Effects of Disease Type and Latency on the Value of Mortality Risk

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Abstract

We evaluate the effects of disease type and latency on own willingness to pay (WTP) to reduce environmental risks of chronic, degenerative disease. Contingent-valuation data were collected from approximately 1,250 respondents in Taiwan. These data suggest the existence of a “cancer premium:” WTP to reduce risk of cancer is estimated to be about 30 percent larger than WTP to reduce risk of a similar chronic degenerative disease. The value of risk reduction also depends on the affected organ, environmental pathway, or payment mechanism: WTP to reduce risk of lung disease due to industrial air pollution is estimated to be twice as large as WTP to reduce risk of liver disease due to contaminated drinking water. Finally, we find that WTP is insensitive to the latency period between exposure to environmental contaminants and manifestation of disease. This insensitivity suggests that respondents anticipate their value per statistical life will grow over time at a rate about equal to their discount rate.

Keywords: health risk, contingent valuation, willingness to pay, value per statistical life, cancer, latency, Taiwan

JEL: I18, D18, D69, D81, J17

1. Introduction

Many environmental regulations are directed toward reducing risks of cancer and other disease. Yet most of the empirical literature on valuing health risk relies on estimates of the compensating wage differentials that workers receive for bearing risks of fatal injury in the workplace (Viscusi, 1993). The applicability of these wage-differential estimates to changes in environmental health risks is uncertain. Environmentally-induced cancer and other diseases differ from occupational fatal injuries in several dimensions that may affect preferences. Two that may be of particular importance are (1) the difference in latency between exposure to the hazardous condition and adverse health effects, and (2) dread or other factors that lead to greater fear of cancer than of other causes of fatality (Revesz, 1999; Sunstein, 1997). In addition, because of the great public attention given to cancer, there may be differences in concern about cancer and other degenerative, fatal diseases.

We use contingent valuation (CV) to test for effects of disease type and latency on individual willingness to pay (WTP) to reduce risks of developing a fatal disease through exposure to environmental pollution. We compare WTP to reduce risks of cancer and of other chronic degenerative diseases that may result from exposure to environmental contaminants. Because the consequences of developing cancer are more similar to those of other chronic degenerative disease than they are to acute trauma in a workplace or other accident, our estimates of the effect of disease type on WTP are likely to understate any difference in WTP between cancer and trauma. Data were collected from 1,248 respondents in Taiwan. We find evidence that there is a statistically significant "cancer premium," that WTP depends on the affected organ or environmental pathway, and that WTP is not significantly related to the latency of the disease.

In the following section, we provide an overview of the economic theory and previous empirical results concerning the effects of disease type and latency on willingness to pay for reductions in mortality risk. The empirical methods are described in Section 3, results are in Section 4, and Section 5 concludes.

2. Economic Theory of WTP to Reduce Mortality Risk

The economic approach to valuing mortality risk was developed by Drèze (1962), Schelling (1968), and Jones-Lee (1974). The individual's rate of tradeoff between wealth and risk in a specified time period (e.g., the current year) is characterized by his marginal rate of substitution between mortality risk p and wealth or income w. The marginal rate of substitution $\frac{dw}{dp}$ (holding utility constant) is called the "value per statistical life" (VSL).

VSL is not a universal constant but varies by individual and circumstance. The standard economic model of preferences for wealth and mortality risk (Jones-Lee, 1974; Weinstein et al., 1980; Drèze, 1962) assumes that an individual's welfare can be represented as

$$EU(p, w) = (1 - p)\, u_a(w) + p\, u_d(w) \qquad (1)$$

where p is the individual's chance of dying during the current period and $u_a(w)$ and $u_d(w)$ represent his utility as a function of wealth conditional on surviving and not surviving the period, respectively. The function $u_d(\bullet)$ incorporates the individual's preferences for bequests and can incorporate any financial consequences of dying (such as medical bills or life-insurance benefits). In this one-period model, wealth and income are treated as equivalent, but the difference between them can be important in multiple-period models.

The individual's VSL is derived by differentiating equation (1) holding expected utility constant to obtain

$$VSL = \frac{dw}{dp} = \frac{u_a(w) - u_d(w)}{(1-p)u_a'(w) + pu_d'(w)} = \frac{\Delta u(w)}{Eu'(w)} \qquad (2)$$

where prime indicates first derivative.

The numerator in equation (2) is the difference in utility between surviving and dying in the current period. The denominator is the expected marginal utility of wealth, i.e., the utility associated with additional wealth conditional on surviving and dying, weighted by the probabilities of these events. Assuming that life is preferred to death and that greater wealth is preferred to less, both numerator and denominator are positive and so VSL is positive. If the marginal utility of wealth is non-negative, and greater in the event of survival than death (i.e., $u_a'(w) > u_d'(w) \geq 0$), then VSL increases in mortality risk

p. Weak risk aversion with respect to wealth, conditional on survival and on death (i.e., $u_a'' \leq 0$, $u_d'' \leq 0$), is a sufficient condition for VSL to increase with wealth.

