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Sensitivity of willingness to pay to the magnitude of risk reduction: a Taiwan–United States comparison

JAMES K. HAMMITT*
Center for Risk Analysis, Harvard School of Public Health, 718 Huntington Avenue, Boston, MA 02115–5924, USA

JIN-TAN LIU
Department of Economics, National Taiwan University and Institute of Economics, Academia Sinica, Taipei

WEN-CHING LIN
Department of Economics, National Taiwan University, Taipei

Abstract

Estimates of willingness to pay (WTP) for health, environmental, and other goods obtained using contingent valuation (CV) have been criticized as inadequately sensitive to the scope or magnitude of the good. We investigate the sensitivity of WTP to variation in the magnitude of reductions in health risk using survey data collected in two countries, Taiwan and the United States, that differ dramatically with respect to economic development and cultural background. WTP is elicited for reductions in acute risks associated with food poisoning and blood transfusion, and for reductions in the chronic risk of pneumonia at advanced ages. Results are similar in the two countries and provide little evidence that CV-based estimates are sufficiently sensitive to the magnitude of the risk reduction. Inadequate sensitivity of estimated WTP to the magnitude of risk reduction suggests that improved methods are required for estimating consumers' rates of substitution between health risk and other goods.

1. Introduction

Stated-preference methods such as contingent valuation (CV) have become increasingly popular for estimating trade-offs between wealth and health. In comparison with the alternative, revealed-preference methods, CV and other stated-preference methods are extremely flexible and can in principle be used to elicit values for a wide range of goods, including goods which are not available in any market. However, important questions have been raised about the extent to which stated-preference methods estimate consumer preferences. A primary concern is that values estimated using CV are not sufficiently responsive to the 'scope' or magnitude of the good to be consistent with any plausible preferences.

Insensitivity to scope can manifest in alternative forms. In one form, WTP is elicited for different quantities of a good and the estimated values differ little. Although dimin-

*Author to whom correspondence should be addressed: e-mail: James_Hammitt@Harvard.edu

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ishing marginal rates of substitution between wealth and most goods are anticipated, in many cases the difference in estimated WTP between large and small quantities of a particular good is much smaller than the WTP for the small quantity, which suggests a decline in the marginal rate of substitution that is implausibly sharp. For example, Desvousges *et al*. (1993) found that WTP to protect migratory waterfowl from dying in waste-oil holding ponds was insensitive to the number of birds affected: WTP to prevent the deaths of 2 000, 20 000, and 200 000 birds averaged \$59, \$59, and \$71 per household per year, respectively. If the number of birds protected constitutes an important element of the good in question, the implied marginal values of \$0 and \$12 for protecting the incremental 18 000 and 198 000 birds seem implausibly small compared with the \$59 value of protecting the first 2000 birds.

In another form, WTP for a composite commodity elicited jointly is much less than the sum of WTP for components of the composite elicited individually. For example, Diamond *et al*. (1993) found that WTP to prevent development of several wilderness areas considered individually significantly exceeded WTP to prevent development of all of them jointly. Effects of substitution among wilderness areas were controlled by eliciting values for preservation conditional on other areas being preserved and developed.

For many goods, economic theory provides only modest guidance for determining how sharply marginal WTP can decline with increasing quantity, so it is difficult to be certain that WTP is insufficiently sensitive to scope. In the migratory waterfowl example (Desvousges *et al*., 1993), if the good is conceived as preventing injury to wildlife occasioned by human industry the number of birds affected may be of little importance. In contrast, when the good is a small reduction in the probability of suffering an adverse health effect, theory provides stronger guidance.

The standard model of WTP for reductions in current mortality risk is based on the assumption that individuals seek to maximize their expected state-dependent utility of income

$$U(p, w) = (1-p)u_1(w) + pu_0(w) \tag{1}$$

where p is the probability of dying in the current period and $u_1(w)$ and $u_0(w)$ are the utility of income w conditional on surviving and not surviving the period, respectively (Drèze, 1962; Jones-Lee, 1974; Weinstein *et al*., 1980). Holding the expected utility constant yields the marginal rate of substitution between income and risk

$$\frac{\mathrm{d}w}{\mathrm{d}p} = \frac{u_1(w) - u_0(w)}{(1-p)u'_1(w) + pu'_0(w)} \tag{2}$$

The numerator is the difference in utility between surviving and dying and the denominator is the expected marginal utility of income. Under the conventional and reasonable assumptions that $u_1(w) > u_0(w)$ and $u_1'(w) > u_0'(w) \geqslant 0$, $\mathrm{d}w/\mathrm{d}p$ increases in income and risk. This marginal rate of substitution is called the 'value per statistical life' (VSL) as it represents the payment that a large number of individuals would make to prevent one expected fatality among them.

The effect of risk on VSL – the 'dead-anyway effect' (Pratt and Zeckhauser, 1996) – reflects the difference in the marginal utility of income depending on whether or not the individual survives the period. The effect is largest when the marginal utilities are as different as possible, that is, for $u'_0(w) = 0$. In this case, decreasing the mortality

risk p by Δp decreases VSL by the proportional change in survival probability $(1-p)/(1-p+\Delta p)$. For the usual case where the baseline risk p is a few per cent or less, the proportional decrease in VSL is approximately equal to $1-\Delta p$.

