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Valuation of the risk of SARS in Taiwan

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Summary

Two surveys conducted in Taiwan during the spring 2003 severe acute respiratory syndrome (SARS) epidemic reveal a high degree of concern about the threat posed by SARS to Taiwan and its residents, although respondents believe they are knowledgeable about the risk of SARS and that it is susceptible to individual control. Willingness to pay (WTP) to reduce the risk of infection and death from SARS is elicited using contingent valuation methods. Estimated WTP is high, implying values per statistical life of US$3 to 12 million. While consistent with estimates for high-income countries, these values are substantially larger than previous estimates for Taiwan and may be attributable to the high degree of concern about SARS at the time the data were collected. Copyright © 2004 John Wiley & Sons, Ltd.

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Introduction

Severe acute respiratory syndrome (SARS) is an infection that was first reported in spring 2003. It is believed to have originated in mainland China and significant outbreaks occurred in Southeast Asia and Toronto, Canada. By summer, the outbreaks were largely contained. Through 11 July, nearly 8500 probable cases had been reported to the World Health Organization (WHO), of which 813 proved fatal. The largest outbreaks were in mainland China (5327 probable cases, 348 deaths), Hong Kong (1755 cases, 298 deaths), Taiwan (671 cases, 84 deaths), Canada (250 cases, 38 deaths), and Singapore (206 cases, 32 deaths) [1].

In Taiwan, most of the early cases were imported from China and Hong Kong, or were family members, friends or medical workers in close contact with these patients. On 22 April, an outbreak occurred at the Taipei Municipal Hoping Hospital after which the situation deteriorated rapidly. Two days later, the Taipei City government established a SARS Emergency Response Task Force and closed the hospital. All 930 staff members and 240 patients were confined to the hospital to prevent further infection. At its peak, Taiwan reported 60 SARS cases in a single day. The situation was brought under control in late May and the WHO announced it would remove Taiwan from the list of areas with local transmission on 5 July[a]. The epidemic was concentrated in Taipei city and county, with 518 of a total of 665

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probable cases located in the northern part of Taiwan [2].

During this period, we conducted two surveys to assess Taiwan residents' perceptions of the risk of contracting SARS and their willingness to pay (WTP) to reduce the risk. In the next section, we describe the surveys and data collected, summarize risk perceptions and WTP for a vaccine to prevent SARS. The last section concludes.

Data collection and sample statistics

Two surveys elicited information on respondents' perceptions of the SARS risk, precautions taken, and WTP for a hypothetical SARS vaccine. The larger survey (the 'Taiwan sample') was conducted between 6 and 12 May using random-digit-dial telephone interviewing to sample Taiwan residents aged 20–65 years. The survey was conducted during the peak of the epidemic and only included questions about SARS. In total, 1028 interviews were completed, 77% of the 1334 individuals contacted.

The smaller survey (the 'Taipei sample') was conducted between 19 April and 25 May. It was a general health and food-safety survey of women in Taipei city and county that included questions about SARS. Initial interviews were conducted in-person at the respondent's home, but as the SARS outbreak worsened this mode proved infeasible and on 28 April a mixed-mode mail/telephone approach was substituted. In this mode, questionnaires were mailed to respondents who completed a follow-up telephone interview 1–2 weeks later. In total, 488 interviews were completed. Response rates among contacted individuals for the two survey modes were similar, 86% ($=\frac{198}{230}$) for the in-person interviews and 83% ($=\frac{290}{350}$) for the mail/telephone mode.