Accounting for Latency

In equation (2), VSL is defined in terms of wealth and mortality risk in a single period. Many environmental risks are characterized by a latency period between the time an individual is exposed to an agent and the time when he may die from its toxic effect. Since preventive measures must be undertaken before the exposure occurs, there is often a need to determine WTP now to reduce the risk of fatality in a future period.

Standard economic theory suggests that the appropriate procedure to account for latency is to value the risk change using the VSL representing the individual's value when the risk manifests, and to adjust for the time-value of money and the chance that the individual will die before then (Cropper and Sussman, 1990; Cropper and Portney, 1990). The adjustment is made by discounting the future value of the risk reduction back to the time when the expenditure must be incurred (at the individual's rate of interest). For example, assume that pollution-control equipment that could be installed today would reduce an individual's risk of dying from cancer by 1 chance in 100,000, that the cancer would prove fatal 20 years after exposure, that his VSL in 20 years will be $8 million, and that the individual can earn a 5 percent annual return on investments. In 20 years, he would be willing to pay $80 to reduce a contemporaneous fatality risk of 1 in 100,000. The amount he would be willing to pay now is the present value of $80, about $30 (= $80 x 1.05^{-20}). This amount should be multiplied by the probability that the individual will survive the intervening 20 years, since the cancer-risk reduction is of no benefit in the event that he dies of other causes before the environmental pollutant could have killed him. In many cases, this survival factor is much less important than the discount factor. For the average American, the probability of surviving 20 years is greater than 0.7 if the individual is younger than 55 (National Center for Health Statistics, 1998).[1]

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[1] This example considers only the fatality risk. The individual would presumably be willing to pay an additional amount to reduce the risk of cancer-related morbidity.

The difference between an individual's current and future VSL depends on two factors: he will be older, and the date will be later. The effect of age has been examined in theoretical models and, to a limited extent, by empirical studies. Theoretical models (e.g., Shepard and Zeckhauser, 1984; Rosen, 1988; Ng, 1992) represent the individual's lifetime utility as the expected present value of his utility in each time period. Utility within a period depends on consumption, which is limited by current income, savings and inheritance, and ability to borrow against future earnings. The individual seeks to maximize lifetime utility by allocating his wealth to consumption, savings, and reductions in current-period mortality risk.

Two factors influence the life-cycle pattern of VSL. First, the number of future life years at risk declines as one ages, so the benefit of surviving the current period (the numerator in equation (2)) declines. Second, the opportunity cost of spending on risk reduction (the denominator in equation (2)) also declines with age as savings accumulate, the investment horizon approaches, and the current risk p increases. The net effect of these changes may cause VSL to fall or rise with age (Ng, 1992; Hammitt, 2000a).

In models that assume an individual can borrow against future earnings, VSL declines monotonically with age. For example, Shepard and Zeckhauser (1984) calculate that VSL for a typical American worker falls by a factor of three from age 25 to age 75. If individuals can save but not borrow, VSL rises in early years as the individual's savings (and earnings) increase before it ultimately declines. In this case, Shepard and Zeckhauser find that VSL peaks near age 40 and is less than half as large at ages 20 and 65.

Ng (1992) argues that the rate at which individuals discount their future utility is likely to be smaller than the rate of return to financial assets, whereas Shepard and Zeckhauser (1984) assume these rates are the same. If the utility-discount rate is smaller than the rate of return, individuals should save more when they are young and consume more when old. Under these conditions, VSL may not peak until age 60 or so (Ng, 1992). Even if individuals discount future utility at the rate of return, younger people who are prudent[2] might be anticipated to save more, and spend less on reducing mortality risk, because of the greater range of future financial contingencies they face.

Although many CV studies include age as one of several covariates in a regression model explaining WTP for risk reduction, these studies have not typically focused on estimating the effect of age on VSL. The results of these studies are somewhat contradictory, with several finding VSL increases with age (e.g., Gerking et al., 1988; Johannesson et al., 1997; Lee et al., 1997) and others finding VSL decreases with age (e.g., Buzby et al., 1995; Hammitt and Graham, 1999; Corso et al., 2001). Jones-Lee et al. (1985) included both linear and quadratic age terms in their regression models and concluded that VSL peaks at about the mean age in their general-population sample (which is not reported).

Two recent empirical studies are specifically directed toward estimating the effect of age on VSL. Krupnick et al. (2001) conducted a CV study of WTP for a hypothetical intervention that would reduce the respondent's risk of dying in the next 10 years by either 1 in 1,000 or 5 in 1,000. The sample was restricted to individuals aged 40 years and above. Krupnick et al. estimate that VSL is roughly constant for ages 40 – 69, and is about 30 percent smaller for individuals aged 70 and above. Smith et al. (2001) estimate compensating-wage differential estimates using data from the Health and Retirement Survey. Their estimates of VSL for individuals aged 51 – 65 are not sensitive to age and are comparable to standard estimates for younger populations.

