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Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan*

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A contingent valuation survey was conducted in Taiwan to elicit willingness to pay (WTP) to avoid a recurrence of the episode of acute respiratory illness most recently experienced by the respondent. We estimate a model in which willingness to pay depends on the attributes of the illness (duration and number of symptoms, and nature of the illness) and on respondent characteristics (such as income and health history), and allow mitigating behavior to be endogenously determined with willingness to pay. WTP of Taiwanese households is compared with benefits transfer extrapolations that adjust WTP for the United States by Taiwan household income, relative to U.S. household income. © 1997 Academic Press

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1. INTRODUCTION

Developing countries face particularly difficult choices in balancing efforts to protect the environment with efforts to spur economic growth. A key, but generally absent, element of such decisions is an estimate of the social benefits that an improved environment will bring. The heavy demand for such estimates has led analysts to transfer values for environmental and health improvements from the United States, where such estimates are in relatively plentiful supply, to the developing country, usually with adjustments for income differentials between the countries (Krupnick et al. [9]).

The drawback of such benefits transfers is obvious: without further documentation, there is no reason why the preferences of people in other countries should be identical to preferences in the United States. Cultural factors, especially those that affect perceptions of illness, may alter people's willingness to trade income for health. Along with income differentials, differences in health and educational status and the availability and cost of health care are some additional reasons to expect differences in such trade-offs. These concerns imply that the best approach to health benefits analysis in developing countries is to do original valuation studies in the country of interest.

What is reported here is one such study. In September of 1992 we interviewed 864 people in three cities in the Republic of China (Taiwan) about the value they placed on avoiding minor illness. Specifically, we asked each respondent to describe their most recent episode of acute respiratory illness and tell us whether he/she would pay a stated amount to avoid a recurrence of the episode. The answers to this question and to subsequent follow-up questions enabled us to estimate willingness to pay to avoid illness as a function of the characteristics of the illness episode and of the respondent.

We feel that the results are of interest for three reasons. First, they provide information that could be used to value the benefits of air pollution control programs or other health programs in Taiwan. We used the willingness to pay results, together with the results of an epidemiological study that measures the effects of changes in the Pollution Standard Index on acute illness (Shaw et al. [15]), to value reductions in this index in Taiwan.

Second, our study allows us to compare the values that people in Taiwan place on avoiding minor illness with values obtained in the United States. In particular, we are interested in seeing whether, and by how much, willingness to pay to avoid acute illness differs between the two countries using alternative approaches to benefits transfer.

Third, our study asked respondents to value an illness that they had actually experienced, rather than a "synthetic" illness that the interviewer describes to them—the standard approach in contingent valuation studies of acute illness. We estimate a function linking willingness to pay to measures of severity and descriptors of the nature of the episode, and find that willingness to pay to avoid illness increases with episode duration and number of symptoms, but does so at a decreasing rate.

The paper is organized as follows. The second section of this paper presents a model of willingness to pay for reductions in acute illness associated with air pollution. Its purpose is to provide a framework for interpreting our survey results. Section 3 describes the health valuation survey and the samples to which it was administered. The raw data from the survey are described in Section 4. In Section 5, we introduce a statistical model in which respondent characteristics and characteristics of the illness valued are allowed to influence willingness to pay. Section 6 describes estimates of the willingness to pay function, including estimates from a model in which mitigating behavior is endogenous. Section 7 presents estimates of the benefits of air pollution improvements in Taiwan as well as results of alternative approaches to benefits transfer between the United States and Taiwan. Section 8 is the conclusion.

2. A MODEL OF WILLINGNESS TO PAY

Models that describe what an individual should pay for health improvements associated with air pollution are, by now, well established in the literature (Berger et al. [4]; Harrington and Portney [8]; Cropper and Freeman [5]). We reproduce such a model below to provide a framework for interpreting the willingness to pay (WTP) estimates obtained in our survey. The approach is to allow air pollution to affect duration of illness in a household production model of health. A nonmarginal change in air pollution will therefore cause a nonmarginal change in duration of illness. Because there is a one-to-one correspondence between the two, we asked people to value a nonmarginal change in duration of illness in the willingness to pay survey. The model identifies the variables on which willingness to pay for this change in duration of illness depends.

A Formal Model of Willingness to Pay to Reduce Air Pollution

A person's willingness to pay to avoid air-pollution-related illness may be developed in the context of the following household production model. Ideally, one would embed such a model in a dynamic programming framework in which utility in period t depends not only on acute illness in that period, but also on the stock of acute illness experienced to date. In such a framework, the actions a person would take to mitigate illness in period t would also depend on illnesses experienced in the past and on the realization that mitigating illness today would reduce the future disutility of illness. Elegant as such a model might be, we are forced to adopt a simpler approach given data limitations.

In the model that follows we view the individual's reaction to acute illness in a static framework: actions taken to mitigate illness in period t are independent of acute illnesses experienced in the past and are not motivated by the impact of these actions on future utility. We believe that this is an acceptable approximation of reality for two reasons. Based on a companion epidemiologic study (Alberini and Krupnick [3]), we know that people in Taiwan experience very little acute illness over the course of a year; hence, the complementarity between past illnesses and current illness is likely to be low. Second, most of the acute respiratory illnesses experienced by our respondents are relatively minor (over 65% are colds), suggesting that people might react to them without considering the implications of their actions on future health.