Summary statistics and definitions of the variables are reported in Table 1. The Taiwan sample is broadly representative of the island's non-elderly adult population. The respondents' mean age is 40 years and 16% reside in Taipei city and county. Compared with the Taiwan-sample respondents, the women in the Taipei sample are older (mean age of 50 years), more likely to be

Table 1. Variable definitions and descriptive statistics

		Taiwan sample		Taipei sample	
Variable	Definition	Mean	Std dev.	Mean	Std dev.
Risk	Dummy = 1 if risk per month = 5×10^{-5}, 0 if 3×10^{-5}	0.515	(0.500)	0.600	(0.490)
Mortality	Dummy = 1 if conditional mortality risk is 0.10, 0 if 0.05	0.492	(0.500)	0.481	(0.500)
Duration	Dummy = 1 if SARS vaccination is effective for 12 months, 0 for 6 months in Taiwan sample (1 if 6 months, 0 if 3 months in Taipei sample)	0.561	(0.496)	0.519	(0.500)
Telephone	Dummy = 1 if the survey is conducted by mail–telephone, 0 if personal interview			0.579	(0.494)
Age	Respondent's age in years	39.644	(9.765)	49.923	(6.193)
Education	Years of schooling	12.355	(3.171)	10.711	(3.930)
Male	Dummy = 1 if respondent is male, 0 otherwise	0.563	(0.496)		
Married	Dummy = 1 if respondent is married, 0 otherwise	0.741	(0.438)	0.898	(0.303)
Family members	Number of people in household	4.355	(1.976)	4.162	(1.374)
Log (income)	Log of monthly family income (NT$)	10.437	(0.499)	10.813	(0.705)
Health status	Respondent's perceived health status, 1 = very poor, 5 = excellent	4.021	(0.808)	3.340	(0.838)
Taiwanese	Dummy = 1 if ethnicity is Taiwanese, 0 if Chinese	0.920	(0.272)	0.891	(0.311)

Table 1 (*continued*)

Variable	Definition	Taiwan sample		Taipei sample	
		Mean	Std dev.	Mean	Std dev.
Taipei Dummy	Dummy = 1 if respondent lives in Taipei City and Taipei country, 0 otherwise	0.159	(0.366)		
Religion belief	Dummy = 1 if respondent has religious belief, 0 otherwise	0.750	(0.433)		
Mask	Dummy = 1 if respondent wears mask outside, 0 otherwise	0.471	(0.499)	0.666	(0.472)
Economy	Respondent perceives SARS to be serious impact on Taiwan's economy, 1–5, 1 = not at all, 5 = very serious	4.473	(0.852)		
Income risk	Effect of SARS on respondents' income this year, 1–10, 1 = not at all, 10 = very much	5.110	(3.287)		
Flu shot	Dummy = 1 if respondent had flu shot in last 6 months, 0 otherwise			0.057	(0.233)
Visit	Dummy = 1 if respondent would visit China or Hong Kong in next year, 0 otherwise	0. 058	(0.229)		
Severity	Severity of SARS epidemic in Taiwan, 1 = not at all serious, 5 = very serious	4.067	(0.837)	3.768	(0.849)
Danger	Effect of SARS risk on respondent's life, 1 = none at all, 10 = very serious	6.333	(3.143)		
Fatal	Perceived fatality of SARS, 1 = not at all fatal, 5 = extremely fatal	4.085	(0.873)	4.147	(0.662)
Knowledge	Knowledge about how SARS is spread, 1 = little knowledge, 5 much knowledge	4.021	(0.722)	3.783	(0.808)
Control	Degree of personal control of SARS risk, 1 = not at all controllable, 5 = extremely controllable	3.317	(0.970)	3.537	(0.883)
Concern	Concern about SARS infection, 1 = not at all concerned, 5 = very concerned			3.584	(1.036)
Sample size		1.015		464	

married (90% vs 74%), and have somewhat less schooling (10.7 vs 12.4 years) and substantially greater household income (US$21 300 vs US$13 400 per year).

