 in 1,000 risk reduction, the VSL estimates climb, reaching upwards of \$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. While 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 US EPA in its recent policy analyses.

B. WTP, Age, Health and Income

In this section, we examine the relationship between WTP, age, health, and income. To motivate our analysis and the selection of the independent variables to be included in the regression models, we reason that the life-cycle model predicts that WTP at age j to reduce one's risk of dying is:

$$WTP_{j,j\,j} = (1-d_j)\sum_{t=j+1}^{T}\pi_{j,t}(1+r)^{j-t}\frac{u(X_t)}{\partial u/\partial X_t} \quad (2)$$

where d is the probability of dying during period j, $\pi_{j,t}$ is the probability of surviving until period t, given that one is alive at j, *u* is the utility function, and X_t is consumption in period t (Cropper and Sussman, 1990).

According to equation (2), age influences WTP in two possible ways. First, it affects the future probabilities of survival (with and without the risk reduction). It may, in addition, influence the rate at which individuals trade off income for the probability of survival—in other words, the last term of (2).

In the policy debate, it is sometimes argued that VSL should be adjusted for age. Specifically, some observers note that if the lives of the people saved by the policy are those of older people, these people should be assigned a lower VSL because of their shorter remaining life. This is akin to focusing to the sum of the future survival probabilities, π, which decreases with current age j. This reasoning, however, ignores the possibility of increasing marginal values for future years of life.

Under certain assumptions, and for specified values of the parameters entering in the utility function, economic theory predicts that WTP should first rise and then decline with age (Shepard and Zeckhauser, 1982).

Similar considerations hold for individual health status. The baseline risks should be higher for people in poor health, and some observers argue that people in poor health value less increased probabilities of survival (or each additional year of life) if survival implies poor quality of life. On the other hand, health can influence the rate at which people tradeoff income for longevity, implying that the net effect of (age and) health on WTP is an empirical issue.

We present results of interval-data Weibull regressions of WTP on several individual characteristics, including age and health, in Table 10 for the 5 in 1,000 risk reduction based on wave 1 for both the U.S. and Canadian samples. The Weibull regressions posit 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. This is, effectively, an accelerated life model.

In the first specification, as shown in table 10, we formed dummies denoting whether the respondent fell in the 50 to 59 age group, 60 to 69, and 70 and older. When these dummies are included in the right-hand side of the Weibull model, the coefficients of the age 50-59 and 60-69 age group dummies are indistinguishable from that of the 40-49 age bracket (captured by the intercept). The coefficient of the oldest age bracket, however, is significantly lower for the Canada sample. This remains true when other covariates are included in the regression. No age effects were found using the U.S. sample.

Table 10. Weibull Interval-Data Regression Results for Canada and U.S.
(Standard Errors in Parentheses)