The effect of calendar time on VSL has received relatively little attention in the literature, except to observe that if economic welfare grows over time, VSL would be expected to increase. The US Environmental Protection Agency (EPA) has sometimes accounted for the anticipated growth of income and VSL in regulatory impact assessments, especially when benefits extend across generations. For example, in evaluating the effects of restrictions on use of CFCs to protect stratospheric ozone, EPA assumed that VSL would grow at annual rates of 0.85 – 3.4 percent (EPA, 1987).

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[2] An individual is prudent if financial risk increases his expected marginal utility of income, which requires that the third derivative of his utility function for wealth is positive (Kimball, 1990).

The rate at which VSL increases with income growth (the income elasticity[3]) is not well estimated. The primary source of VSL estimates—compensating-wage-differential studies—usually do not provide information about the income elasticity, because the wage rate is the dependent variable and so income cannot be used as an explanatory variable.

The income elasticity can be estimated by meta-analysis of compensating-wage-differential studies where the study populations differ in income, risk, and other factors, but these studies lack power. Liu et al. (1997) estimated the relationship between VSL, income, and workplace-fatality risk for a sample of 17 compensating-wage-differential studies in the US and other industrialized countries. Their point estimate for the income elasticity is 0.54, with a standard error of 0.85. Mrozek and Taylor (2002) expanded on this approach by including multiple VSL estimates from each of 33 wage studies and controlling for the average wage, risk, and other factors. They report four specifications yielding estimated elasticities of VSL with respect to the wage rate between 0.36 and 0.49 with standard errors of 0.20 and above.

CV studies elicit WTP directly and can be used to estimate the income elasticity of VSL. Typical estimates range from 0.2 to 0.5. For example, Jones-Lee et al. (1985) estimated values of 0.25 to 0.44, Mitchell and Carson (1986) estimated 0.35, and Corso et al. (2001) estimated 0.41.

Several studies have attempted to empirically estimate the effect of calendar time and age on the benefits of public life-saving programs, by asking respondents to choose between hypothetical lifesaving programs that protect people of different ages or at different dates. These results do not necessarily reflect individual WTP to reduce different risks to oneself, since survey respondents are unlikely to compare programs solely in terms of their own private benefits. Horowitz and Carson (1990) estimated that respondents discounted for calendar time at rates of 5 – 12 percent for delays of three to five years. Cropper et al. (1994) estimated a somewhat larger rate of 17 percent for five

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[3] Carson et al. (2001) note that the income elasticity of demand and income elasticity of WTP are fundamentally different. The former describes how the quantity demanded

years, falling to 4 – 5 percent for delays of 50 – 100 years. Cropper et al. also asked respondents about programs to save people of different ages. Their results suggest that respondents most prefer to protect people in young middle age. Lives of 30 year olds were valued about 11 times more highly than lives of 60 year olds. For comparison, lives of 20 and 40 year olds were valued as equal to about eight and seven 60 year olds, respectively. These results are not sensitive to the age of the respondent.

Subramanian and Cropper (2000) asked respondents to choose between different public programs to reduce health risks, and then asked how much more effect (in terms of lives saved) the less preferred program would need to be to make the respondent indifferent between programs. In each case, the risks presented the same health endpoint but differed in delay until benefits would be achieved, voluntariness, controllability, and other factors. Using a multivariate regression to control for the effects of various factors, Subramanian and Cropper (2000) found that people discounted for delay. They estimated a marginal rate of substitution of –0.15, which implies that a 1.5 percent increase in the number of lives saved would compensate for a 10 percent increase in delay.

In summary, the effects of latency on WTP to reduce own mortality risk are unknown. In theory, latency increases WTP if individual VSL increases faster than the interest rate, and decreases WTP otherwise. Empirical studies have not resolved this ambiguity.

Magnitude of Cancer Premium

The value of preventing a fatal cancer is often considered to be greater than the value of preventing a fatal trauma in a workplace or transportation accident. Cancer is also frequently viewed as more threatening than other degenerative conditions, such as heart disease. A striking example is provided by the controversy over whether to encourage hormone replacement therapy for postmenopausal women. Therapy reduces risk of heart disease and hip fracture but increases the risk of breast and endometrial cancers. Because heart disease is five times more likely to kill a woman than is breast

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increases with income while the latter describes how WTP for a fixed quantity of a good changes as income increases.

cancer, the net effects of treatment are substantial with gains in life expectancy as large as three years (Col et al., 1997).

There are a number of differences between cancer and accidental fatalities that might affect relative WTP to reduce each risk, including the often protracted suffering from cancer before death and the knowledge with cancer that one's condition will deteriorate and lead to death. Despite the plausibility that there may be a "cancer premium," the empirical literature supporting this supposition is limited. There are a few studies that provide information about the relative value of reducing risks of cancer and of acute trauma (e.g., motor vehicle fatality) but no studies of which we are aware have compared the value of reducing risks of cancer and of other fatal disease.