Formally, assume that utility is derived from goods consumed, X, leisure time, L, and that disutility is received from time spent ill, D, adjusted for the severity of illness, S. Let $I = D \cdot S$ denote an illness index that represents the *quantity* of illness experienced. Disutility also depends on the *nature* of the illness, N. For example, is the illness a cold or a lower respiratory tract infection? Z represents a vector of individual characteristics (e.g., health history, age) that affect the disutility received from I and N, as well as the utility received from X and L:

$$U = U(X, L, I, N; Z). \tag{1}$$

We assume that duration of respiratory illness (D) depends on air pollution (P), on the nature of the illness (N), and on an exogenous measure of severity (E). E indicates how bad a case of N one has, *before* anything is done to relieve one's symptoms. S measures the severity of illness *after* mitigating behavior, M, which includes medication taken and medical attention received[1]:

$$I(P, N, M, E) = D(P, N, E) \cdot S(M, E). \tag{2}$$

The quantity of illness, I, also enters the household's budget constraint by influencing the amount of productive time available for work. Specifically, the budget constraint is

$$Y + w(T - L - I) = p_X X + p_M M, \tag{3}$$

where Y is nonwage income, w is the wage rate, T equals total time, the term in parentheses is time spent working, and the p_is, with $i = X, M$, are prices.[2] The health production model assumes that the individual allocates time not spent ill between work and leisure activities, and income between medicine and other goods to maximize utility, subject to the budget constraint (3).

The Value of a Policy that Reduces Air Pollution

Consider now a policy that will affect air pollution levels and hence the amount of time the individual is likely to experience respiratory illness. If we ask what it would be worth to the individual to reduce air pollution, this would be the amount of money we could take away from him while reducing pollution and keeping his utility constant. Because of the one-to-one relationship between air pollution and duration of illness, however, one can always translate the change in air pollution into an equivalent change in D and evaluate willingness to pay for the change in D. Since we believe that it is easier for individuals to value a change in duration of illness, we follow the latter approach.

[1] In the models of Harrington and Portney [8] and Cropper and Freeman [5] activities to avoid exposure to air pollution also enter Eq. (2). We ignore avoidance activities for two reasons. First, based on a companion epidemiologic survey in which we asked questions about averting behavior, we do not believe that it is very important in Taiwan. Second, we wish in our contingent valuation survey to separate the valuation of health from attitudes toward air pollution.

[2] One might think that D, rather than I, should enter the budget constraint. We argue, however, that this is not so. How much productive time is lost from work depends on the severity of the illness.

The value of a nonmarginal change in D may be defined using the pseudoexpenditure function (Cropper and Freeman [5]). This is the minimum value of expenditure minus wage income necessary to keep utility at U^0, or

$$E = \min\left\{p_X X + p_M M - w(T - L - D \cdot S) + \lambda\left[U^0 - U(X, L, D \cdot S, N; Z)\right]\right\}, \tag{4}$$

where λ is a Lagrange multiplier. Willingness to pay for a nonmarginal change in D may be defined, using (4), as the expenditure necessary to achieve U^0 at the original duration of illness, D^0, minus the expenditure necessary to achieve U^0 at the new (lower) duration of illness D^1:

$$\text{WTP} = E\left(p_X, p_M, Y, w, N, S, Z, D^0, U^0\right) - E\left(p_X, p_M, Y, w, N, S, Z, D^1, U^0\right). \tag{5}$$

Equation (5) implies that willingness to pay should vary with income, prices, individual characteristics, the nature of the illness, its severity (which depends on mitigating behavior), and D^0 and D^1. This suggests that, to validate WTP responses, we regress willingness to pay on these variables.

We emphasize that, in light of our simplifying assumptions, WTP represents the value of reducing a single illness episode, independently of the number of such episodes experienced in the recent past. Our approach is thus analogous to valuing a fishing day independently of the number of trips taken during a fishing season (see Provencher and Bishop [13] for a recent attempt to view fishing decisions within a dynamic framework).

From Theory to Contingent Valuation

It is, however, a big step from the theoretical model to a contingent valuation survey. In particular, we must determine the commodity to be valued, which can be defined in two ways. One way is to describe an illness of a specific nature (N), duration (D), and severity for the respondent (for example, a severe head cold, with runny nose, that lasts 5 days) and ask him what he would pay to avoid it. This is the approach traditionally taken in the literature (Loehman et al. [10]; Loehman and De [12]; Tolley et al. [16]). One problem with this approach is that the respondent's scope for mitigating the effects of the illness is unclear: Does he value the illness assuming he can purchase medicine to relieve his symptoms, or are the symptoms described what he is supposed to suffer *after* mitigation has occurred?

To circumvent this problem we asked the respondent to describe a recent illness that he suffered and to record its nature and duration. We then asked him to value avoiding a recurrence of this illness episode. The advantage of this approach is that the illness being valued is meaningful to the respondent. Furthermore, the valuation task focuses on episodes of illness that may last several days and entail concurrent symptoms, rather than separate symptom-days, as is often done with researcher-defined illness.

3. SURVEY DESIGN AND HEALTH VALUATION QUESTIONNAIRE

In September of 1992 we administered an in-person survey about acute respiratory illness and the value of avoiding it to 864 adults in Taiwan.[3] The goal of our questionnaire (reported in Alberini et al. [1]) was to have people value reductions in acute respiratory illness using respondent-defined, rather than researcher-defined, definitions of illness. To define the illness episode, we asked each respondent to recall the last time he experienced acute respiratory illness and to check on a card all the symptoms he experienced.[4] These symptoms, together with the answer to the question ''Was the episode a cold?,'' characterize the nature of the illness (N). The respondent was also asked to indicate on a time line how long each symptom lasted (D). To capture severity of illness (S), we asked people if the illness episode caused them to miss work or school, stay in bed, or in any other way interrupt their normal activities. The associated numbers of work-loss days, bed disability days, and restricted activity days were recorded by the interviewer.[5]

To focus the individual's attention on factors that might influence willingness to pay, we asked if time was missed from work, whether income was lost as a result, and what activities the respondent undertook to relieve his symptoms, such as taking nonprescription medicine, increasing his intake of fruits and vegetables, and visiting a hospital or a doctor (M). If any of these activities was undertaken, we asked whether it was effective and how much money the respondent spent on it.

