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Valuing health effects from the industrial air pollution in rural Tianjin, China

YANG Zhi-feng, XU Lin-yu

(State Key Joint Laboratory of Environmental Simulation and Pollution Control, Institute of Environmental Sciences, Beijing Normal University, Beijing 100875, China. E-mail: zfyang@bnu.edu.cn; xly@mail.bnu.edu.cn)

Abstract: High concentrations of air pollutants such as total suspended particulates(TSP) and sulfur dioxide(SO_2) have serious impacts on nearby populations. In this paper, a survey of rural Tianjin residents' willingness-to-pay for health improvement was reported on, and the MBDC(multiple bounded discrete choice) model was adopted to study the respondents' willingness-to-pay to prevent respiratory illnesses. The results showed that the willingness-to-pay for health improvement was affected by respondents' health condition, work situation and environmental awareness, but not by personal habits, such as smoking. If person's willingness-to-pay to avoid respiratory diseases can be considered equal to the cost to personal health caused by air pollution, the total cost will reach 538×10^6 RMB Yuan(RMB, equal to 65 million USD) per year.

Keywords: health loss; MBDC; willingness-to-pay; TVIE; Tianjin City

Introduction

Air pollution in Tianjin is very serious, and is mainly caused by coal consumption. The average concentration of total suspended particulates (TSP) has reached 0.35 mg/m^3 from 1990 to 1998, exceeding China's level II Environmental Criterion, which is 0.20 mg/m^3. Township and village industrial enterprises (TVIEs) are the main source of air pollution in Tianjin(Hu, 1997). High concentrations of air pollutants such as TSP and sulfur dioxide (SO_2) can seriously damage human's health. As some epidemiological surveys have shown, cases of respiratory illnesses, such as bronchitis and pneumonia correlate with increased concentrations of air pollutants. According to the World Health Organization(WHO), respiratory illnesses will become more serious if a person is exposed to soot or SO_2 over a long time period when the average concentration has exceeded 0.100 mg/m^3, or for a short time period in which the concentrations exceed 0.250 mg/m^3 (Guo, 1990). The Human Capital Method is generally used to calculate the public health impacts of air pollution, but it ignores the effects on individual victims. In fact, residents in a polluted area would be willing to pay additional money to prevent sicknesses caused by air pollution. Their unrealized willingness-to-pay can be thought of as a potential economic loss. In this research, the method named MBDC(multiple bounded discrete choice) has been adopted to calculate the health effects of air pollution on individuals so that the psychological costs to pollution victims can be quantified.

1 Research methods

1.1 The contingent valuation method

Willingness-to-pay (WTP) is defined as the willingness of a consumer to purchase some commodity or service at a given price (Robert, 1989). This concept can be illustrated with a sketch map as shown in Fig.1. In the figure, the vertical axis represents the likelihood of an individual paying, while the horizontal axis represents the price of the commodity or service.

The contingent valuation(CV) method is commonly used to study WTP. It can be applied not only to the valuation of environmental resources or the losses caused by environmental pollution, but also to the investigation of prices for goods that have not come into the market. A number of techniques can be used to gain willingness-to-pay from respondents, such as dichotomous choice, open-ended choice, and fixed-value payment card. However, contingent valuation practitioners, experimental economists, and psychologists have long recognized that the use of different contingent valuation elicitation formats can produce divergent value estimates(Cameron, 1998). For example, the numerical value attained from dichotomous choice is always greater than that from payment card(Boyle, 1996). In general, if the CV method chosen asks for only one price, the result will be greater than that from a CV method asking for multiple prices. The respondents to a contingent valuation survey may instead have a range of economic values in their mind or a valuation distribution (Cameron, 1994; DuBourg, 1994), rather than having a single point economic value, as a number of experiential studies have suggested. It has been argued that uncertainty is an inherent characteristic during economic valuation processes for both market and non-market commodities. Thus, an individual's valuation should be characterized as a random variable with an associated distribution(Wang, 1997a; 1997b).