Jones-Lee et al. (1985) asked respondents to choose between public programs that would reduce the number of people dying in the next year by 100 from one of three causes (motor-vehicle accidents, heart disease, and cancer), and to indicate how much they would voluntarily contribute to reducing the number of deaths from the cause they selected. A large majority of respondents (76 percent) chose to reduce cancer deaths, and the mean voluntary contribution was larger for cancer than for the other causes. Interpreting the mean contributions as estimates of WTP yields a VSL of £23 million for cancer, £13 million for heart disease, and £7 million for motor vehicle accidents.

Savage (1993) asked survey respondents to allocate a hypothetical $100 contribution to research intended to reduce risks of stomach cancer, household fires, commercial-airplane accidents, and automobile accidents. He found that respondents would allocate the largest amount to stomach cancer ($47) with much smaller amounts ($15 – $21) to the other risks. Although this study suggests greater WTP to reduce cancer risks, it does not measure individual WTP to reduce own risk. The value of research on methods to reduce risk of cancer (or the other fatality risks) depends on the probability that the research will identify interventions to reduce the risk, the magnitude of the risk reduction produced by the interventions, and the cost of implementing them. None of these parameters were specified, and so we cannot know what assumptions respondents made about them. In addition, the pattern of responses seems inconsistent with a measurement of WTP. The optimal response is to allocate all $100 to whichever risk the respondent believes will benefit most, since significant diminishing marginal efficacy of spending is implausible for contributions of $100.

McDaniels et al. (1992) conducted a CV study with only 55 respondents to estimate WTP for programs to reduce a wide range of health risks. The programs were described as public goods that would reduce risks to the relevant populations, not only to the respondent. The authors also elicited risk-perception variables, such as dread. They found that WTP to reduce risk was positively associated with dread.

Magat et al. (1996) used a risk-risk survey to elicit preferences for reductions in the risk of fatal automobile accidents and three chronic diseases: terminal lymph cancer, curable lymph cancer, and non-fatal nerve disease. The latency periods for the diseases were not specified in the survey instrument. The median respondent was indifferent between equal reductions in the probability of terminal lymph cancer and of fatal automobile accident, suggesting that there is no cancer premium or that any cancer premium is offset by an assumed difference in latency. The loss in utility due to curable lymph cancer and non-fatal nerve disease were estimated as 58 percent and 40 percent as great as the loss from a fatal automobile accident, respectively, which suggests that the utility loss from lymph cancer morbidity is 45 percent larger than the loss from nerve disease.

3. Contingent Valuation Survey

To estimate the effects of disease type and latency on WTP to reduce mortality risk, we conduct a contingent valuation (CV) survey. This section describes the survey instrument and sampling plan.

Survey Instrument

Respondents were questioned about their WTP to protect everyone in their household from each of four environmental health risks. The valuation questions are provided in the Appendix.

The risks vary among respondents and differ with respect to whether the disease is latent or acute, cancer or non-cancer, and whether it affects the lung or the liver. To enhance credibility of the scenarios, the risks associated with liver disease are described as being produced by a contaminant in the water supply, and the risks associated with lung disease are attributed to industrial air pollution. The payment mechanism differs accordingly. In the liver case, respondents are asked about their willingness to pay higher water bills to cover the cost of additional treatment at the water utility. In the lung case, respondents are asked about their willingness to pay higher prices for unspecified manufactured goods. Because the affected organ, environmental pathway, and payment mechanism are perfectly correlated in our design, we cannot distinguish their effects on WTP.

The risk reduction is described as an intervention to reduce current exposure to environmental contaminants. In the case of acute disease, respondents are told that, if they develop the stated disease, symptoms will begin within a few months and they will live only about two to three years longer. In the latent case, they are told they will not know if they were sufficiently exposed to develop the disease until they experience symptoms about 20 years in the future. After developing symptoms, the prognosis is identical to the acute case. The symptom description is relatively brief and is identical for cancer and non-cancer disease, and for liver and lung disease. Respondents may make additional assumptions about the specific symptoms from the disease name.

The magnitude of the risk reduction is also varied (either 2 or 8 per 100,000 per year). Under conventional economic theory, WTP for a small reduction in mortality risk is nearly linear in the magnitude of the risk reduction. The sensitivity of estimated WTP to magnitude of risk reduction can be used as a diagnostic test of the performance of the survey instrument (Hammitt and Graham, 1999; Hammitt, 2000b; Corso et al., 2001).

A split-sample design is employed in which respondents are randomly assigned to one of eight groups. All respondents are presented with four WTP questions, with the specific risk reductions varied among the sub-samples as detailed in Table A-1 (in the Appendix).

WTP is elicited using double-bounded discrete-choice questions. Each respondent is randomly assigned to one of five initial bid values (NT$50, 100, 200, 300, and 500).[4] These amounts represent additional monthly expenditures. There is one follow-up question, where the bid is equal to twice the initial bid if the respondent indicates he would be willing to pay the initial amount, and equal to half the initial bid otherwise. Each respondent receives the same initial bid for the first two questions (which pertain to a common organ/environmental pathway) and a different initial bid for the second two questions (which pertain to the other organ/environmental pathway). Hence estimates of the cancer premium and the effect of latency on WTP are not contaminated by any effect of the initial bid. Discrete-choice questions are often preferred to open-ended questions because they appear to be easier for respondents to answer. The referendum format is inventive-compatible and was recommended by the NOAA panel (Arrow et al., 1993). The double-bounded formulation is more efficient than a single-bounded dichotomous-choice formulation (Hanemann et al., 1991).