After describing his illness episode in detail, the respondent was given the following valuation question:

> We are now going to ask you a hypothetical question. Suppose you were told that, within the next few days, you would experience a recurrence of the illness episode you have just described for us. What would it be worth to you—that is, how much would you pay—to avoid the illness episode entirely?
>
> Remember that you are paying to eliminate all of your pain and suffering, your medical expenditure, the time you spent visiting the doctor or clinic, and your missed work, leisure, or daily activities.
>
> Bear in mind if you pay to completely avoid being ill this time, you have to give up some other use of this money. For example, you may reduce your expenditures for entertainment or education.
>
> Would you pay [FILL X1] NT dollars to avoid being sick at all?

Each respondent was given one of three initial willingness to pay (WTP) values [FILL X1]. This was followed by *two* follow-up questions, as shown in Fig. 1. The

[3] Respondents were 864 adults who had previously participated in an epidemiological study of the health effects of particulate matter and ozone from November 1, 1991 to January 31, 1992 and from August 1, 1992 to October 31, 1992 (see Shaw et al. [15] and Alberini and Krupnick [3]). The participants in the epidemiological study lived either in Taipei, the capital of Taiwan, Hualien, an unpolluted city on the east coast of the country, or Kaohsiung, an industrial center on the southwest coast of Taiwan, which is quite polluted. The participants were recruited from the residents of the area within 0.750 km of the monitoring stations, and do not, therefore, constitute a random sample of the population of the three cities, although there is no reason to believe that they are unrepresentative. Out of the 953 persons who completed the epidemiological study, 864 agreed to participate in the contingent valuation survey, which was administered in September of 1992, in the middle of the second round of health diaries.

[4] The symptoms on the card are listed in Table I.

[5] A restricted activity day is any day on which a person's normal activities are impaired, although the impairment need not be so severe as to restrict the individual to bed or prevent him from going to work.

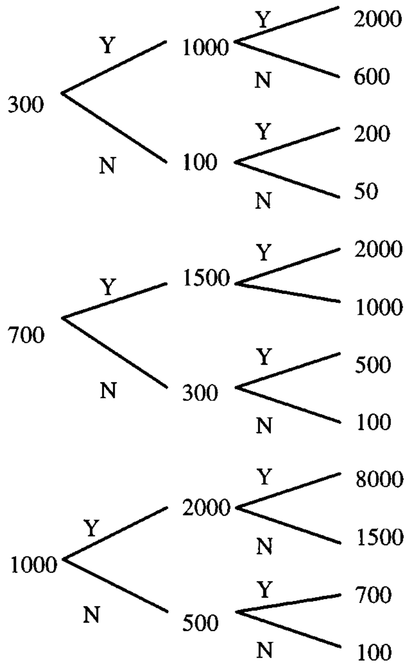

FIG. 1. Structure of the bids in the Taiwan CV study. All amounts in NT$ (at the 1992 exchange rate, NT$25 are equivalent to U.S.$1).

valuation questions asked respondents to provide information about willingness to pay to avoid a certain recurrence of an episode like the one they had most recently experienced, but did not draw any connection with air pollution or the ultimate purpose of the study.[6] The valuation question was followed by standard demographic questions, questions about income, the respondent's attitude about health and pollution issues, his health history, and environmental quality in the home and at the workplace.

Because of the emphasis we place on acute morbidity, subjects who had reported spells longer than 30 days were deleted from the data set we used for our analysis. This reduced the size of our usable sample from 864 to 832. The descriptive statistics and regression analyses reported in this paper are based on the ‘‘cleaned’’ sample of 832 individuals, unless otherwise indicated.

4. SURVEY RESPONSES

Since it is up to the respondents to define the illness they are valuing, we first examined the acute respiratory illnesses reported in the questionnaire. Table I gives the frequency distribution of symptoms reported. The symptoms most fre-

[6] In this sense, our study contrasts with Loehman, Park, and Boldt [11], who elicited WTP values for changes in air quality that would affect the number of healthful/unhealthful days and accordingly affect visibility.

TABLE I

Percentage of Respondents Reporting at Least 1 Day of Each Symptom (Based on Complete Sample)

Symptom	Percent
Headache	39.1
Runny nose	33.3
Sore throat	27.1
Dry cough	19.9
Cough with phlegm	19.1
Fever	14.8
Dry/scratchy throat	13.7
Eye irritation	12.5
Croup	9.3
Sinus problem	9.0
Aching muscles	6.7
Chest pain	5.6
Allergy	2.4
Rash	2.2
Shortness of breath	2.1
Wheezing	1.0
Asthma	0.7
Other symptoms	6.8

quently experienced were, in order, headache, runny nose, sore throat, and cough. It is not, therefore, surprising that 68.5% of respondents characterized their illness as a cold.

We also note that headache, a frequently reported symptom, was the only symptom for 12% of the sample, and was experienced concurrently with other symptoms by 28% of the respondents. Headaches without any other symptoms indeed account for a large part of the 1-day episodes reported by the respondents.

We define the duration of the illness episode as the time from the beginning of the first symptom to the end of the last symptom experienced. The median duration of an episode was 4 days; the mean duration was 6.8 days. During the episode, the median number of symptoms experienced was 1 and the mean was 2.2. More specifically, illnesses consisted of one symptom in 44% of the cases, two symptoms in 25% of the cases, and three symptoms in 14% of the cases, with fewer reported instances of four or more concurrent symptoms.

After engaging in mitigating behavior, the majority of respondents were not prevented from going about their daily activities: Only a quarter of respondents experienced at least one restricted activity day (RAD)—a day on which their normal activities had to be curtailed. About 12% of the respondents were confined to bed for at least 1 day, with the same percent of workers reporting work-loss days. Only 2.6% of the respondents reported a loss of income as a result of missing work.