Although theory places no obvious constraints on the income effect, empirical estimates suggest the income elasticity of VSL is no greater than one (e.g. Blomquist, 1979; Jones-Lee *et al.*, 1985; Liu *et al.*, 1997). If so, the proportionate change in VSL as one buys risk reductions is less than the proportionate change in income, and so if WTP for the risk reduction is less than a few per cent of income, this effect cannot cause WTP to deviate from proportionality by more than a few per cent.

Near-proportionality does not depend on the assumption that the individual maximizes his expected utility. Most alternative theories of decision making under uncertainty are locally linear in the probabilities (Machina, 1987; Smith and Desvousges, 1988) which is all that is required. In contrast, near proportionality need not hold under theories of decision making such as prospect theory (Kahneman and Tversky, 1979) that allow for thresholds in the way people evaluate probabilities.

WTP to reduce the risk of non-fatal illness can also be analysed using the model in (1) if $u_1(w)$ and $u_0(w)$ are interpreted as the utility of income if healthy and ill, respectively (e.g. Viscusi *et al.*, 1987; Viscusi and Evans, 1990). The between-state difference in the marginal utility of income is likely to be smaller when the states represent health and illness than when the states represent survival and death. It is also possible that the marginal utility of income if ill exceeds the marginal utility if healthy (i.e. if illness is viewed as equivalent to a loss of income). In any event, for small changes in risk the difference in marginal utilities has little effect on the rate of substitution between income and risk of illness. Unless the total WTP for the risk change is a substantial fraction of income or the income elasticity of WTP is substantially greater than one, WTP to reduce risk of illness is nearly proportionate to the change in probability.

Despite theoretical predictions of near linearity between WTP and change in probability, CV studies of health and mortality risks have generally found that WTP varies much less than proportionately to the change in risk. Hammitt and Graham (1999) identified 25 CV studies of numerically specified changes in health risk published since 1980. Of these, 14 studies provide sufficient information to determine whether WTP for a risk reduction depends on the magnitude of the reduction, based on comparisons either within or between subsamples. In every case, mean WTP varies less than proportionately to the change in probability; in some cases, there is no significant relationship between WTP and change in probability. Eight of these studies concerned fatal risks and six concerned non-fatal risks.

Between-sample comparisons ('external tests') provide a more demanding test of CV methods than do within-sample comparisons ('internal tests') because respondents value only one of the risk changes and have no opportunity to make their responses consistent with how they would respond to questions about valuing a larger or smaller risk change. The previous literature shows that, even within sample, respondents may not always demonstrate sensitivity to magnitude. For example, Jones-Lee *et al.* (1985) found that 42% of respondents would pay the same amount to reduce their fatality risk on a trip by motorcoach from 8/100 000 to 1/100 000 as they would pay to reduce the risk from 8/100 000 to 4/100 000, and 8% of respondents stated that they would pay more for the smaller risk reduction. For non-fatal injuries, Viscusi *et al.* (1987) found that WTP to reduce poisoning and eyeburn risks from consumer products (insecticides and

toilet-bowl cleaners) was less than proportionate to the change in probability. WTP to reduce both risks by 10/10 000 was about 30% larger than WTP to reduce both risks by 5/10 000 (from an initial value of 15/10 000). Viscusi *et al*. also found evidence of a certainty effect which led to greater WTP to eliminate the risks than to reduce their probabilities by the same magnitude.

Recent work in Taiwan yields estimates consistent with the general pattern: WTP depends on the magnitude of risk reduction, but it varies less than proportionately to the magnitude of the risk change. Fu *et al*. (1999) elicited WTP among Taiwanese women for reductions in the lifetime cancer risk associated with consuming pesticide residues on bok choy, a popular vegetable. All survey respondents indicated their WTP to reduce the lifetime cancer risk from consuming bok choy by 25%, 50%, and 90% (i.e., comparisons are within sample). Median WTP for these reductions is estimated as NT$11.62, NT$13.98, and NT$18.64 per Taiwanese kg of bok choy, respectively. (The exchange rate in 1995 when the Fu *et al*. data were collected was approximately NT$28 = US$1. One Taiwanese kg = 0.6 international kg.) The differences in WTP are statistically significant but less than proportional to the difference in risk.

There are several possible explanations for the apparently inadequate sensitivity of CV-based estimates of WTP to the magnitude of risk reduction. First, many people have a limited intuitive understanding of differences in numbers, especially of small probabilities of the order of one per thousand or smaller. Second, as proposed by Viscusi's prospective reference theory, respondents may not accept the stated probabilities as applicable to them, but may use the stated probabilities to update personal prior probabilities, yielding posterior probabilities for differing risk reductions that are more similar than are the stated probabilities. Thus, even if WTP is not proportional to the stated magnitude of risk reduction, it may be proportional to individuals' posterior estimates of the magnitude (Viscusi, 1985, 1989; Smith, 1992). Third, people often compare quantities in terms of the proportional rather than absolute difference, a heuristic which can lead one to believe that a small risk reduction is more valuable than a large one if it represents a larger fraction of some baseline (e.g. a 90% reduction in the chance of food poisoning today may be viewed as more valuable than a 1% reduction in the chance of food poisoning for an entire year) (Baron, 1997b). Fourth, opportunities to trade wealth for reductions in small health risks may be sufficiently unfamiliar to people that they do not have well-developed preferences over these commodities, or do not have preferences that can be adequately accessed using typical CV studies.