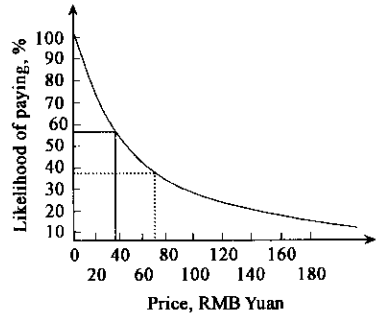

Fig.1 Curve of willingness to pay

1.2 MBDC method

Considering the limitations of the contingent valuation methods, Welsh and Bishop (Welsh, 1993) and Welsh and Poe(Welsh, 1998) have devised a method named multiple bounded discrete choice (MBDC). MBDC comes from return potential. It not only supplies a

series of prices from which respondents can choose, but also gives the likelihood of each price. The probability matrix thus formed can be used to estimate a distribution function of *WTP*.

Typically, a two dimensional matrix is generated. One dimension denotes different social situations, and the other represents respondents' levels of valuation. Welsh and Bishop have demonstrated that the "return potential" supplied by the CV method can then be used to evaluate *WTP*. In our application of this method, one dimension denotes a series of possible prices of some commodity or service, while the other represents the likelihood of paying for the commodity or service at that price. There are five kinds of likelihood: Definitely No, Probably No, Not sure, Probably Yes, and Definitely Yes.

Letting H_0 represent a person's health condition and V_0 represent his use function, we can posit this relationship: $V_0 = V(Y, H_0, E, Z, \varepsilon_0)$. Where Y means income per annum; H_0 means personal original health condition; E is the environmental quality; Z is the social economic variety; and ε_0 is the variation which can not be fully represented by Y, H_0, E or Z. When H changes to H_1, we can generalize the following equation: $V_1 = V(Y, H_1, E, Z, \varepsilon_0)$. If an individual is willing to pay money equal to WTP to achieve H_1, then: $V(Y - WTP, H_1, E, Z, \varepsilon_0) = V(Y, H_0, E, Z, \varepsilon_0)$. Assuming E, t, and ε remain the same, thus we calculate that: $WTP = WTP(Y, H_0, H_1, E, Z, \varepsilon_0) = E[WTP] + \varepsilon_1$. Here E is the expectation of *WTP* and ε_1 is the error due to random variation. After calculating *WTP* for a series of prices, the cumulative valuation distribution function can be formed. Letting a person's cumulative valuation distribution function be $F(T)$, the probability that he is willing to purchase some commodity or service in order to maximize his utility is:

$$
\begin{aligned}
&P(\text{Yes}) \\
&= P\{V(Y - T, H_1, E, Z, \varepsilon) > V(Y, H_0, E, Z, \varepsilon_0)\} \\
&= P\{V(Y - T, H_1, E, Z, \varepsilon) > V(Y - WTP, H_1, E, Z, \varepsilon_0)\}. \\
&= P\{WTP > T\} \\
&= 1 - F(T)
\end{aligned}
$$

Here, V is the indirect utility function; Y is the income per annum; H is the personal health condition; T is the price supplied in order to achieve H_1; and *WTP* means personal willing-to-pay in order to achieve H_1.

Letting the maximum acceptable price of the ith person be X_{iu}, and the minimum unacceptable price be X_{il}, then the *WTP* of that person will fall within $[X_{il}, X_{iu}]$. Using $F(T)$ as the cumulative valuation distribution function of the ith person, then the probability that the individual's *WTP* falls within $[X_{il}, X_{iu}]$ is $F(X_{iu}) - F(X_{il})$. The result is determined according to the Maximum Likelihood Estimate Function(Chen, 1997): $\ln(L) = \sum_{j=1}^{n} \ln[F(X_{iu}) - F(X_{il})]$. If all of the respondents accept all the prices, $X_{iu} \to +\infty$, or in the opposite case, $X_{il} \to -\infty$.

2 Case study

2.1 Questionnaire

From April to May 2000, we surveyed 347 residents and 331 workers of Tianjin random using a prepared questionnaire. Imagining that there is a medical treatment that would prevent a person from developing respiratory diseases, the willingness-to-pay for such a treatment would equal the potential health cost of people except those who are sick. The questionnaire includes seven parts: health condition, personal information, environmental awareness, pollution control, personal exposure to pollution, household condition and willingness to pay. The last of these, the primary focus of this paper is designed as Table 1.