Survey Sample

The survey was conducted in May 2001 using random-digit-dial computer-assisted telephone interviewing in Taiwan. The sample was restricted to individuals aged 16 years and older with earned income and residing in Taipei city or county, Taoyuan county, or Kaohsiung city or county. In total, 1,248 interviews were completed.

Table 1 reports the definitions of all variables together with the sample means and standard deviations. The respondents' mean age is 39 years, with a range of 16 to 70. Three-quarters of the respondents are married and 55 percent are male. Almost one-quarter have obtained a college degree. The mean income is about US$14,000 per year. Average self-reported health is 3.6 on a five-point scale (where 5 is best). More than one-quarter of the respondents are current smokers, and about one-sixth report they suffer from respiratory illness. About two-thirds routinely use seatbelts when traveling in an automobile.

4. Results

WTP is modeled as a function of health risk attributes, the respondent's socio-economic characteristics, and variables characterizing risk attitudes. Regression models

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[4] The exchange rate was 34.5 New Taiwanese dollars per US dollar in May 2001.

are estimated using the maximum-likelihood method under the assumption that WTP is lognormally distributed.[5] This section reports estimates of how WTP to reduce health risks depends on the characteristics of those risks as well as on respondents' personal characteristics.

Effects of Health-Risk Characteristics on WTP

To determine how WTP depends on the characteristics of the health risks, we pool the responses to the four WTP questions and estimate a regression that includes only dummy variables for the various risk characteristics: cancer/non-cancer, latent/acute, liver/lung, and magnitude of risk reduction. The results are shown in column 1 of Table 2.

The estimated coefficients of the cancer and risk-magnitude variables are positive and significant, and that of the liver variable is negative and significant. WTP to reduce the risk of cancer is estimated as 31 percent higher than WTP to reduce the risk of an alternative disease. WTP to reduce the risk of liver disease from water pollution is estimated as 48 percent smaller than WTP to reduce the risk of lung disease from air pollution.

The estimated coefficient of the latent variable is negative, but not significantly different from zero. The point estimate suggests that WTP to reduce current exposure to environmental contaminants that may cause fatal disease is 5 percent smaller if the latency period before the disease manifests is 20 years rather than a few months. The insensitivity of WTP to latency suggests that respondents anticipate that their VSL will increase at a rate which just offsets their discount rate.

The estimated coefficient on risk magnitude allows us to reject the hypothesis that WTP is insensitive to the magnitude of risk reduction, but the magnitude of the coefficient is much smaller than the value ($\log(4) \approx 1.4$) required for estimated WTP to be proportional to magnitude of risk reduction. This result—that WTP is sensitive to risk magnitude, but less than proportionate—is consistent with most previous CV studies of

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[5] Using a χ^2 test we found that the lognormal model provides a better fit than the Weibull, exponential, and log-logistic models. The estimated coefficients using alternative

health-risk reduction (Hammitt and Graham, 1999) and may reflect inadequate communication of the quantitative risk reduction to survey respondents.

To control for question-order effects, we add three question-dummy variables (Q1 – Q3) to the variables describing the risk characteristics. As shown in column 2, estimated WTP is higher in the first and the second valuation questions than in the third and fourth. Payne et al. (2000) also found that question order has a significant effect on CV estimates of WTP. In their study, WTP for the first of five environmental goods was significantly larger than WTP for the remaining goods. Despite the significant effect of question order, controlling for this factor has a negligible effect on the estimated coefficients of the risk characteristics.

Effects of Respondent Characteristics on WTP

We add respondent characteristics to the risk-characteristic and question-order variables. We omit 96 observations for which personal characteristics are missing, so the sample size falls from 4,992 (1,248 respondents) to 4,608 (1,152 respondents). The estimates are reported in column 3 of Table 2.

Addition of the respondent characteristics has a minimal effect on the estimated coefficients of the risk-characteristic variables. The cancer premium is estimated as 28 percent and WTP to reduce the risk of liver disease due to water contamination is estimated as 50 percent smaller than WTP to reduce the risk of lung disease due to air pollution. The coefficient on latency remains negative and not significantly different from zero.

Socio-economic characteristics of the respondents are significantly associated with estimated WTP. The estimated income elasticity (0.54, standard error = 0.10) is consistent with estimates obtained in other studies of health risk (e.g., Jones-Lee et al., 1985; Mitchell and Carson, 1986; Liu et al., 1997; Corso et al., 2001; Mrozek and Taylor, 2002). Estimated WTP declines with age at a rate of about 1.8 percent per year, and college-educated respondents are estimated to value risk reduction about 23 percent more than respondents with less education. In contrast, there is no significant association

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distributions have the same signs.

between WTP and either sex or marital status. Moreover, WTP is not significantly associated with perceived health status or presence of respiratory disease.