The most common mitigating activities were taking over-the-counter medication (30.5% of the sample), changing diet (53.6%), or going to the doctor (55.0%). Although we do not know the average out-of-pocket cost of a doctor's visit, we do know the extent of insurance coverage for each respondent and whether the respondent had paid sick leave. We treat these as proxies for the money and time costs of a doctor's visit.

5. ECONOMETRIC ANALYSIS

As a test of the internal validity of responses, and to facilitate benefits transfer, we estimate an equation relating willingness to pay to its determinants, as shown in Section 2. Equation (5) indicates that WTP to avoid an episode of illness should depend on the nature and duration of the episode (which we denote x), on mitigating behavior, M, which influences severity, on individual characteristics (health history, age, education), and on determinants of the budget constraint (p_M, w, Y), which we denote z.

We assume that the logarithm of willingness to pay is a linear function of these characteristics or transformations of them. Formally,

$$\log \mathrm{WTP}_i = x_i \beta + z_i \gamma + M_i \delta + \varepsilon_i, \tag{6}$$

where β, γ, and δ are coefficients, and i indexes the respondent $(i = 1, 2, \ldots, n)$. ε_i, which represents unmeasured characteristics of the episode or the respondent, is assumed to be independently and identically normally distributed for all respondents, with variance $\sigma_\varepsilon{}^2$.

Mitigating behavior, M_i, in turn depends on income, prices, individual characteristics, and the nature and duration of the episode. Of the possible measures of mitigating behavior, we focus on whether or not a doctor was seen, a dichotomous variable. We assume that the respondent's behavior during the recurrence of his illness is the same as during the original episode. M measures the person's *propensity* to visit a doctor, which is a function of episode attributes (x_i) and individual characteristics (z_i):

$$M = x_i \tau + z_i \alpha + \eta_i. \tag{7}$$

The error term of the mitigating behavior equation, η_i, is assumed to be distributed as a standard normal. It is independent across respondents, but presumably correlated with the error term of the WTP equation, ε_i, due to unobserved severity (E) or other sources of unobserved heterogeneity. This makes propensity to see a doctor endogenously determined with willingness to pay in Eq. (6), and requires that appropriate estimation techniques be used to avoid obtaining biased estimates.

We rewrite the two equations in reduced form:

$$\log \mathrm{WTP}_i = x_i(\beta + \delta\tau) + z_i(\gamma + \delta\alpha) + \upsilon_i, \tag{8}$$

$$M_i = x_i \tau + z_i \alpha + \eta_i, \tag{9}$$

where $\upsilon_i = \varepsilon_i + \delta\eta_i$. There are now two possible approaches to estimating Eqs. (8) and (9): they can be estimated separately or, on recognizing that the error terms υ_i and η_i are correlated, as part of a system of seemingly unrelated equations.

Respondents do not report their WTP values directly, but we know that after answering the follow-up questions, respondent i's willingness to pay lies between two values, WTP_i^L and WTP_i^U, which are determined by the amounts stated in the payment questions and by the responses given by the subject.[7] Similarly, we cannot

[7] For instance, if the initial payment question states NT\$300, the associated response is a "yes," and the response to the follow-up amount of NT\$1000 is a "no," $\mathrm{WTP}^L = 300$ and $\mathrm{WTP}^U = 1000$. WTP^L and WTP^U may be equal to 0 and $+\infty$, depending on the sequence of "yes" and "no" responses to stated WTP amounts.

observe the underlying propensity to go to the doctor: however, we do observe whether the respondent did or did not go to the doctor. We assume that a subject saw a doctor if the underlying propensity M was greater than zero and did not see a doctor if the underlying propensity was less than or equal to zero.

When the two equations are estimated separately, the log likelihood function for our log normal willingness to pay is expressed as

$$\log L_{\mathrm{WTP}} = \sum_{i=1}^{n} \log\left[\Phi\left(\frac{\log \mathrm{WTP}_i^H}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}\right) - \Phi\left(\frac{\log \mathrm{WTP}_i^L}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}\right)\right], \tag{10}$$

where $\pi_1 = \beta + \tau\delta$, $\pi_2 = \gamma + \alpha\delta$, $\sigma = \sqrt{\mathrm{Var}(v)}$, and $\Phi(\cdot)$ is the standard normal cdf. Respondent i's probability of seeing a doctor is equal to $\Phi(z_i\alpha)$, which gives a probit model for doctor visits.

Willingness to pay and doctor visits can also be estimated jointly. Respondent i's contribution to the likelihood is

$$\Phi\left(\frac{\log \mathrm{WTP}_i^U}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}\right) - \Phi\left(\frac{\log \mathrm{WTP}_i^L}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}\right) - \Phi\left(\frac{\log \mathrm{WTP}_i^U}{\sigma} - \frac{x_i\tau_1 + z_i\pi_2}{\sigma}, -x_i\alpha, \rho\right) + \Phi\left(\frac{\log \mathrm{WTP}_i^L}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}, -x_i\alpha, \rho\right) \tag{11}$$

for those respondents who did see a doctor and

$$\Phi\left(\frac{\log \mathrm{WTP}_i^U}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}, -x_i\alpha, \rho\right) - \Phi\left(\frac{\log \mathrm{WTP}_i^L}{\sigma} - \frac{x_i\pi_1 + z_i\pi_2}{\sigma}, -x_i\alpha, \rho\right) \tag{12}$$

for those respondents who did not see a doctor, where $\Phi(\cdot, \cdot, \rho)$ is the bivariate standard normal cdf and ρ is the correlation between the two normally distributed reduced-form error terms.[8]

The Choice of Variables

In our empirical work we measured duration of episodes by the length of time between the appearance of the first symptom and the end of the last symptom experienced. We characterized the nature of illness by the number of symptoms experienced and whether or not the episode was a cold.