In this paper, we report tests of sensitivity of elicited WTP for health risk reductions in Taiwan and the United States. We elicit WTP for the same risk reductions in both countries and compare (within country) the WTP for risk reductions of differing magnitude. We examine three risks: food poisoning by *Salmonella* bacteria, infection with HIV (human immunodeficiency virus, by which AIDS is transmitted) or hepatitis virus through blood transfusion, and fatal pneumonia at advanced age. To avoid confounding our tests of sensitivity to magnitude with a possible certainty effect which leads to greater WTP to eliminate a risk than to reduce its probability by the same magnitude (Viscusi *et al*., 1987), we consider risk reductions that do not eliminate the risk. In all cases, we examine the relationship between estimated WTP and differences in risk using the more stringent, between-subsample comparisons of WTP for risk reductions of differing magnitude.

The survey design, administration, and respondents' characteristics are described in section 2. The risk reductions are described in section 3, and empirical results are in section 4. Conclusions are presented in section 5.

2. Survey design

Surveys were undertaken in Taiwan and the United States. This section describes the survey administration and sampling plan, summarizes respondents' characteristics, and describes general aspects of the survey instrument.

2.1. SURVEY ADMINISTRATION AND RESPONDENTS

Data were collected from three surveys: one in Taiwan and two in the United States. The Taiwan data were obtained in July 1998 using in-person interviews of a sample of 800 persons. The sample was restricted to individuals aged 25 years and older with earned income and residing in Taipei, Taichung, or Kaohsiung. In total, 768 questionnaires were completed.

The US data were collected by nationwide random-digit-dial telephone surveys of individuals 18 years of age or greater. Two independent surveys were undertaken. About 80% of eligible respondents who were initially contacted completed the interview, yielding total sample sizes of about 1000 in each survey. The food-safety and blood-transfusion scenarios were presented in a June 1996 survey and the pneumonia-vaccine scenarios in a June 1998 survey.

Sample demographics are similar in the two US samples and reasonably similar to the Taiwan sample. As summarized in Table 1, the samples are about evenly divided between men and women. The US samples are slightly older (mean age 44 compared with 41 in Taiwan), more educated (13–14 years of schooling compared with 12 years) and less likely to be married (60% compared with 78%). Mean income in the US samples is US$44 000–48 000 per year, substantially greater than the mean in the Taiwan sample (NT$520 000, about US$16 000 per year; the 1998 exchange rate was approximately NT$33 = US$1).

2.2. ELICITATION FORMAT

In all cases, WTP was elicited using double-bounded dichotomous-choice questions (Hanemann *et al*., 1991). With a dichotomous-choice or binary question, the respondents are asked to indicate whether they would or would not purchase the specified

Table 1. Demographic characteristics.

	Taiwan	*US 1996*	*US 1998*
Age (years)	40.7	43.6	43.6
Annual income	NT$520,000	US$44,200	US$48,400
Education (years)	11.7	12.7	14.0
Male (%)	53	50	47
Married (%)	78	61	57
N	768	1003	1000

Note: The US samples for the food safety and blood transfusion topics are from the 1996 survey and the US sample for the pneumonia vaccine is from the 1998 survey.

good at a stated bid or price. Such questions are often preferred to open-ended questions (in which the respondents are asked to state the maximum amount they would pay for the good) because they appear to be easier for respondents to answer and do not invite a strategic bargaining response. Because dichotomous-choice questions provide only an upper or lower bound on the respondents' WTP, they are often accompanied by a follow-up question in which the respondents are asked whether they would purchase the good at a follow-up price which is higher or lower than the initial price, depending on whether the respondents indicated they would or would not purchase the good at the initial price. If the respondents answer 'yes' and 'no' respectively whenever their WTP is above and below the specified bid, their WTP can be inferred to be greater than any bid to which they responded 'yes' and less than any bid to which they responded 'no.' If the respondents answer 'no' to both initial and follow-up questions, their WTP is assumed to be bounded below by zero. If they answers 'yes' to both questions, no upper bound is obtained.

Responses to the follow-up question can be influenced by anchoring on the initial bid, yea-saying bias (Kanninen, 1995), and other response effects (Cameron and Quiggin, 1994; Alberini *et al*., 1997). We test for these biases by comparing results from the double-bounded estimates with results from the single-bounded estimates obtained using only the response to the initial question (Hanemann *et al*., 1991). Finding no significant differences in the inferred distributions of WTP (using a chi-squared test), we report the more efficient double-bounded results.