Public conceptions of risk are complex and influenced by qualitative factors [3], including the extent to which a given risk is viewed as fatal, uncontrollable, and unknown. These factors may also influence WTP to reduce risk [4–8]. We measured these factors using variables with five and 10 point scales. *Fatal* describes the perceived risk of fatality if one contracts SARS, *Control* describes the extent to which the risk of infection can be modified by the individual, and *Knowledge* describes the respondents' degree of knowledge about the mechanisms by which SARS is transmitted. Perceived threat to the respondent is summarized by three variables: *Concern* (the respondent's overall degree of concern about SARS), *Danger* (the effect of SARS on the respondent's own life), and *Income risk* (the effect of SARS on the respondent's income this year). In addition, *Severity* and *Economy* summarize how serious the respondent believes the effects of the epidemic will be on Taiwan and its economy.

Willingness to pay (WTP) to reduce the risk of developing SARS was elicited using contingent valuation (CV) methods including double-bounded binary-choice questions [9]. Respondents were asked if they would be willing to purchase a vaccine (if it existed) that would eliminate the chance of becoming infected with SARS. To test for sensitivity of elicited WTP to the scope or magnitude of the benefit [10], the baseline risk of SARS, the conditional mortality risk, and the duration of protection were randomly varied among respondents. The risk of infection with SARS was described as either 3 per 100 000 or 5 per 100 000 per month in Taiwan, the mortality risk conditional on developing SARS as either 10 or 5%[b] and the period over which the vaccine would protect the individual as either 12 or 6 months (in the Taiwan sample) or as either 6 or 3 months (in the Taipei sample).

Results

Perceived risk

Frequency distributions for the three risk-characteristic variables are reported in Table 2, with means and standard deviations in Table 1. SARS risk was widely perceived as fatal, moderately controllable, and not unknown. These results suggest that SARS was not likely to be among the most feared risks, since risks that are perceived to be uncontrollable and unknown tend to elicit greater fear [3].

Respondents revealed a somewhat higher degree of concern about the threat of SARS to Taiwan than to themselves, potentially reflecting optimism bias [11]. On a five point scale, the average ratings of the variables reflecting the threat to Taiwan (*Severity* and *Economy*) are 4.1 and 4.5, respectively. In contrast, the average rating of *Concern* (about becoming infected) is 3.6 (Taipei sample) and the average values on a 10 point scale of *Danger* (the effect of the epidemic on the respondent's life) and *Income risk* (the effect of SARS on the respondent's income) are 6.3 and 5.1, respectively (Taiwan sample).

Table 2. Perceived risk: frequency distribution by variable level (percentage of respondents)

Variable	1	2	3	4	5
Taiwan sample					
Fatal risk	0.5	3.9	19.5	38.8	37.3
Knowledge	0.3	3.5	12.7	60.8	22.7
Controllable	7.3	7.3	39.1	39.2	7.1
Taipei sample					
Fatal risk	0	0.9	13.2	56.6	29.4
Knowledge	1.1	9.2	12.1	66.0	11.7
Controllable	2.6	9.2	30.0	48.7	9.6

WTP to reduce risk

The fractions of respondents who indicated they would purchase a vaccine declined significantly with the stated price[c]. Following conventional practice, the logarithm of WTP is assumed to be normally distributed with a mean that is a linear function of risk and individual characteristics. Regression models are estimated using maximum-likelihood methods [12].

Three regression models are estimated for each sample. The simplest models include only the dummy variables characterizing the magnitude of risk reduction (columns (1) and (4) in Table 3). The second set adds individual characteristics (columns (2) and (5)) and the third set adds risk perception variables (columns (3) and (6)).

WTP is estimated to increase with the magnitude of the risk reduction. The coefficients on *Risk*, *Mortality*, and *Duration* are all positive. Aggregating across models in the Taiwan sample, five of the six coefficients on *Risk* and *Duration* are significantly different from zero at the 1% level and one of the coefficients on *Mortality* is significant at the 10% level (columns (1)–(3)). Estimated values of the coefficients are similar in the Taipei sample but significance levels are lower, perhaps because of the smaller sample size. The estimated coefficients are substantially smaller than the values implied by the standard prediction that WTP for small reductions in health risks should be nearly proportional to the reduction in probability of harm[d]. Under the standard model, the coefficients on risk should be approximately equal to the log of the ratio of the larger risk reduction to the smaller risk reduction, i.e., the coefficients on *Risk* should be approximately equal to $\log(\frac{5}{3}) \approx 0.51$ and the coefficients on *Duration* and *Mortality* should be approximately equal to $\log(2) \approx 0.69$. For the Taiwan sample, the