Table 1 MBDC questionnaire and the statistics of responses

Cost of treatment, RMB Yuan	Definitely No	Probably No	Not sure	Probably Yes	Definitely Yes
Free	133	25	119	46	228
10	144	43	108	104	152
21	172	43	136	100	100
40	208	64	127	86	66
60	241	70	135	61	44
90	276	82	120	37	36
150	333	83	84	30	21
200	363	81	70	20	17
300	385	76	62	15	13
500	415	59	50	14	13
1000	435	49	47	10	10

Before the respondents fill in the table, those who were sick were excluded, and the others be asked to pay attention to the following instructions: Imagining that there is a medical treatment that would prevent a person from developing respiratory diseases for three months. By the end of six months the treatment would have lost its effectiveness and another treatment would be required. Suppose that the new treatment was expensive to administer and was in limited supply. If you could afford it at a price indicated in the left column, how likely is it you would purchase the treatment for yourself?

2.2 Calculation

All of the respondents returned the questionnaire, but 70 residents and 57 workers did not supply any numbers on the above table. Therefore the real response rate is 79.8% and 82.8% respectively. Table 1 also summarizes the responses from the 277 residents and 274 workers who answered the question. To further analyze these responses we assume that "Definitely No", "Probably No", "Not sure", "Probably Yes", "Definitely Yes" equate to 100%, 75%, 50%, 25% and 0% probabilities of WTP respectively. The average WTP for each price is shown as Table 2.

Table 2 Paying likelihood of every price

Price, RMB Yuan	0	10	20	40	60	90	150	200	300	500	1000
Likelihood	0.596	0.535	0.461	0.381	0.317	0.262	0.193	0.158	0.135	0.115	0.097

The paying likelihood of every price can also be described with Fig. 2. When price increases, the percent of WTP decreases. The curve can be simulated with index function and gain their average WTP, which is 176.6 RMB Yuan per year per person. Similarly, the willingness-to-pay of residents and workers can also be calculated separately as Table 3 shows. The average WTP of residents is 147.3 RMB Yuan per year per people, and that of workers is 193.8 RMB Yuan per year per people. From Fig.3, the estimated WTP curve of workers is also higher than that of residents, which means the WTP of workers is higher than that of residents.

Table 3 Percent of WTP at each price of residents and workers

Price, RMB Yuan	0	10	20	40	60	90	150	200	300	500	1000
Worker	0.554	0.531	0.489	0.421	0.362	0.298	0.218	0.181	0.147	0.122	0.108
Resident	0.601	0.532	0.432	0.342	0.273	0.221	0.168	0.135	0.123	0.107	0.086

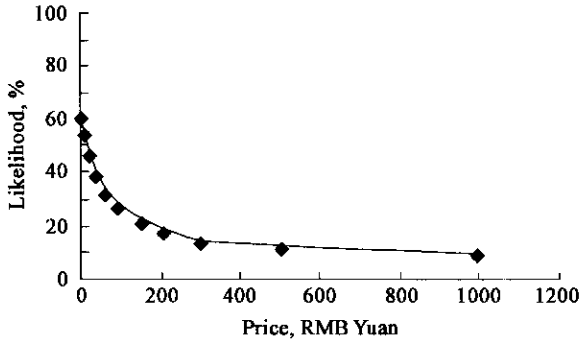

Fig.2 Average WTP curve

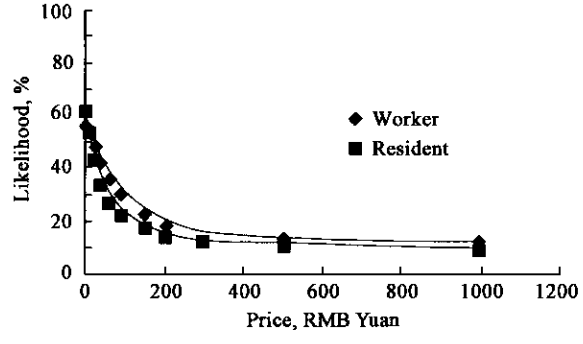

Fig.3 Paying likelihood of each price of resident and worker

The result can be extended across all of suburban Tianjin. According to the City Yearbook (China municipal statistical yearbook, 1997), the population of suburban Tianjin is 3047300. If person's willingness-to-pay to avoid respiratory diseases can be considered equal to the cost to of personal health caused by air pollution, the total cost will reach 538×10^6 RMB Yuan per year. This demonstrates that TVIEs have caused great negative influence to society and environment, though they have stimulated the development of economy.