2.3. CONFIDENCE IN RESPONSE

Contingent-valuation questions can be difficult to answer if the condition described is not familiar to the respondent. Since CV is often used to elicit values of goods that are rarely purchased in markets, respondents may have little experience in examining their trade-offs between these goods and money, and their responses may be subject to substantial random error. Johannesson *et al*. (1993), Li and Mattson (1995), and Ready *et al*. (1995) allowed respondents to indicate their degree of confidence in responses to WTP questions and found systematic differences associated with respondents' self-reported confidence in their responses. For example, Johannesson *et al*. (1993) found that WTP responses are more strongly related to plausible explanatory variables for respondents who express greater confidence in their answers. Respondents lacking confidence may be more uncertain about their preferences and may be more influenced by particulars of the question wording (Fischhoff, 1993; Baron, 1997a).

Following the WTP elicitation for each good, we reminded respondents of their budget constraints and asked them to indicate how confident they were in their answers to the preceding dichotomous-choice questions. In the following analyses, we distinguish respondents reporting the highest confidence levels from other respondents to determine whether self-reported confidence is related to sensitivity to scope.

3. Specification of health risks

Three distinct health risks are considered: the risk of food poisoning from consuming a single meal, the risk of infection through a blood transfusion, and the risk of dying from pneumonia at an advanced age. The details of each scenario are described in this section.

3.1. FOODBORNE ILLNESS

The food-safety context involves choosing between two lunch stands, indoor and outdoor, which differ in the probability of food poisoning. We describe the symptoms associated with a common foodborne illness, Salmonellosis, as follows.

> Eating food that was improperly handled can lead to illness caused by bacteria. The most common illness, called Salmonellosis, is a mild flu-like intestinal disease that typically lasts a few days. The symptoms are stomach pains, nausea, vomiting and diarrhoea. Of those people who get sick, about 1 out of 1000 die from Salmonellosis.

The probability of developing Salmonellosis is higher at the outdoor than the indoor food stand. The probability at the outdoor stand differs between two subsamples of respondents, and differs slightly between the US and Taiwan samples. In the US sample, the probabilities of illness in the high-risk and low-risk scenarios are 1/13 700 and 1/137 000, respectively. These values were selected to replicate the values used by Hayes *et al*. (1995) to elicit WTP in an experimental auction setting. In the Taiwan sample, the values were rounded to 1/15 000 and 1/150 000. At the indoor stand, the risk is almost zero (1 per 100 million in both samples). We elicit incremental WTP to eat at the lower risk, indoor food stand. To familiarize respondents with the context, we begin by asking them to recall any episodes of foodborne illness they have experienced and to report the average amount they spend for lunch each day. We also elicit from respondents their concern about getting ill and about reducing the risk using a ten-point scale.

3.2. BLOOD TRANSFUSION

The blood-transfusion question involves the risk of infection with hepatitis, HIV (the virus which causes AIDS), or both. We compare WTP to reduce each risk individually with WTP to reduce both risks jointly. Because the probabilities associated with each risk are the same for all respondents, this test is less dependent on respondents' comprehension of the numerical values than are the tests in our other risk contexts.

The respondents are asked to assume that they are to undergo elective surgery during which a blood transfusion is likely to be required. The transfused blood may be infected with HIV or hepatitis virus. The risk of infection is small; specifically, a 4/1000 000 chance of infection with HIV and a 300/1000 000 chance of infection with hepatitis virus. Independent subsamples of respondents are offered the opportunity to order one of three tests to reduce the risk of contamination by hepatitis virus, HIV, or both viruses to almost zero (1 per 100 million in the US sample, 1 per billion in the Taiwan sample). The cost of the test is not covered by National Health Insurance in Taiwan or other sources in the US. To help respondents think about the risk, we first ask about whether they have undergone surgery and donated blood.

Since the consequences of infection by HIV and hepatitis virus differ substantially, we do not assume that WTP for reducing each of the two risks should be proportional to the respective changes in probability. However, we can examine consistency by testing whether WTP for the two risk reductions individually sum to the WTP for reducing both jointly (an 'adding-up' test; Diamond and Hausman, 1994; Diamond, 1996):

$$\text{WTP(Both)} = \text{WTP(HIV)} + \text{WTP(Hep)} \tag{3}$$

Strictly, one should consider the possibility that infection with HIV and hepatitis are complements or substitutes. However, the probabilities of infection with each of the two viruses are small and independent, so the chance of infection with both viruses is negligible (3×10^{-10}).

3.3. PNEUMONIA VACCINE

This scenario is intended to provide information about how individuals value future risk and longevity as distinct from near-term mortality risk. To date, there have been few studies that attempt to value longevity and little testing of different methods of communicating longevity benefits. In one of the earliest studies, Moore and Viscusi (1988) incorporated life expectancy in a compensating-wage-differential study and estimated an implicit value of US$175 000 per life year. In a CV study of Swedes, Johannesson and Johansson (1996, 1997) estimated a maximum WTP of US$1500 (paid now) to increase life expectancy, conditional on reaching age 75, from 10 to 11 years. In Canada, Johnson *et al*. (1998) used conjoint analysis to estimate WTP for an added year of longevity in various health states. They estimated a value of CN$14 000 (about US$10 000) for a year with mild health impairment. Other attempts to estimate the value of longevity have been based on allocating a standard value of statistical life over a life expectancy or discounted life expectancy (e.g. Tolley *et al*., 1994).