Variable	Canada			U.S.		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Intercept (ages 40 to 49)	6.47** (0.08)	6.96** (0.36)	6.84** (0.36)	6.39** (0.13)	6.20** (0.84)	6.85** (0.90)
Ages 50 to 59	0.10 (0.15)	0.09 (0.15)	0.12 (0.15)	0.05 (0.21)	0.06 (0.24)	-0.03 (0.23)
Ages 60 to 69	-0.37 (0.46)	-0.38 (0.47)	-0.20 (0.47)	0.03 (0.22)	-0.21 (0.24)	-0.30 (0.24)
Ages 70 and older	-0.39** (0.20)	-0.55** (0.21)	-0.55** (0.21)	-0.21 (0.23)	-0.18 (0.28)	-0.27 (0.28)
Male	--	-0.19 (0.13)	-0.06 (0.13)	--	-0.51** (0.18)	-0.49** (0.18)
Black	--	--	--	--	0.69** (0.36)	0.75** (0.36)
Bottom 25% of distribution of income (=1 if income < C$24,500)	--	-0.23 (0.17)	-0.35** (0.17)	--	--	--
Income per Person	--	--	--	--	$2x10^{-5}$** ($7x10^{-6}$)	$2x10^{-5}$** ($7x10^{-6}$)
Education (Years of Schooling)	--	-0.03 (0.02)	-0.03 (0.02)	--	-0.05 (0.04)	-0.06* (0.04)
Cardiovascular disease	--	0.27 (0.23)	0.19 (0.23)	--	0.04 (0.26)	0.22 (0.26)
Chronic lung disease	--	-0.01 (0.16)	-0.12 (0.16)	--	0.31 (0.24)	0.14 (0.24)
High blood pressure	--	0.13 (0.17)	0.15 (0.17)	--	0.33 (0.21)	0.33 (0.20)
Cancer	--	0.60* (0.37)	0.57 (0.37)	--	0.19 (0.31)	0.16 (0.31)
Family history of chronic illness (exluding cancer)	--	0.22* (0.13)	0.25** (0.13)	--	0.83** (0.31)	0.70** (0.30)
Family history of cancer	--	--	--	--	0.60** (0.28)	0.32 (0.29)
ER visit in last five years or hospitalization in last year	--	-0.17 (0.21)	0.01 (0.21)	--	-0.07 (0.32)	0.05 (0.33)
No Insurance	--	-0.04 (0.16)	-0.08 (0.15)	--	0.35 (0.29)	0.29 (0.29)
Does not believe risk figures (dummy) (Flag7)	--	--	-0.07 (0.16)	--	--	-0.29 (0.22)
Does not believe the product would be effective (Flag8)	--	--	-0.20 (0.14)	--	--	-0.18 (0.18)
Thought there would be side effects (dummy) (Flag10)	--	--	0.08 (0.15)	--	--	-0.38* (0.23)
Other benefits (dummy) (Flag11)	--	--	0.58** (0.13)	--	--	0.07 (0.20)
Did not consider if could afford payments (dummy) (Flag15)	--	--	-0.62** (0.15)	--	--	-1.02** (0.19)
Did not understand timing of payments (dummy) (Flag 16)	--	--	0.05 (0.19)	--	--	0.07 (0.25)
Scale parameter	1.27 (0.06)	1.26 (0.07)	1.22 (0.06)	1.44 (0.09)	1.38 (0.10)	1.34 (0.09)

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.

Based on these results, we ran a parsimonious regression model that includes the intercept and a dummy variable taking on a value of one if the respondent is 70 years of age or older. The results are reported in Table 11. Median WTP for respondents is $262 (U.S. dollars) for Canadian respondents of ages 40 to 69 years, and drops by approximately 25 percent to $201 for respondents of ages 70 years and older. These two median WTP values are statistically different at the 5 percent level. In comparison, median WTP for U.S. respondents aged 70 years and older was only about 20 percent lower than that for the younger age group. This difference, however, did not prove to be statistically significant. We conclude that the impact of age on WTP is modest, and that the adjustment of VSL for age has limited empirical support.

Regarding respondent health, we experimented with all available measures of health status. The relationship between physical health status and WTP differs across the two studies. In the Canada sample, for instance, the only health effect of import appears to be cancer. Respondents so affected had a median WTP (reported in table 11) equal to $510 (U.S. dollars), compared to $308 for a person without cancer. Care is necessary when interpreting these results, however, because only a very small portion of the total Canadian sample has or has had cancer (26 respondents). Furthermore, these people were well enough to travel to the facility to take the survey, and may therefore not be representative of cancer patients or survivors in the population.

In the U.S. study, on the other hand, although persons with a cancer history were more numerous, their WTP was not different from that of other respondents. Instead, it was histories of chronic lung disease and high blood pressure that had a statistically significantly effect on willingness to pay values. Interestingly, however, the effects of health history on WTP do not withstand the inclusion of variables controlling for the respondents' acceptance or understanding of the scenarios presented.

More important than respondent health in either sample, it appears, is *family* history of chronic illness. In both samples, family history of chronic illness other than cancer (among

Table 11.
Median WTP for Respondents of Specified Ages and Health Status.*
(U.S. dollars, Standard errors in parentheses)

Characteristic	**CANADA**	**U.S.**
Age 40 to 69 years	262 (19.1)	359 (31.8)
Age 70 years and older	201 (35.1)	283 (59.4)
Resp. with Chronic illness**	318 (32.6) n=251	376 (40.6) n=305
Respondent with no chronic illnesses	314 (28.4) n=365	319 (39.5) n=251
Respondent with CARDIO	302 (73.0) n=65	384 (69.3) n=119
Respondent with No CARDIO	317 (22.5) n=549	241 (31.1) n=437
Respondent with chronic respiratory illness	344 (49.3) n=124	489 (89.3) n=95
Respondents with no chronic respiratory illness	309 (23.8) n=492	325 (29.3) n=461
Respondent has or has had Cancer	510 (114.4) n=26	407 (122.0) n=59
No cancer	308 (21.6) n=590	339 (29.5) n=477

* Respondents with FLAG1=1 deleted.
** Definition of chronic: (for Canada) respondent has one or more of the following: asthma, emphysema, high blood pressure, heart disease, or cancer; (for the U.S.) respondent has one or more of the following: asthma, emphysema, chronic bronchitis, any of the CARDIO conditions, or cancer.
*** 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.

parents and/or siblings) was statistically significant at the 5 percent level in both specifications in which they were included.