3 Discussion

According to the analysis of WTP for air quality improvement in Bulgaria conducted by Wang(Wang, 1999), WTP is related to income, education and age (Table 4). We found that the residents and the workers investigated in Tianjin display a similar pattern. From the perspective of environmental psychology, every person wants to prevent his own sickness. Especially when he doubts his own vulnerability to illness, he is willing to pay more to avoid illness due to pollution. If somebody falls ill, he will pay more to achieve his expected level of health in regardless his low income. Therefore, the main factors causing their different willingness-to-pay are health condition and working environment. In addition, environmental awareness may affect WTP, while the habit of smoking has little effect to it.

Table 4 Comparing resident with worker in income, education and age

Group	Income, RMB Yuan per annum	Education, year	Age
Resident	6913	12.48	36.13
Worker	7458	11.25	37.14

The work situation may affect WTP. The TVIEs are among the worst emitters of pollution. From air monitoring data, the TSP, SO_2 and NOx of the 84 factories surveyed is 5.6 mg/m^3, 2.55 mg/m^3 and 0.473 mg/m^3 respectively, while that of Tianjin City as a whole is far less at 0.371 mg/m^3, 0.36 mg/m^3 and 0.112 mg/m^3 respectively. Under this conditions, about 41% of workers feel not content or dissatisfied. About 43% of workers are exposed to harmful soot and about 19% of workers are aware that the harmful soot has affected their health condition. Hence, the workers of the 84 factories are willing to pay 193.8 RMB Yuan per year per person for purchasing medicine to prevent sickness of respiratory organs, which is more than the total average WTP (176.6 RMB Yuan per year per person). All these things showed that workers face the greatest risk of being sick in polluted TVIEs. In fact, according to a survey by the World Bank, the dose-response relationship between the concentration of air pollution and health does exist. When the concentrations of NOx, SO_2 and TSP increase by 1%, the rate of respiratory diseases will increase 0.102%, 0.181% and 0.183%, respectively, according to the citation to World Bank(Cao, 1999).

Environmental awareness is also a main factor affecting WTP. Residents will be more sensitive than workers to the outside air environment. From the survey data, we can see that 62% of residents and only 34% of workers think the problem of air pollution is very serious, and 68% of residents and only 42% of workers think the problem of sand blown by wind is very serious. All of them are willing to pay a little more than average level. From the analysis we see that the stronger environmental awareness the person has, the more is he willing to pay.

Moreover, personal habits can cause different health condition. Smoking is the main factor. It is found that 28.2% of residents and 38.1% of workers smoke. While the average willingness-to-pay of smoking residents and workers, 136.7 and 145.4 RMB Yuan per year per person respectively, are lower than the means for all residents and workers that are 147.3 and 193.8 RMB Yuan per year per person, respectively. Perhaps do they know the fact that women smoke less but suffer illness as much as men. Hence, they do not think smoking relates to respiratory illness.

The survey of willingness-to-pay is still subjective. Therefore information on other possible factors that will affect the result is needed to confirm these findings. At the end of the questionnaire, the attitude of the respondents is surveyed. It is found that many residents and workers disbelieve the purpose of the medicine. When they are asked to answer the following three questions, their responses showed: (1) 69.9% of resident and 73.4% of workers disbelieve the existence of the medicine; (2) only 22.1% of residents and 21.4% of workers believe in the efficacy of the medicine; (3) 41.7% of residents and 53.8% of workers think the actual period of validity will decrease.

Hence, when they are asked whether they really need this kind of medicine, 35% residents and 49% workers answer "never mind". From the above analysis, if the suspicion of the responders about the premise of the survey can be eliminated, their willingness-to-pay will increase and exceed 538×10^6 RMB Yuan per year.

4 Conclusions

MBDC is a feasible method to measure real benefit. While the survey of WTP, especially by the MBDC method, is rarely applied in China, though there are many articles about it in foreign countries. Hence, this paper is an experiment to apply MBDC to calculate the willingness-to-pay of people in a rural area of China. After designing questionnaires and investigating residents and workers in rural Tianjin, the health effects from the township-village industrial air pollution can be gained through calculating the willingness-to-pay, which is 538×10^6 RMB Yuan per year.

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