Respondent characteristics that may affect the disutility of illness include age, education, gender, and marital status. The respondent's baseline health status

[8] While the coefficients τ and α are always identified, the parameters of the structural equation for log WTP can be uniquely recovered only if either δ is equal to zero or δ is different from zero and ε and η are uncorrelated.

should also influence willingness to pay. Persons with a history of chronic illness, especially chronic respiratory illness, should be willing to pay more to avoid an illness episode, assuming increasing marginal disutility of episodes of illness. We used two dummy variables to capture these effects: one indicates that the respondent has at some time suffered from serious lung disease (pneumonia, chronic bronchitis, emphysema); the other indicates that he suffers (or has suffered) from a chronic illness that is not related to the lungs.

We have also included in our WTP equation variables that are supposed to capture the respondent's budget set and the price of health care faced by the respondent. An example of the first type of regressors is dummies for the respondent's place of residence: holding nominal household income constant, differences in *real* disposable income which may affect WTP can arise if the cost of living is different in Taipei, Kaohsiung, and Hualien. Another example is the number of sick leave days available to the respondent, which affects the time price of mitigating behavior and the availability of health insurance. (Descriptive statistics for all respondent characteristics are reported in Table II.)

Our theoretical model suggests that the likelihood of seeing a doctor should depend on illness characteristics, income, insurance status, available sick leave, and variables that affect the disutility of illness.

6. WILLINGNESS TO PAY FOR REDUCED ILLNESS

The Effect of Illness Characteristics on Willingness to Pay

The results (reported in Table III for the equation that combines the responses to all rounds of follow-up questions) support our specification of the WTP function

TABLE II
Summary of Respondent Characteristics

Individual characteristic	
Age (years)	42.36
Sex (male)	46.9%
Years of schooling	11.07
Currently employed	69.7%
Is a resident of	
Taipei	41.2%
Hualien	17.4%
Kaohsiung	41.4%
Sick leave plan[a]	30.2%
Smoke	23.7%
Has health insurance	83.0%
Monthly household income	
Mean	NT$58,875
Median	NT$47,500
Has ever had a serious lung disease (pneumonia, chronic bronchitis, emphysema)	26.0%
Has had other chronic disease	13.5%

[a] Percentage of employed respondents who reported such a plan.

TABLE III

Willingness to Pay Equations[a]
Interval-Data Estimation Based on All Rounds of Responses
(t-statistics in parentheses; sample size = 789)

		Willingness to pay equations[a]				
Regressor	Sample average	(A)	(B)	(C)	(D)	(E)
Intercept		3.9145	3.9382	6.2417	3.6094	4.2200
		(35.481)	(3.627)	(34.731)	(5.479)	(13.087)
Log(duration of episode in days)	Avg. duration 5.3064	0.3062		0.4091	0.3154	0.4572
		(4.193)		(4.058)	(3.163)	(4.805)
Log(number of symptoms)	Avg. symptoms 2.2255	0.3394		0.4325	0.3368	
		(4.135)		(3.268)	(2.595)	
Cold dummy	0.6948	−0.3992		−0.4614	−0.4068	−0.3087
		(−4.408)		(−2.779)	(−2.483)	(−1.998)
Age	41.98	−0.0349	−0.0328		0.0064	
		(−1.830)	(−0.672)		(0.982)	
Age squared	1916.74	0.0004	0.0004			
		(1.781)	(0.802)			
Log(monthly income in 000s)	Monthly household income NT$58,249	0.4488	0.4750		0.4136	0.3849
		(5.622)	(3.356)		(3.165)	(3.917)
Years of schooling	11.1131	0.0519	0.0608		0.0504	0.0534
		(2.511)	(2.587)		(2.279)	(2.690)
Resident of Kaohsiung Dummy	0.4142	0.0495	−0.0491			
		(0.548)	(−0.318)			
Resident of Hualien Dummy	0.1690	0.4308	0.4561			
		(4.466)	(2.200)			
Sick leave days	1.2718	0.0468	0.0501		0.0497	
		(2.836)	(2.933)		(2.969)	
Married	0.8333	0.4225	0.4411			
		(3.845)	(1.260)			
Married * family size	4.0600	−0.0169	−0.272			
		(−0.446)	(−0.598)			
Sex (male)	0.4669	0.1036	0.0815			
		(1.158)	(0.484)			
Number of persons at respondent's dwelling	4.8836	0.0197	0.0309			
		(0.512)	(0.904)			
Has health insurance	0.8309	0.1478	0.1824		0.1726	
		(1.520)	(0.839)		(0.851)	
Serious respiratory illness dummy	0.2598	0.3312	0.4393		0.3312	
		(3.613)	(2.655)		(2.041)	
Chronic illness dummy	0.1311	0.3804	0.5206		0.3593	
		(3.849)	(2.353)		(1.650)	
σ^2		3.4416	3.5397	3.6527	3.4469	3.5893
		(34.464)	(15.719)	(15.702)	(15.711)	(15.702)
Log likelihood		−1510.97	−1522.89	−1534.98	−1514.81	−2037.75

[a] Equation (A): most general specification; equation (B): individual characteristics only; equation (C): episode attributes only; equation (D): used for predictions and benefit transfers; equation (E) is part of a system of seemingly unrelated regressions (reported log likelihood value refers to the system).

by indicating that willingness to pay increases with duration of illness and with the number of symptoms experienced, and is higher for illnesses that are not colds than for colds.[9, 10] We report specifications of the WTP equation in which no curvature restrictions are imposed on the continuous independent variables associated with the episode of illness—number of symptoms and duration of illness—i.e., they appear in logarithmic form.