hypotheses that WTP is proportional to the magnitude of the risk reduction can be rejected at the 1% level for all three variables. For the Taipei sample, the proportionality hypothesis can be rejected for *Duration* (except in column (5)) and *Mortality* but not for *Risk*. This departure from proportionality is pervasive in the CV literature and suggests that respondents may not have adequately considered the probabilities specified in the questions [10].

Table 3. WTP equations

	Taiwan sample			Taipei sample		
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	8.090***	2.295	2.224	6.664***	2.406	1.069
	(54.436)	(1.594)	(1.520)	(23.332)	(0.889)	(0.387)
Risk	0.240**	0.254**	0.263***	0.430*	0.270	0.348
	(2.042)	(2.265)	(2.372)	(1.822)	(1.095)	(1.411)
Mortality	0.200*	0.152	0.162	0.244	0.298	0.246
	(1.682)	(1.342)	(1.435)	(1.058)	(1.253)	(1.044)
Duration	0.230*	0.294**	0.283**	0.254	0.139	0.046
	(1.783)	(2.347)	(2.276)	(1.100)	(0.583)	(0.200)
Telephone				0.548**	0.512*	0.546**
				(2.377)	(1.936)	(2.017)
Age		−0.008	−0.006		0.004	0.000
		(1.112)	(0.911)		(0.200)	(0.000)
Education		0.072***	0.061***		0.004	−0.008
		(3.228)	(2.676)		(0.100)	(0.224)
Male		−0.045	0.014			
		(0.374)	(0.100)			
Married		0.023	−0.052		0.335	0.404
		(0.141)	(0.346)		(0.825)	(1.005)
Family members		0.010	0.015		−0.0180**	−0.152*
		(0.332)	(0.500)		(1.970)	(1.670)
Log (income)		0.375**	0.328**		0.478**	0.397*
		(2.567)	(2.256)		(2.319)	(1.952)
Health status		0.086	0.091		−0.151	−0.116
		(1.249)	(1.315)		(1.039)	(0.806)
Taiwanese		−0.489**	−0.480**		−0.300	−0.383
		(2.159)	(2.138)		(0.781)	(1.015)
Taipei dummy		−0.060	−0.032			
		(0.400)	(0.200)			
Religion belief		0.356***	0.365***			
		(2.640)	(2.731)			
Mask		0.116	0.075		0.277	0.237
		(1.025)	(0.663)		(1.020)	(0.872)
Economy		0.190***	0.122*			
		(2.867)	(1.814)			
Income risk		0.037**	0.012*			
		(2.296)	(1.707)			
Flu shot					1.215**	1.229**
					(2.007)	(2.066)
Severity			0.050			−0.120
			(0.648)			(0.728)
Danger			0.065***			
			(3.056)			
Fatal			0.076			0.451**
			(1.072)			(2.406)
Knowledge			0.088			0.003
			(1.091)			(0.000)

Table 3 (*continued*)

	Taiwan sample			Taipei sample		
Independent variable	(1)	(2)	(3)	(4)	(5)	(6)
Control			−0.066			0.009
			(1.091)			(0.000)
Concern						0.254**
						(2.119)
σ	1.534	1.458	1.435	1.963	1.919	1.869
Log likelihood	−1107.7	−1069.4	−1057.9	−500.01	−453.64	−446.78
WTP (NT$)	4686	5231	5400	1918	2397	2595

Notes: *t*-statistics are in parentheses. *, **, *** indicate estimated coefficient is statistically significantly different from zero at 10, 5, and 1%, respectively. WTP is the predicted median at the sample mean of the covariates. The 2003 exchange rate was US$1 = NT$34.95.