E. WTP for future risk reductions

Our last research question investigates the amount people are willing to pay for specified risk reductions with the payment beginning immediately but with the risk reduction incurred in the future. Of the three commodities faced by respondents in the survey, this is the one most representative of the type of risk reduction resulting from environmental policy. We report WTP for this future risk reduction in Table 12 below. The table shows that both mean and median WTP values for the future risk reduction are lower than WTP estimates for an immediate risk reduction of comparable size. This result holds regardless of the age of the respondent at the time of the immediate risk reduction.

It is important to note, however, that, in all interviews with respondents less than 60 years of age, this future risk scenario was the last the respondent faced. We combined the two waves of data, after checking that WTP for the future risk reduction did not vary across the two waves due to possible order/sequencing effects.

It is also important to note that, because of the placement of the future risk questions, it is impossible to conduct an external scope test that would show, across respondents, that future risk reductions are valued less than immediate ones of the same size.

VI. Conclusions and Implications for Policy

Traditional estimates of the willingness-to-pay for mortality risk reductions are seldom conditioned on the age and health status of the respondent. Our survey is designed to provide credible estimates of such values that are applicable to mortality risk reductions associated with environmental policy. These values could also be used in benefit-cost analyses of programs that primarily benefit older persons, many of whom may be in poor health.

We find that for persons aged 40 and older sampled using random digit dialing techniques in Hamilton, Ontario, and in the U.S., WTP for risk reductions varies significantly with the size of the reduction. Mean WTP for an annual reduction in risk of death of 5 in 10,000

Table 12. Willingness to Pay for a Risk Reduction Beginning at Age 70
(U.S. dollars, standard errors in parentheses)

Commodity Being Valued	Canada		U.S.	
	Median WTP	Mean WTP	Median WTP	Mean WTP
Risk reduction at age 70 (both waves)	63 (9.3)	246 (24.5)	169.17 (13.67)	350.43 (24.48)
	N=638		N=702	
Compare with…				
Risk reduction of same size starting immediately (ages 40-64; wave 1)	326 (25.0)	622 (52.8)	366.05 (35.79)	806.47 (113.85)
	N=506		N=395	
Risk reduction of same size starting immediately (ages 70 and over; wave 1)	251 (68.6)	375 (57.8)	314.90 (49.49)	684.83 (128.83)
	N=67		N=161	

Note: Results based on cleaned data -- respondents with FLAG1=1 were excluded. Only respondents aged less than 65 years were asked about risk reductions beginning at age 70.

is about 1.5 times WTP for an annual risk reduction of 1 in 10,000 (1.3 for Canada and 1.6 for the U.S.). WTP is, therefore, sensitive to the size of the risk reduction, but not strictly proportional to it. WTP values are very similar across the two samples, and translate into values of a statistical life of approximately $4,830,000 for a 1 in 10,000 annual risk reduction and $930,000 for a 5 in 10,000 annual risk reduction.

We find that WTP does not vary much by age up to 70. Mean WTP for the 5 in 1,000 risk change remains approximately constant age until about age 70, decreasing by about one-third thereafter. This latter WTP is probably the most relevant one for use in valuing most of the lives "saved" from air pollution reductions. The effect is significant in Canada but not in the U.S. study.

Regardless of the measure of physical health status used (with few exceptions), WTP does not vary appreciably with physical health status either—an important result for environmental policy, since older people and people with chronic conditions are often the beneficiaries of improvements in environmental quality. We do, however, find that in the Canada study individuals with cancer are WTP over 60 percent more for a mortality risk reduction than their counterparts without cancer. By contrast, individuals in the U.S. study are willing to pay more for the risk reduction if they have a heart ailment.

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 (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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