Several variables are included as indicators of risk attitudes. Current smokers' WTP is estimated as 31 percent less than non-smokers' WTP, consistent with wage-differential studies which also show that smokers value safety less than non-smokers (Hersch and Viscusi, 1990; Hersch and Pickton, 1995; Viscusi and Hersch, 2001). Similarly, respondents who have residential air conditioning are estimated to be willing to pay 50 percent more than others (only 7 percent of the sample does not have air conditioning). In contrast, there are no statistically significant relationships between WTP and use of automobile seatbelts or having a home water filter.

WTP is associated with ethnicity and region. Ethnic Taiwanese have a significantly higher WTP than ethnic Chinese, and Taipei city residents have smaller WTP than residents of other areas.

Value per Statistical Life

The value per statistical life is calculated by dividing WTP for a reduction in risk by the magnitude of the reduction (equation (2)). Table 3 reports estimates of VSL as a function of disease type, latency, and organ/environmental pathway. These are calculated using the corresponding estimates of WTP from the regression models in Table 2 to predict median WTP at the sample mean of the covariates for each risk reduction, dividing by the risk reduction, then averaging over the small and large risk reductions.

Estimated VSL ranges between US$2.8 million and US$7.7 million. These values are comparable to US estimates (Viscusi, 1993), even though mean sample income (US$14,000 per year) is less than half the comparable US value. They are substantially larger than most previous estimates of VSL in Taiwan. Using compensating wage differentials, Liu et al. (1997) estimated a value of approximately US$0.5 million using actuarial risk estimates for 1982–1986, and Liu and Hammitt (1999) estimated VSL in 1995 as US$0.6 million (controlling for injury risk) and US$1.2 million (not controlling for injury risk), using workers' subjective risk estimates. Using CV, Fu et al. (1999) estimated WTP per statistical case of cancer avoided by reducing pesticide residues on food in Taiwan as US$0.58 – 1.3 million in 1995. In contrast, Hammitt et al. (2000)

estimated compensating wage differentials for the period 1982 – 1997 which suggest VSL increased from about US$0.5 million in the mid 1980s to US$4 – 5 million for 1991 – 1997, consistent with the estimates presented here.

The reasons for the large VSL estimated in this study are not apparent. Although the wage-differential estimates of VSL might be smaller than the general-population CV estimates because of the selection of low-VSL individuals to high-risk jobs and a higher value assigned to fatal degenerative disease than to fatal accident, these factors cannot explain the difference from the Fu et al. (1999) estimates. Alternatively, the current estimates may be valid if VSL has risen sharply in recent years (as suggested by Hammitt et al., 2000). Even if the absolute VSLs are biased upward by some aspect of the study design, the estimated relative effects of disease type and latency may be unbiased.

5. Conclusion

Health benefits of environmental regulations are frequently associated with reduced risks of cancer and of other degenerative and fatal diseases. To date, there is little evidence regarding the extent to which individual WTP to reduce fatal risks differs by characteristics of the risk, including the type of disease or trauma and the latency period between exposure to the hazard and fatal outcome.

In a general-population contingent valuation study in Taiwan, we find that WTP to reduce risks of fatal cancer due to environmental pollution is significantly larger than WTP to reduce risks of an otherwise similar degenerative disease, and that WTP to reduce risks of lung disease due to industrial air pollution is substantially greater than WTP to reduce risks of liver disease due to water pollution. Because these factors are confounded in our study design, we are unable to separately estimate the effects of differences in the affected organ (liver or lung), environmental pathway (drinking and bathing water or air), and payment mechanism (higher water utility bills or higher payments for manufactured goods).

In contrast, we find that WTP to reduce exposure to environmental pollution is not sensitive to the latency period between exposure and manifestation of disease. The insensitivity of WTP to latency suggests that respondents' anticipate their VSL will grow over time at a rate about equal to their discount rate. As described in Section 2, the anticipated increase in VSL may reflect changes in age and calendar time. Our results suggest that the dominant factor in the anticipated increase is calendar time (presumably due to increases in income) since, cross-sectionally, VSL is estimated to decline with age.

When evaluating the benefits of environmental regulations, our results suggest that benefits of mortality-risk reduction should not be reduced to account for the latency period between exposure and manifestation of disease. They further suggest the existence of substantial differences in VSL associated with specific diseases. In particular, reductions in risk of fatal cancer may be more valuable than comparable reductions in other fatal, degenerative disease. Values of risk reduction may also be sensitive to the affected organ and environmental pathway. These results require confirmation and further refinement for use in policy analysis.