In the Taipei sample, respondents who were interviewed by telephone report significantly greater WTP for a SARS vaccine than those interviewed in person. Because the effects of survey mode and date of interview are confounded in our sample we cannot determine whether this coefficient reflects increasing concern about SARS over time or a survey-mode effect. The Taiwan-sample data, collected during a single week, reveal no temporal effect.

The estimated coefficients of the socio-demographic characteristics appear reasonable and consistent across model specifications. The effect of household income is positive and highly significant. The estimated income elasticity is 0.3–0.5 in both samples, consistent with previous health-valuation studies in Taiwan [15] and elsewhere [16]. Education is positively associated with WTP in the Taiwan, but not the Taipei sample. Age is not a significant predictor of WTP in either sample. In the Taiwan sample, WTP is not significantly related to gender or residence in the Taipei region, but it is larger for respondents who hold religious beliefs and smaller for those of Taiwanese ethnicity. Household size has no significant effect in the Taiwan sample and is negatively related to WTP in the Taipei sample.

The evidence on behavioral factors is mixed. Although the coefficients suggest that respondents who wore a protective mask had higher WTP, none are statistically significant. In contrast, Taipei-sample respondents who obtained a flu shot revealed significantly greater WTP for a SARS vaccine, possibly reflecting a predisposition toward vaccinations.

The performance of the risk-perception variables is mixed. Of the three psychometric variables – *Fatal*, *Knowledge*, and *Control* — only *Fatal* has a statistically significant coefficient, and only in the Taipei sample. The coefficient on *Severity*, reflecting concern about the effects on Taiwan, is insignificant but the coefficient on *Economy*, reflecting concern about the effects on the economy, is positive and significant in the Taiwan sample. The variables directed at personal risk are much more important in explaining variation in WTP. *Danger* and *Income risk* are positive and significant in the Taiwan sample, and *Concern* is positive and significant in the Taipei sample. One standard deviation increases in perceived *Danger* and *Concern* are associated with increases in WTP of 23 and 30%, respectively.

Predicted WTP for the SARS vaccine, calculated at the sample mean of the independent variables, ranges between NT$1918 and 5400 (Table 3). These predictions are adjusted for the indicated levels of the *Risk*, *Mortality*, and *Duration* variables and used to calculate the associated value per statistical life (VSL) reported in Table 4. VSL is the rate of substitution between income and mortality risk, calculated by dividing WTP for the vaccine by the corresponding reduction in mortality risk[e]. To the extent that part of the respondents' WTP is to reduce the risk of morbidity associated with SARS, this calculation will overestimate WTP to reduce mortality risk. Because the estimated coefficients of *Risk*, *Mortality*, and *Duration* are smaller than the values consistent with proportionality between risk reduction and WTP, estimated VSL tends to be larger for the smaller risk reductions.

Table 4. Estimated value per statistical life (US$ millions)

	Taiwan sample			Taipei sample		
	(1)	(2)	(3)	(4)	(5)	(6)
Duration = 12 *months (Taiwan)*, 6 *months (Taipei)*						
Mortality = 0.10						
Risk = 5/100 000	3.1	3.5	3.6	2.8	3.2	3.3
Risk = 3/100 000	5.0	6.0	6.1	4.4	4.7	5.2
Mortality = 0.05						
Risk = 5/100 000	4.0	4.5	4.6	3.0	4.0	3.9
Risk = 3/100 000	6.6	7.7	7.8	4.7	6.0	6.1
Duration = 6 *months (Taiwan)*, 3 *months (Taipei)*						
Mortality = 0.10						
Risk = 5/100 000	4.9	5.2	5.4	4.3	5.5	6.3
Risk = 3/100 000	8.0	8.9	9.2	6.8	8.2	9.9
Mortality = 0.05						
Risk = 5/100 000	6.4	6.7	6.9	4.7	7.0	7.4
Risk = 3/100 000	10.5	11.5	11.8	7.3	10.5	11.6

Note: Columns correspond to the regression models in Table 3.