In this scenario, we explain to respondents that pneumonia is a leading cause of death among the elderly and that the risk of developing fatal pneumonia can be reduced by receiving a one-time vaccination. The benefits of vaccination are described using alternative framings (a reduction in annual mortality risk and an increase in conditional life expectancy) and the magnitude of the benefit is altered by alternatively describing the vaccine as being available at age 60 and at age 70. In the Taiwan sample, respondents are presented with both framings (the change in life expectancy before the annual risk reduction), but only one age at which the vaccine is available. In the US sample, each respondent is presented with only one framing and one age (a total of four subsamples).

For the subsamples presented with the opportunity to obtain the vaccine when they reach age 60, the benefits are described alternatively as a reduction in average annual mortality risk (from age 60 onward) from 4.8% to 4.7%, or as an increase in life expectancy (conditional on reaching age 60) from 21 years to 21 years 5 months. In the subsample presented with the opportunity to obtain the vaccine at age 70, the average annual mortality risk declines from 7.0% to 6.9% and the conditional life expectancy increases from 14 years to 14 years 3 months.

In both cases, the average annual mortality risks are consistent with the conditional life expectancies. In this sense, the annual risk reduction and life expectancy framings describe identical benefits (the exact survival function and the changes to it are not uniquely determined by the information we provided to respondents) and WTP should in principle be independent of the framing. Taking the vaccine at age 60 dominates taking it at age 70 because it offers the benefits of an average 0.1% annual risk reduction for an additional decade. Hence, the value of taking the vaccine at age 60 is unambiguously greater than the value of taking it at age 70. The incremental value of taking the vaccine earlier depends on the probability of surviving from age 60 to 70 and on preferences for life at different ages. Payment for the vaccine is specified

as being made during the current year, not delayed until the vaccine is received. Respondents are told that this payment is not covered by National Health Insurance or other sources. For a given age at which the vaccine is available, WTP should increase with the respondent's age because the benefit will be received sooner and with higher probability for older respondents (who have a higher chance of surviving to the age when the vaccine is available). Respondents are told the probability that persons of their age and gender will survive to the age at which the vaccine is to be administered.

4. Results

Estimated WTP for reductions in the risk of foodborne illness, blood-borne infection, and fatal pneumonia are described in this section. WTP is estimated using maximum likelihood methods (Alberini, 1995). For the food risk and pneumonia vaccine, the error term is assumed to follow a Weibull distribution. Alternative models using a log-normal distribution have slightly smaller maximized likelihood values but yield similar results. To implement the adding-up test for the blood-transfusion risks, we assume the error term is normally distributed.

4.1. FOOD SAFETY

The food-risk questions compare WTP to reduce the risk of food poisoning by salmonella bacteria at a single meal. By choosing to eat at the indoor lunch stand, the risk is reduced from a higher level which differs between independent subsamples. As shown by the estimated coefficients on the 'High risk' indicator variable in Table 2, WTP is not significantly related to the magnitude of the risk reduction in either the Taiwan or US samples. Similarly, restricting analysis to the respondents who express high confidence in their answers to the WTP questions does not yield any significant difference in WTP.

The estimated WTP is implausibly large. In the US sample, median WTP to reduce the risk of a small chance of salmonellosis is US$14, an amount that almost certainly exceeds the average amount spent on lunch. This may be due to the fact that, in the US survey, the scenario was presented as a choice occurring while travelling in a foreign country. The loss if one becomes ill while on business or vacation travel without convenient access to one's regular physician is evidently greater than if the illness were to occur at home. In the Taiwan sample, however, the scenario was described as an everyday occurrence not involving travel away from home. Nevertheless, the median WTP in the Taiwan sample is estimated as almost NT$80 and exceeds the average amount that respondents report spending for lunch (NT$75). These results suggest that consumers are intolerant of food-borne risks and are unwilling to consider trade-offs between risk and money.

Hayes *et al.* (1995) estimated WTP to reduce the risk of salmonella contamination in an experimental auction where participants were required to eat either a sandwich with a 'typical' risk of salmonella contamination or a 'stringently tested' and presumably much safer sandwich. Using an incentive-compatible second-price auction and multiple rounds, they estimated WTP to reduce the probability of salmonellosis from stated values of 1/13 700 and 1/137 000 to an unspecified but much lower level as US$0.92 and US$0.55. These values are also implausibly large, as they imply values

Table 2. External magnitude tests of WTP for food safety (Weibull distribution).