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Table 1. Variable names, definitions, and descriptive statistics

Variable	Definition	Mean	(Std. Dev.)
Cancer	Dummy = 1 if the question is cancer, = 0 non-cancer	0.5024	(0.500)
Liver	Dummy = 1 if the question is liver disease, = 0, lung disease	0.5000	(0.500)
Latent	Dummy = 1 if the question is latent disease = 0, acute disease	0.5304	(0.499)
Risk magnitude	Dummy = 1 if the initial risk is high (8/100,000) = 0 if the initial risk is low (2/100,000)	0.4968	(0.500)
Q1	Dummy = 1 if the question is the first question	0.2500	(0.433)
Q2	Dummy = 1 if the question is the second question	0.2500	(0.433)
Q3	Dummy = 1 if the question is the third question	0.2500	(0.433)
Age	Respondent's age in years	39.093	(10.11)
Sex	Dummy = 1 if the respondent is male, = 0 female	0.5545	(0.497)
Married	Dummy = 1 if the respondent is married	0.7484	(0.434)
Health	Perceived health status, from 1 (worst) to 5 (best)	3.6715	(0.760)
Disease	Dummy = 1 if the respondent has respiratory disease	0.1627	(0.369)
Smoker	Dummy = 1 if the respondent is current smoker	0.2676	(0.443)
Seat belt	Dummy = 1 if the respondent uses the seat belt	0.6466	(0.478)
Ln(income)	Log of monthly income (NT$, 1US$= 34.5NT$)	10.622	(0.509)
Air	Perceived air quality, from 0 (worst) to 10 (best)	5.7382	(2.130)
Water	Perceived drinking water quality, from 0 (worst) to 10 (best)	5.9353	(2.034)
Air conditioner	Dummy = 1 if the respondent has air conditioner	0.9239	(0.265)
Water filter	Dummy = 1 if the respondent has drinking water filter	0.5369	(0.499)
College	Dummy = 1 if the respondent has college degree	0.2380	(0.426)
Taiwanese	Dummy = 1 if the ethnic is Taiwanese, = 0 Chinese	0.8341	(0.372)
Taipei city	Dummy = 1 if the respondent lives in Taipei city	0.2756	(0.447)
Taipei county	Dummy = 1 if the respondent lives in Taipei county	0.3213	(0.467)
Taoyuan county	Dummy = 1 if the respondent lives in Taoyuan county	0.1675	(0.373)
Kaohsiung city	Dummy = 1 if the respondent lives in Kaoshiung city	0.1346	(0.341)

Table 2. Regression results

Variable	(1)	(2)	(3)
Constant	6.1724	6.0238	0.7773
	(0.0838)***	(0.1041)***	(1.0062)
Cancer	0.2684	0.2755	0.2454
	(0.0915)**	(0.0917)***	(0.0945)***
Liver	-0.6520	-0.6533	-0.6983
	(0.00919)***	(0.0921)***	(0.0948)***
Latent	-0.0461	-0.0589	-0.0687
	(0.0791)	(0.0837)	(0.0860)
Risk magnitude	0.3415	0.3437	0.3090
	(0.0784)***	(0.0784)***	(0.0809)***
Q1		0.2620	0.2782
		(0.1147)**	(0.1178)**
Q2		0.3036	0.3094
		(0.1106)***	(0.1135)***
Q3		0.0416	0.0332
		(0.1109)	(0.1135)
Age			-0.0196
			(0.0050)***
Sex			-0.0234
			(0.0946)
Married			-0.1060
			(0.1152)
Health			-0.0023
			(0.0547)
Disease			0.0063
			(0.1121)
Smoker			-0.3743
			(0.1035)***
Seatbelt			-0.0893
			(0.0905)
Ln(income)			0.5356
			(0.0977)***
Air			-0.0123
			(0.0205)
Water			0.0313
			(0.0203)
Air conditioner			0.4105
			(0.1627)**
Water filter			0.0533
			(0.0832)
College			0.2083
			(0.1041)**

Taiwanese			0.2603
			(0.1073)**
Taipei city			-0.4293
			(0.1654)***
Taipei county			-0.2075
			(0.1562)
Taoyuan county			0.1612
			(0.1736)
Kaohsiung city			0.0970
			(0.1735)
Scale	2.3641	2.3603	2.3222
	(0.0451)	(0.0450)	(0.0458)
Sample size	4,992	4,992	4,608

Note: Standard errors are in parentheses. ***, **, and * represent statistical significance at 1, 5, and 10 percent, respectively.

Table 3. Estimated value per statistical life (million US$)

Disease type	Latency	Organ/pathway	(1)	(2)	(3)
Non-cancer	Latent	Liver/water	2.8	2.8	2.8
Non-cancer	Acute	Liver/water	2.9	2.9	3.0
Cancer	Latent	Liver/water	3.7	3.7	3.6
Cancer	Acute	Liver/water	3.8	3.9	3.8
Non-cancer	Latent	Lung/air	5.4	5.3	5.6
Non-cancer	Acute	Lung/air	5.6	5.7	6.0
Cancer	Latent	Lung/air	7.0	7.0	7.2
Cancer	Acute	Lung/air	7.4	7.4	7.7

Note: Estimates correspond to models in corresponding column of Table 2.
VSL calculated as the average of the values for the two risk-reduction magnitudes.

Appendix: Survey Questions

1. Liver disease / water pathway

As you know, the drinking water that is piped to your home is treated to remove microbial and chemical contaminants. However, there is always a risk that some contaminants may be present in the water.