The estimates of VSL reported in Table 4 range from US$2.8 to US$11.8 million. These are larger than previous wage-differential and CV estimates for Taiwan, which range from US$360 000 to US$2.2 million[f] [8,17–19]. The values in Table 4 are similar to estimates for the United States and other high-income countries, for which Viscusi and Aldy [16] (reviewing compensating-wage-differential studies) suggest the most reasonable estimates range from about $4 million to $9 million. The high estimates obtained here may be attributable to the high degree of salience and concern about SARS during the survey period, or to the possibility that respondents believed the risk they faced to be larger than the probabilities stated in the survey.[g]

Conclusions

Two surveys conducted in Taiwan during the peak of the SARS epidemic reveal a high degree of concern about SARS and high willingness to pay for a vaccine to prevent the risk of infection. Although results may be influenced by yea-saying or other potential biases common to CV, the general consistency of results between the two surveys — which encompass different populations and survey modes — provides some evidence that the results are reliable. These high values suggest that the strong actions taken to reduce the risk of SARS infection in Taiwan (and elsewhere) are likely to have been consistent with public preferences. In future work, it would be useful to estimate the marginal costs and efficacy of those actions for comparison.

The risk-perception results suggest that, while SARS was of great concern, respondents also believed they were knowledgeable about the risk and that it was to some degree susceptible to individual control. Among individuals, estimated WTP is related to household income and the perceived threat of SARS to the respondent, but not strongly related to the perceived effect of the epidemic on Taiwan. The estimated VSL is substantially larger than previous estimates for Taiwan, perhaps reflecting the novelty, salience, and high degree of public concern about SARS during the period in which these data were collected. Future work should investigate the extent to which WTP to reduce specific health risks varies with the novelty and degree of public attention focused on the risk.

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Notes

a. The number of new probable cases ranged from 0 to 3 per day before mid April, from about 10 to 25 per day between mid April and mid May, then fell rapidly to zero by mid June [2].
b. The stated risk of infection is consistent with the actual experience. Nearly all of the approximately 670 probable cases in Taiwan occurred within a month. Dividing by the population of about 22 million yields a probability of about 3 per 100 000. The average fatality rate in Taiwan was somewhat larger than stated, 84 deaths of 670 cases or about 13%.
c. In the Taiwan sample, the initial bids and fractions of respondents indicating they would purchase the vaccine in the initial question are NT$500, 89%, NT$1500, 84% and NT$4000, 67%, respectively. In the Taipei sample, the corresponding values are NT$500, 83%, NT$1000, 66%; and NT$5000, 44%, respectively. The 2003 exchange rate was US$1 = NT$34.95.
d. The standard model of WTP to reduce the probability of death (or other adverse health effect) assumes the individual wishes to maximize the expected health-state-dependent utility of wealth. Under this model, marginal WTP falls with the magnitude of the risk reduction (because the individual has less remaining income and is more likely to survive, increasing the expected utility loss from payment). Nevertheless, for risk reductions such that WTP is a small share of income, the departure of WTP from proportionality is negligible [13,14].
e. The reduction in mortality risk is equal to the product of the baseline risk of SARS, the conditional mortality risk, and the duration for which the vaccine is effective. Discounting to adjust for latency of benefit was neglected since it would have minimal effect.
f. Estimates are in nominal dollars but are recent enough that inflation adjustment would have little effect.
g. Binary-choice valuation questions (as used here). Typically yield higher WTP estimates than alternative open-ended and other formats [20–22]. Brown *et al.* [23] reviewed 11 studies that compared formats and found that discrete-choice estimates averaged between 1.1 and 4.8 times larger than open-ended estimates. Binary-choice questions are often preferred because of their apparently greater incentive compatibility [24].

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