As predicted by theory, willingness to pay increases with duration of illness. The coefficient of log duration ranges between about 0.31 and 0.46, depending on the specification, suggesting that WTP increases with duration at a decreasing rate. The elasticity of WTP with respect to the number of symptoms ranges between 0.33 and 0.43, implying that WTP also increases at a decreasing rate with the number of symptoms experienced. Both of these results accord with studies conducted in the United States. Tolley et al. [16] reported that mean WTP for a combination of symptoms is always less than the sum of the WTPs for the individual symptoms, holding duration constant. Both Tolley et al. and Loehman et al. [10] found that WTP increases with duration of illness at a decreasing rate.

The coefficient of the cold dummy is negative and significant, and implies that having a cold (as opposed to a more serious illness) reduces WTP by about 33%.

The Effect of Respondent Characteristics on Willingness to Pay

Together with the attributes of the illness, equation (A) in Table III includes several potential determinants of willingness to pay, many of which are intended to capture taste for health, such as education, marital status, gender, age, age squared, and the number of people living in the respondent's dwelling. Willingness to pay does increase with household income, with years of education, and with chronic and prior respiratory illness.

Somewhat surprisingly, willingness to pay first decreases and then increases with age; however, the coefficients of the age and age squared terms are significant at the 10% level only in our most general specification [equation (A)], and become insignificant in other specifications.

Residents of Hualien reported WTP amounts that are 57% larger than those reported by residents in the other cities, but no significant differences are found between the WTP values of residents of Taipei and those of residents of Kaohsiung. The number of sick leave days afforded by one's job is a significant determinant of willingness to pay, but having health insurance is not.[11]

[9] The coefficients of the WTP equation remain relatively stable over successive rounds of bidding. Hausman tests indicate that the coefficients obtained from different rounds of bidding are not significantly different (Alberini et al. [1]). We checked our models for starting point bias, but found no evidence of it. We also compared our models with others that assume WTP has a different distribution. The basis for comparison is the log likelihood function adjusted for the number of parameters to be estimated. The fit of the log normal is almost as good as that of a Weibull (a distribution that has a flexible shape), somewhat better than that of a log logistic, and much better than that of the exponential distribution (see Alberini et al. [1]).

[10] We also tried a more detailed specification that included the number of days of each individual symptom (cough, headache, etc.) on the right-hand side of the WTP equation. This specification did not add much explanatory power over that provided by the more "aggregate" description of the illness.

[11] One might argue that the coefficient of sick days should be negative, in the sense that it should be more important to avoid illness for those respondents who are unable to take paid time off work. However, the coefficient of paid sick days is positive in all specifications of the WTP equation—a finding that we attribute to the fact that, in our sample, respondents who enjoy sickness leave benefits typically have more highly paid jobs or are government employees.

The income elasticity of WTP is of special interest (see Flores and Carson [7]). Our most general model pegs income elasticity of WTP to avoid illness at about 0.45. This value is, in fact, in the range of income elasticities reported by Loehman and De [12] in their study of WTP to avoid acute illness in Tampa, Florida.[12]

Column (B) reports a specification of the WTP equation in which episode attributes are omitted in order to focus on individual characteristics. Of these, household income, educational attainment, sick leave days, and health history remain statistically significant determinants of willingness to pay, and the signs and magnitudes of their coefficients are similar to those in the more general specification of column (A). Similarly, residents of Hualien consistently reported larger willingness to pay values, holding all other individual characteristics unchanged. Jointly considered, the coefficients of all individual characteristics are significant at the 5% level: the value of the likelihood ratio (LR) test is 64.62, which exceeds the appropriate critical level for the chi square with 14 degrees of freedom. We conclude, therefore, that individual characteristics do influence willingness to pay.

By contrast, in equation (C) we focus on the descriptors of illness and omit individual characteristics. The independent variables included in this regression are the logs of episode duration and number of symptoms, and the dummy indicating whether the episode was a cold. All coefficients are highly significant, and have the same signs and somewhat larger magnitudes than in (A) and (B).[13] The elasticities of willingness to pay with respect to duration and number of symptoms remain well below 1, confirming that willingness to pay increases at a decreasing rate with the number of sick days and the number of symptoms.

Based on these results, we conclude that WTP varies as expected with characteristics of the episode and of the respondent, and that our responses meet criteria of internal validity.

Additional Specifications Searches

Equation (D) is the WTP equation we used for prediction and benefit transfer purposes. We arrived at this model after starting with the general specification, (A), and sequentially removing variables that did not prove significant. We also omitted the city dummies because we felt they would be irrelevant for the purpose of comparing WTP amounts across countries.

Column (D) shows that log duration and log symptoms remain significant at the 1% level. Both have estimated coefficients of about 0.3. The income elasticity of willingness to pay is estimated to be 0.41, and having suffered from serious respiratory illness and being a chronic patient raise willingness to pay by about 39 and 43%, respectively, although the impact of the latter condition on willingness to pay is significant only at the 10% level. Finally, willingness to pay does not vary systematically with age and insurance status.

[12] Loehman and De fitted separate equations to model log WTP for each of the symptoms or symptom complexes valued. They included the length of the spell and log income among the regressors in each equation. The elasticity of WTP with respect to income is found to range between 0.26 (minor coughing and sneezing/eye irritation complex) and 0.60 (severe shortness of breath).

[13] A LR test for the significance of all coefficients of episode attributes takes on a value of 40.44, which falls in the critical region for the chi square with 3 degrees of freedom, once again confirming that episode attributes do influence willingness to pay to avoid the episode altogether.

Our initial probit regressions suggested that episode type and severity measures were significant determinants of doctor visits, but most individual characteristics were not.[14] This prompted us to keep the specification parsimonious when we fitted the WTP and doctor equations jointly. We report results for the WTP equation only in Table III, column (E).