Consider what you would do if you learned that there is a contaminant in the water supplied to your home that may cause [liver cancer / liver failure]. You and other people in your household can be exposed to the contaminant by drinking the water, and also by using it for bathing. The chance that you or someone in your household will be exposed to enough of this contaminant to cause [liver cancer / liver failure] is [2 / 8] chances in 100,000 per year.

Insert [Acute] or [Latent] description:

[Acute] The type of [liver cancer / liver failure] caused by this contaminant is always fatal. If you are exposed to enough of the contaminant to develop [liver cancer / liver failure], you will develop symptoms within a few months, and you will live only about 2 to 3 years longer.

[Latent] The type of [liver cancer / liver failure] caused by this contaminant is always fatal, but it takes a long time to develop. If you are exposed to enough of the contaminant to develop [liver cancer / liver failure], you will not know it until you experience symptoms about 20 years later. After you develop these symptoms, you will live only about 2 to 3 years longer.

If you develop [liver cancer / liver failure], the symptoms will be mild at first. Eventually, you will become so weak that you will have to stay in bed or a wheel chair most of the time. You will not be able to take care of yourself. Once this occurs, you will die within one to two months.

The water-treatment plant can install additional treatment equipment to reduce the chance that the contaminant will be in your water. The treatment equipment is expensive, and the people who manage the plant are not sure if it is worth the cost. If the treatment equipment is installed, it will reduce the chance that you will be exposed to enough of the contaminant to develop [liver cancer / liver failure] from [2 / 8] chances in 100,000 per year to almost zero—to only 1 chance in 10 million per year.

If the plant installs the equipment, it will need to recover the cost by increasing the amount that consumers pay for their water. If the additional cost to your household would be NT$ [50, 100, 200, 300, 500] per month, would you want the plant to install the treatment equipment to reduce the chance that you or someone else in your household would develop [liver cancer / liver failure]?

2. Lung disease / air pathway

Air pollution that is released from factories may cause [lung cancer / bronchitis]. Consider what you would do if you learned that the chance that someone in your household will be exposed to enough of this pollution to cause [lung cancer / bronchitis] is [2 / 8] chances in 100,000 per year.

Insert [Acute] or [Latent] description:

[Acute] The type of [lung cancer / bronchitis] caused by this contaminant is always fatal. If you are exposed to enough of the contaminant to develop [lung cancer / bronchitis], you will develop symptoms within a few months, and you will live only about 2 to 3 years longer.

[Latent] The type of [lung cancer / bronchitis] caused by this contaminant is always fatal, but it takes a long time to develop. If you are exposed to enough of the contaminant to develop [lung cancer / bronchitis], you will not know it until you experience symptoms about 20 years later. After you develop these symptoms, you will live only about 2 to 3 years longer.

If you develop [lung cancer / bronchitis], the symptoms will be mild at first. Eventually, you will become so weak that you will have to stay in bed or a wheel chair most of the time. You will not be able to take care of yourself. Once this occurs, you will die within one to two months.

The government can require factories to install additional air-pollution-control equipment to reduce the amount pollution coming out of the factory. The equipment will reduce the chance that you will develop [lung cancer / bronchitis] from [2 / 8] chances in 100,000 per year to almost zero—to only 1 chance in 10 million per year.

If the government requires the factories to install this pollution-control equipment, it will increase the cost of many of the goods you buy. This would increase your cost of living. If the additional cost to your household would be NT$ [50, 100, 200, 300, 500] per month, would you want the factories to install the pollution-control equipment to reduce the chance that you or someone else in your household would develop [lung cancer / bronchitis]?

Table A-1. Survey design

Sub-sample	A1	A2
Question 1	low risk, latent, liver cancer	high risk, acute, liver cancer
Question 2	low risk, acute, liver cancer	high risk, latent, liver cancer
Question 3	low risk, latent, bronchitis	high risk, latent, bronchitis
Question 4	low risk, acute, bronchitis	high risk, acute, bronchitis
Sub-sample	A3	A4
Question 1	low risk, latent, liver failure	high risk, latent, liver failure
Question 2	low risk, acute, liver failure	high risk, acute, liver failure
Question 3	low risk, acute, bronchitis	high risk, latent, bronchitis
Question 4	low risk, latent, bronchitis	high risk, acute, bronchitis
Sub-sample	B1	B2
Question 1	low risk, latent, lung cancer	high risk, acute, lung cancer
Question 2	low risk, acute, lung cancer	high risk, latent, lung cancer
Question 3	low risk, acute, liver cancer	high risk, latent, liver cancer
Question 4	low risk, latent, liver cancer	high risk, acute, liver cancer
Sub-sample	B3	B4
Question 1	low risk, latent, bronchitis	high risk, latent, bronchitis
Question 2	low risk, acute, bronchitis	high risk, acute, bronchitis
Question 3	low risk, acute, liver cancer	high risk, latent, liver cancer
Question 4	low risk, latent, liver cancer	high risk, acute, liver cancer

Note: Describes the risk characteristics of the four questions asked to each of eight sub-samples of respondents.