	Taiwan			*United States*		
	Full sample	*Confident*[a]	*Not confident*	*Full sample*	*Confident*[a]	*Not confident*
Constant	2.871**	3.199**	–0.431	2.837**	4.044**	1.075
	(0.769)	(0.821)	(2.162)	(0.733)	(1.080)	(1.017)
High risk[b]	0.022	0.035	–0.060	0.001	0.012	–0.094
	(0.075)	(0.081)	(0.166)	(0.224)	(0.303)	(0.338)
Male	–0.062	–0.090	0.148	–1.160**	–1.452**	–0.611
	(0.080)	(0.086)	(0.177)	(0.261)	(0.372)	(0.356)
Age	0.005	0.002	0.029*	0.312**	0.318**	0.289*
	(0.005)	(0.005)	(0.012)	(0.082)	(0.111)	(0.123)
Income	0.116	0.099	0.283	0.132	0.127	0.098
	(0.077)	(0.082)	(0.243)	(0.096)	(0.130)	(0.146)
Indicator for	–0.335*	–0.294	–0.374	–0.290	–0.609	–0.166
missing income[c]	(0.166)	(0.184)	(0.283)	(0.431)	(0.656)	(0.538)
Education	0.023*	0.026*	0.047	–0.073	–0.135	0.108
	(0.012)	(0.013)	(0.049)	(0.176)	(0.238)	(0.270)
Scale[d]	0.593	0.611	0.327	1.699	1.892	1.418
	(0.036)	(0.039)	(0.067)	(0.173)	(0.249)	(0.230)
n	755	713	42	978	785	193
	Median	Median	Median	Median	Median	Median
Large risk	78.68	80.99	60.41	13.95	24.25	4.78
redn.[e]	(11.10)	(11.53)	(25.31)	(2.95)	(7.66)	(1.21)
Small risk	76.45	78.00	62.08	13.94	23.94	5.26
redn.[e]	(11.01)	(10.85)	(24.32)	(2.94)	(7.54)	(1.36)
Ratio[f]	1.03	1.04	0.97	1.00	1.01	0.90

*, ** denote statistically significantly different from 0 at 5%, 1% respectively.
[a] Confident respondents reported they were 'very confident' about their answers to WTP questions.
[b] Indicator variable = 1 if respondent presented with high-risk and 0 if presented with low-risk scenario.
[c] Indicator variable = 1 if income is missing and 0 otherwise (missing income set equal to sample mean).
[d] Estimated scale, Weibull distribution of residuals.
[e] Predicted median WTP and its standard error at sample-mean of covariates (in national currency).
[f] Ratio of predicted median WTP for high risk to median WTP for low risk.

per statistical case avoided of US$13 million and US$75 million, respectively. By contrast, conventional estimates of VSL for the US are of the order of US$5 million (Viscusi, 1993).

4.2. BLOOD-TRANSFUSION RISK

The blood-transfusion questions compare WTP to reduce the risk of infection with HIV, hepatitis virus, or both viruses. In order to test the hypothesis that WTP to reduce the risks of HIV and hepatitis infection individually sum to the WTP to reduce both risks jointly, the regression models are estimated omitting the intercept but including three independent variables: Both, HIV + Both, HEP + Both. The coefficient of Both estimates the difference between WTP to reduce both risks jointly and the sum of WTP to reduce each risk individually, and the *t*-statistic for this coefficient can be used to test the adding-up hypothesis. (Let b_0, b_1, and b_2 denote the coefficients on Both, HIV

+ Both, and HEP + Both, respectively. Consider an alternative model containing no intercept but indicator variables Both, HIV, and HEP, with coefficients c_0, c_1, and c_2, respectively. The coefficients are related as: $c_0 = b_0 + b_1 + b_2$, $c_1 = b_1$, and $c_2 = b_2$. The adding-up condition is $c_0 = c_1 + c_2$. Substituting the expressions involving b_0, b_1 and b_2 into this equation yields the equivalent condition $b_0 = 0$.)

Results are presented in Table 3. In all cases, WTP to reduce both risks together is greater than WTP to reduce either risk individually. As shown by the significance level of the coefficient on Both, the adding-up condition is violated in the Taiwan full sample and both subsamples, but is not rejected in the US full sample and confident subsample. The difference between WTP for reducing both risks jointly and the sum of WTP for reducing each risk individually is more similar between countries than the significance

Table 3. External scope tests of WTP for blood safety (normal distribution).

	Taiwan			*United States*		
	Full sample	*Confident*[a]	*Not confident*	*Full sample*	*Confident*[a]	*Not confident*
Both	12884.11**	11318.86**	16277.39*	–570.64	–298.00	–979.34*
	(3596.61)	(4305.59)	(6728.16)	(443.34)	(704.04)	(540.60)
HIV+Both	–11195.96**	–9546.16*	–15083.69*	1348.31**	1326.95*	1415.25**
	(3597.14)	(4299.71)	(6745.95)	(411.79)	(651.30)	(501.50)
Hep+Both	–10972.23**	–9208.95*	–14107.98*	819.021*	633.95	1159.58*
	(3573.11)	(4272.96)	(6771.12)	(404.15)	(631.19)	(506.41)
Male	–855.65*	–661.86	–1337.25*	–231.04	63.03	–681.65**
	(371.99)	(461.76)	(632.70)	(138.81)	(212.19)	(180.93)
Age	–14.00	–6.30	–39.89	–47.00	–59.25	–57.73
	(22.90)	(28.51)	(39.19)	(44.80)	(70.77)	(55.36)
Income	1517.53**	1261.77**	2095.04**	187.15**	270.79*	72.11
	(362.53)	(430.69)	(689.79)	(60.76)	(94.24)	(77.59)
Indicator for	–1516.41	–1196.09	–1982.49	383.49	683.77	6.32
missing income[b]	(835.66)	(1062.19)	(1384.58)	(230.83)	(365.11)	(280.68)
Education	53.35	115.18	–101.90	–290.57*	–437.87**	–71.60
	(55.40)	(67.57)	(97.83)	(107.74)	(167.82)	(136.41)
Scale[c]	4094.97	4160.86	3920.98	1562.31	1907.09	1179.30
	(161.23)	(202.64)	(262.20)	(88.04)	(159.74)	(91.02)
n	763	530	233	734	491	242
	Median	Median	Median	Median	Median	Median
Both[d]	6332	6665	5612	1508	1840	1148
	(1055)	(1088)	(1065)	(196)	(310)	(246)
HIV[d]	4345	4435	3347	1239	1472	988
	(982)	(984)	(1812)	(187)	(289)	(239)
Hep[d]	4537	4740	4378	721	789	667
	(1034)	(1080)	1141	(192)	(300)	(239)
HIV + Hep	8882	9175	7725	1961	2261	1655
(HIV + Hep)/Both	1.40	1.38	1.38	1.30	1.23	1.44