The independent variables in specification (E) include log duration, the cold dummy, education, and household income in the WTP equation. The same variables except for income, which was earlier found irrelevant, are entered in the doctor equation. All regressors in both the WTP and the doctor equations are significant, and have signs and magnitudes comparable to those in the other specifications in Table III.[15] The correlation coefficient between the error terms of the reduced form model is estimated to be 0.20, a figure that is significantly different from zero at the 5% level.[16]

7. WILLINGNESS TO PAY TO AVOID ILLNESS IN THE UNITED STATES AND IN TAIWAN

Willingness to Pay for Reduced Illness in Taiwan

Using the estimates from specification (D) of Table III, we calculated median WTP for our sample at the sample averages of the covariates. Median WTP to avoid a recurrence of the average episode is NT$980 or U.S.$39.20 (s.e. 3.00).[17] This figure represents willingness to pay to avoid an episode of about 5.3 illness days and 2.2 symptoms. For the results of our survey to be useful for policy purposes, it is important to distinguish the type of illness that respondents are valuing and the length of the illness episode.

In Table IV, we report WTP for illnesses that were colds and those that were not, for 1- and 5-day episodes. The table shows that WTP varies considerably with the nature of the illness valued. For a 1-day episode with 2.2 symptoms, WTP ranges from $20 (for a cold) to $31 (for an episode that is not a cold). For average illness episodes—those of 5.3 days and 2.2 symptoms—WTP *per day* is much lower than for 1-day episodes ($7 and $10, respectively).

[14] Only marital status, being a resident of Kaohsiung, and years of schooling significantly affect the propensity to see a doctor.

[15] Estimating this equation as part of a system of seemingly unrelated equations gives only negligible gains in efficiency over estimating separate equations, a finding that confirms those discussed in Alberini and Kanninen [2] and Poe, Welsh, and Champ [14].

[16] If we are prepared to assume that the error terms ε and η of the original equations, (8) and (9), are independent, we can retrieve the *structural* coefficients of the WTP equation from the reduced form coefficients reported in (E). δ, the coefficient of the propensity to visit a doctor, as well as the covariance between the error terms of the reduced form equations, is estimated to be 0.3791 (t-statistic 4.26). This implies that seeing a doctor raises willingness to pay by about 46%, other factors being unchanged.

[17] The expression for the estimated median is $\exp(\bar{x}\hat{\beta}_r)$, with $\hat{\beta}_r$ the estimated slope coefficient from the rth round of estimation and $\bar{x}$ the vector of the sample means of the regressors. We use median, rather than mean, WTP because it provides a robust lower bound to the mean and is insensitive to large WTP amounts.

TABLE IV
Willingness to Pay to Avoid Illness in Taiwan (in 1992 U.S.$)[a]
(standard errors in parentheses)

	Episode is a cold		Episode is not a cold	
	1-Day episode	5-Day episode	1-Day episode	5-Day episode
WTP to avoid entire episode	$20.45 (3.49)	$34.62 (2.98)	$30.73 (6.36)	$52.01 (7.54)
WTP per day of the episode	$20.45 (3.49)	$6.53 (0.56)	$30.73 (6.36)	$9.81 (1.42)

[a]All episodes consist of 2.2 symptoms.

Health Benefits of Improved Air Quality in Taiwan

Table IV has two implications for valuing the benefits of air pollution reduction in Taiwan. First, the value of reducing illness by a given number of days will depend on the length of the illness episodes reduced. Willingness to pay to avoid a day of illness is much higher for a 1-day episode than for each day of a 5-day episode. Second, the nature of the illness significantly affects WTP values.

To illustrate how Table IV could be used in a benefit–cost analysis, we used it to estimate the benefits of lowering pollution levels in urban areas of Taiwan. Shaw et al. [15] in their analysis of the effects of air pollution on acute illness in Taiwan, calculated that reducing the Pollution Standard Index (PSI) (which weights monitored concentrations of PM10, NO_2, SO_2, ozone, and CO) from existing levels (which varied from 19 to 187 in 1992) to a PSI = 50 in all urban areas in Taiwan would have eliminated 16.8 million person-days of acute illness.

Because the marginal valuation function falls so rapidly with days ill, the estimate of benefits is sensitive to whether a few people experience many days of a symptom or a large number of people experience one or a few symptom-days. Unfortunately, the dose–response functions linking air pollution to symptoms are not precise enough to estimate the distribution of these person-day illness reductions in the population.

Accordingly, we used bounding assumptions on this distribution. If we assume the benefits are all in terms of 1-day colds, the morbidity value of the pollution reduction is approximately U.S.$262.58 million. The benefits are only U.S.$109.74 million if the 16.8 million days are assumed to represent 3.17 million average episodes of the same type (colds).[18]

Benefits Transfer

An important question when performing benefit–cost analyses of pollution control in developing countries is whether estimates of WTP computed in the United States can be transferred to other countries. There are a variety of approaches to making such a transfer. The simplest approach in the literature

[18] This analysis assumes that the Taiwan sample is representative of the population in urban areas of Taiwan. In fact, our sample appears to be wealthier and better educated than the population.

corrects only for income differentials between the countries and assumes that the elasticity of WTP with respect to income is 1.0. A slightly more sophisticated approach is to use an estimated income elasticity from the valuation literature. The Taiwan study estimated an income elasticity of about 0.4, while the Loehman et al. study valuing acute health effects estimated that the income elasticity is between 0.26 and 0.6. These results imply that, *other things being equal*, WTP is lower in a low income country than in a higher income country, but less than proportionally to the income differential.

A still more sophisticated approach to benefits transfer involves transferring a WTP *function* from one country to another, using the coefficients of the estimated equation along with mean values for the exogenous variables taken from the target country to estimate WTP for that country (Desvousges et al. [6]).

To test the performance of these approaches, we compared the ‘‘transferred’’ value of a symptom-day from U.S. studies to a point estimate and associated confidence interval from our study. Specifically, we transfer estimates of WTP to avoid a 1-day head cold from Tolley et al. [16] and Loehman et al. [10] to Taiwan assuming, alternately, that the income elasticity of WTP is 1.0 and that it is 0.4. Our third approach to benefit transfer uses the WTP function estimated for Taiwan to predict WTP to avoid a 1-day cold in the United States.

Table V first presents the results of using the simplest benefits transfer approach. In the first half of the table, estimates of WTP from U.S. studies are multiplied by the ratio of income in our sample to income in the U.S. study to predict Taiwanese WTP to avoid 1 day of head cold. To illustrate, Tolley et al.'s estimate of WTP to avoid ‘‘one day of severe head congestion and throat irritation,’’ which resulted in a restricted activity day, is $40. The predicted WTP for our Taiwan sample is $28. Loehman et al.'s estimate of WTP to avoid ‘‘one day of head congestion, eye, ear and throat irritation,’’ transferred to Taiwan, is $8 if the episode does not entail a restricted activity day and $16 if it does.[19]

We compared these estimates to our Taiwanese sample's WTP to avoid a 1-day cold with 2.2 symptoms. As shown in Table IV, this figure is $20.45, with 95% confidence bounds of $13.61 and $27.29. For one restricted activity day of head

[19] Both of these studies treat restricted activities as exogenous attributes of the illness being valued. By contrast, in our study restrictions in daily activities are endogenous behaviors. We do not enter variables accounting for such endogenous behaviors in the right-hand side of the WTP equations, and our WTP predictions do not distinguish between episodes with and without restricted activity days.

TABLE V

Willingness to Pay to Avoid a Head Cold: United States vs. Taiwan
(September 1992 U.S.$; 95% confidence intervals in brackets)

	With restrictions in daily activities			Without restrictions in daily activities		
	Value for United States	Prediction for Taiwan ($\alpha = 1$)	Prediction for Taiwan (= 0.4)	Value for United States	Prediction for Taiwan ($\alpha = 1$)	Prediction for Taiwan ($\alpha = 0.4$)
Tolley et al. (1986)	$40.32	$28.07	$34.88			
Loehman et al. (1979)	$19.23	$16.37	$18.06	$8.91	$7.61	$8.37

cold, the prediction of Tolley's study ($28.07) falls outside of the confidence interval for our sample for a 1-day cold, while the prediction of Loehman's study ($16.37) falls within the confidence interval for our sample. For a day of head cold that is not a restricted activity day, Loehman's prediction ($7.61) falls below the lower endpoint of the 95% confidence interval of our sample.

We also performed the same analysis using an income elasticity of 0.4. This approach raised the Taiwan WTP estimates ''transferred'' from the U.S. studies from $28.07 to $34.88 based on the Tolley et al. study, and from $16.37 to 18.06 (with a restricted activity day) and from $7.61 to $8.37 (without restrictions in daily activities) based on the Loehman et al. study. The new estimate based on the Tolley et al. study lies outside the 95% upper bound estimate from our study, as does the figure from Loehman's study that assumes no restrictions in daily activities.

To use the WTP *function* approach to benefits transfer, we need WTP functions from the Tolley et al. and Loehman et al. studies and estimates of mean values of the explanatory variables for Taiwan. Unfortunately, these studies have not published their WTP functions. An alternative approach is to use the Taiwanese WTP function and mean values of the explanatory variables for the United States to estimate U.S. WTP values.

We obtained mean values from the Tolley et al. sample for many of the variables contained in the WTP specification (D) (Table III), including income, education, age, sex, and health history. To make our predictions comparable, we reestimated the WTP function only on the set of variables covering the intersection of the Taiwan and Tolley et al. data sets. The new regression coefficients along with the mean values for the variables from the Tolley et al. study yielded a median WTP estimate for a 1-day head cold with restrictions in daily activities of $62.12, with a 95% confidence interval of $26–98. The Tolley et al. estimate for this effect is $40.32, which falls within this relatively wide confidence interval.

We conclude from this limited empirical evidence that none of the existing approaches to benefits transfer outperforms the others. The WTP estimates from the U.S. studies are not sufficiently similar to permit an unambiguous test of alternative benefit transfer methods. Considering the two simplest approaches, some of the transferred estimates based on one study are within the confidence interval of the Taiwan study estimate, while the other estimates are outside of the confidence interval. The third, more sophisticated, approach (albeit applied to a transfer from Taiwan to the United States) yields reasonable agreement between the estimates.

8. CONCLUSIONS

This study investigated the value of reducing illness in Taiwan and related methodological issues. Previous studies that valued reductions in acute illness asked respondents to value a set of symptoms that were described for them. This study approached the matter somewhat differently, by allowing the respondent to describe his most recent episode of acute respiratory illness. We felt that this would make the commodity valued more meaningful to the respondent, resulting in more reliable WTP estimates and estimates that better represent values for average illness episodes. The drawback of this approach is that it may be difficult for a respondent to recall his most recent illness episode. If this is the case, WTP values obtained from self-described illness episodes may be unreliable.

Our results suggest that WTP responses to avoid respondent-described illnesses are internally valid. Willingness to pay to avoid illness increased with duration of illness, with the number of symptoms experienced, and with education and income.

Finally, we tried to shed light on the issue of benefits transfer. We compared the performance of three benefits transfer approaches. For two of these, which focused only on adjusting for income differentials in the United States and Taiwan, we compared WTP estimates from our survey with predictions of Taiwanese WTP based on U.S. studies. For the third approach, based on using the WTP *function*, we compared a WTP estimate for the United States to predictions of U.S. WTP obtained using the Taiwanese WTP function. None of the methods yields unambiguously superior results. Better tests can be devised and more credible "transferred" WTP estimates can be obtained by designing original valuation studies to support future use in a benefit transfer analysis.

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