*, ** denote statistically significantly different from 0 at 5%, 1% respectively.
[a] Respondents who reported they were 'very confident' about their answers to WTP questions.
[b] Indicator variable = 1 if income is missing and 0 otherwise (missing income set equal to sample mean).
[c] Estimated scale parameter of residual error.
[d] Predicted median WTP and its standard error at sample-mean of covariates (in national currency).

levels suggest, however. As reported in the bottom row of Table 3, the sum of WTP to reduce the two risks individually is 40% greater than WTP to reduce both risks jointly in the Taiwan sample and 30% greater in the US sample. In the confident subsample of the US data the excess is somewhat smaller, 23%. Viscusi *et al*. (1987) found that the sum of WTP to eliminate each of two consumer-product injury risks separately exceeded WTP to eliminate the two risks together for three of four injury pairs. They failed to reject the adding-up condition for any of the pairs.

The relative values of WTP to reduce the HIV and hepatitis risks differ between countries. In the US sample, WTP to reduce the HIV risk is significantly greater than WTP to reduce the hepatitis risk. The values per statistical case avoided are on the order of US$300 million for HIV and US$2.5 million for hepatitis. Both estimates are large compared with conventional estimates of VSL (e.g. US$5 million; Viscusi, 1993). In the Taiwan sample, WTP to reduce the hepatitis risk is slightly (but not significantly) greater than WTP to reduce the HIV risk. As for the US sample, the value per statistical case of HIV infection is also much larger than the value per statistical case of hepatitis infection, roughly US$30 million for HIV and US$0.5 million, respectively. These estimates are also large compared with estimates of VSL in Taiwan of about US$0.5 million (Liu *et al.*, 1997; Liu and Hammitt, 1999).

There is no necessary relationship between WTP to reduce each risk. HIV generally leads to more debilitating illness than does hepatitis but the risk of contracting hepatitis is stated to be much larger than the risk of HIV infection. Hepatitis is more prevalent in Taiwan than in the US, which suggests that Taiwanese respondents may be more familiar with the disease and consequently perceive it as more serious than do US respondents who may view the risk as more abstract.

4.3. PNEUMONIA VACCINE

WTP for the pneumonia vaccine provides evidence about the valuation of longevity. Results are reported in Table 4. There is no statistically significant difference in WTP associated with the magnitude of the benefit. As shown by the coefficient on the indicator variable corresponding to whether the vaccine is available to the respondent at age 60 or 70, the difference in WTP is of the theoretically anticipated sign in the Taiwan sample but of the opposite sign in the US sample. The difference is not statistically significant in either sample. Similarly, there is no statistically significant difference in WTP associated with the framing of the benefit, although the coefficients on life expectancy suggest that WTP is greater when the benefit is described as a gain in life expectancy rather than as a reduction in annual mortality risk. In the Taiwan sample, WTP is positively associated with income and higher for males than females. In contrast, none of the covariates have a statistically significant effect in the US sample. Contrary to the theoretical prediction, WTP is negatively associated with age (significantly so in the Taiwan but not in the US sample), which might reflect less favourable perceptions of the quality of life among older respondents.

The magnitude of WTP is small. The value of a one-year gain in life expectancy (the value of a statistical life year or VSLY) can be estimated by discounting WTP for the difference between the respondent's age and the age at which the benefit is obtained (defined for simplicity as the sum of the age at which the vaccine is available and the conditional life expectancy on reaching that age) and dividing the result by the stated

Table 4. External magnitude tests of WTP for pneumonia vaccine (Weibull distribution).

	Taiwan			*United States*		
	Full sample	*Confident*[a]	*Not confident*	*Full sample*	*Confident*[a]	*Not confident*
Constant	4.166**	4.118**	6.343	3.206	2.969	3.459
	(0.977)	(1.013)	(3.506)	(1.829)	(3.08)	(2.170)
Vaccine at 70	–0.154	–0.151	–0.563	0.150	0.298	0.130
	(0.141)	(0.146)	(0.594)	(0.257)	(0.467)	(0.278)
Life expectancy[b]	0.129	0.120	0.468	0.132	0.272	0.156
	(0.144)	(0.148)	(0.633)	(0.265)	(0.465)	(0.295)
Interaction[c]	0.039	0.043	–0.232	0.253	0.128	0.285
	(0.201)	(0.207)	(0.762)	(0.367)	(0.640)	(0.417)
Male	0.296**	0.298**	–0.137	0.242	0.550	–0.008
	(0.099)	(0.103)	(0.347)	(0.186)	(0.325)	(0.210)
Age	–1.246**	–1.273**	–0.314	–0.062	–0.111	–0.017
	(0.240)	(0.261)	(0.584)	(0.069)	(0.123)	(0.075)
Income	0.045**	0.044**	0.238**	0.236	0.269	0.197
	(0.016)	(0.017)	(0.068)	(0.183)	(0.308)	(0.215)
Indicator for	0.037	–0.011	1.538**	–0.082	–0.171	–0.044
missing income[d]	(0.107)	(0.110)	(0.505)	(0.290)	(0.512)	(0.326)
Education	0.007	0.009	–0.011	–0.046	–0.176	0.050
	(0.007)	(0.007)	(0.022)	(0.088)	(0.156)	(0.096)
Scale[e]	1.588	1.602	1.102	2.054	2.602	1.548
	(0.052)	(0.054)	(0.165)	(0.094)	(0.174)	(0.094)
n	1524	1454	70	610	336	274
	Median	Median	Median	Median	Median	Median
LE gain[f]	2060	2067	2820	162	124	218
	(697)	(682)	3555	(24)	(29)	(41)
Annual risk	1777	1796	1954	117	64	177
redn.[f]	(609)	(602)	(2312)	(19)	(21)	(27)
Vaccine at 60[f]	2067	2075	2960	115	83	157
	692	(685)	(3921)	(19)	(23)	(30)
Vaccine at 70[f]	1780	1797	1904	161	104	229
	(616)	(600)	(1866)	(23)	(28)	(36)
Ratio[g]	1.16	1.15	1.55	0.71	0.80	0.69

*, ** denote statistically significantly different from 0 at 5%, 1% respectively.
[a] Respondents who reported they were 'very confident' about their answers to WTP questions.
[b] Indicator variable = 1 if benefit framed as increase in life expectancy, 0 if framed as annual risk reduction.
[c] Interaction between Vaccine at age 70 and Life expectancy.
[d]. Indicator variable = 1 if income is missing and 0 otherwise (missing income set equal to sample mean).
[e] Estimated scale parameter of residual error.
[f] Predicted median WTP and its standard error at sample-mean of covariates (in national currency).
[g] Ratio of predicted median WTP for vaccine at age 60 to median WTP for vaccine at age 70.

gain in life expectancy. Using a 3% annual discount rate, the value for the Taiwan sample is estimated as NT$1500 (US$45) and NT$2000 (US$61) using the results for age 60 and 70, respectively. For the US sample, the corresponding estimates are US$84 and US$180. (Without discounting for the delay between payment and receipt of benefit, the estimates are US$150 and US$220 for the Taiwan sample and US$280 and US$640 for the US sample for vaccines available at ages 60 and 70, respectively.) These values

are much smaller than the estimates from previous studies, the smallest of which is approximately $1500 estimated in Sweden by Johannesson and Johansson (1996, 1997). The values estimated for the Taiwan and US samples are consistent with each other, however, assuming an income elasticity near one. The mean annual income in the Taiwan sample is one-third of that in the 1998 US sample and the estimated VSLYs for the Taiwan sample are 55% and 34% of the values estimated for the US sample (for vaccines available at ages 60 and 70, respectively).

5. Conclusion

We elicited WTP for reductions in several different health risks in the US and Taiwan, two countries that differ dramatically with respect to economic development and cultural background. The health risks range from the mundane acute risks associated with bacterial food contaminants to the exotic acute risks of infection by HIV and hepatitis virus during surgery to the future chronic risk of fatal pneumonia. Interviews were conducted by telephone in the US and in person in Taiwan. Across countries and health risks, we find little difference in WTP as a function of the magnitude of the risk reduction.

Estimated WTP is completely insensitive to a ten-fold variation in the reduction in risk of illness from eating contaminated food. This lack of sensitivity differs from the approximate two-fold difference in WTP obtained by Hayes *et al.* (1995) in an experimental, repeated-auction setting.

WTP to reduce qualitatively different risks of viral infection transmitted by blood transfusion does suggest some sensitivity of WTP to difference in risk. The adding-up consistency condition is rejected in the Taiwan sample but not in the US sample. Quantitatively, the results are comparable: the sum of WTP to reduce each risk individually exceeds WTP to reduce both risks together by 40% in the Taiwan and 30% in the US samples.

Estimates of WTP for the pneumonia vaccine are not significantly related to whether the benefits of the vaccine are available for the decade from age 60 to 70, or begin only upon reaching age 70. The estimated sign of the effect is as anticipated in the Taiwan sample but not in the US sample.

In summary, these results provide little support for the hypothesis that CV can be used to estimate values of reductions in health risk that accord with theoretical expectations. This result is consistent with most of the previous literature and suggests the need to develop improved methods of eliciting values of small changes in risk. Such improvements will likely require a more detailed understanding of how respondents interpret CV questions and better methods for communicating small changes in risk. The similarity of results in the US and Taiwan suggests that the promise and problems of using CV to estimate values of health risk reductions are much the same in the two countries and, by extension, are likely to be similar in many other countries as well.

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