

Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

## Journal of Environmental Management

journal homepage: [www.elsevier.com/locate/jenvman](http://www.elsevier.com/locate/jenvman)

## Air quality assessment by contingent valuation in Ji'nan, China

Yan Wang\*, Yi-Sheng Zhang

School of Environmental Science and Engineering, Shandong University, Ji'nan, China

## ARTICLE INFO

## Article history:

Received 31 January 2007  
 Received in revised form 5 March 2008  
 Accepted 17 March 2008  
 Available online xxx

## Keywords:

Air quality  
 Willingness to pay  
 Contingent valuation method  
 Ji'nan

## ABSTRACT

Along with urbanization and environmental deterioration within China, many residents' desire for improved air quality has increased. To address this topic, this study focuses on the relationship between poor air quality and residents' willingness to pay for improved air quality in the city of Ji'nan. As a means of quantifying an individual's willingness to pay (WTP) for improved air quality, a contingent valuation method (CVM) was employed. A sample of 1500 residents was chosen, based on the stratified sampling method. The respondents' WTP was then elicited through a series of face-to-face interviews, conducted using a range of hypothetical, open-ended scenario questions. The results showed that 59.7% of respondents were able to express a positive WTP, and that the average WTP was 100 Chinese Yuan (CNY) per person, per year. In order to establish the relationship between endogenous variables and WTP, both a Probit model on the probability of a positive WTP, and a stepwise regression model were constructed. Most parameters in the econometric analysis demonstrated the expected results. It was found that annual household income, expenditure on the treatment of respiratory diseases and workers in the family significantly influenced WTP. The rates of positive WTP and the monetary amount were also larger for men than for women. Unlike developed countries, most respondents regard air quality improvement as a government responsibility in that more than 40% of respondents had no incentive to bear the costs of attempting to achieve better air quality, indicating a relatively low environmental consciousness.

© 2008 Published by Elsevier Ltd.

## 1. Introduction

Air pollution is a persistent concern in the cities of developing countries. This is especially the case in China, which has faced serious deterioration of air quality over the past several decades (Wang, 2004; Watts, 2005). A recent report by the State Environmental Protection Administration (SEPA, 2006) stated that two out of every five cities in China failed to meet the residential area air quality standard, resulting in the exposure of their population to the risk of adverse health effects. Energy consumption, especially coal consumption, is the primary source of air pollutants, such as particles, SO<sub>2</sub>, and NO<sub>2</sub>, in most cities in China. As the primary energy source, coal has, in recent years, accounted for about 65–70% of total energy consumption (China Statistical Yearbook 2006, 2007), with numerous undesirable consequences.

In general, ambient air pollution is closely associated with industrialization and urbanization. This means that the urban population is likely to be the primary group exposed to high levels of ambient air pollution. In recent decades, the Chinese government has established air quality monitoring sites in nearly every city. These can be used to provide the public with detailed information

regarding air condition and daily air pollution index (API). As a result of the information becoming more readily available, residents can now more easily track the progress of, and express concerns about, air quality in the city. This may, in turn, be a cause of urban residents' increasing desire for improved air quality. A survey carried out in China in 2005 showed more than 80% of interviewees regarded the issue of air pollution as a serious one (SEPA and Chinese Academy of Social Sciences, 2006). This idea is further developed by new research suggesting that an improvement in air pollution level can also be linked to a decrease in mortality and morbidity rates over a stated period for each person exposed to air pollution (The World Bank and SEPA, 2007; HEI International Scientific Oversight Committee, 2004). It is therefore increasing important to work at understanding residents' desire for improved air quality. Furthermore, China is now developing Green GDP Accounting. Costs incurred by air pollution can be monetized by contingent valuation method (CVM), which is then eliminated from GDP accounting, thus achieving a more reasonable index for measurement of economic development rate.

Since air pollution can affect many aspects of a society, including human health, agricultural yield and industrial production (Xia, 1998), it is difficult to measure the benefit of air quality improvement by traditional means such as the dose–response method. The contingent valuation method (CVM), however, is a useful tool when dealing with this type of issue, as it can obtain a monetary value for

\* Corresponding author. Tel./fax: +86 531 88361157.

E-mail addresses: [wy@sdu.edu.cn](mailto:wy@sdu.edu.cn) (Y. Wang), [wy405@hotmail.com](mailto:wy405@hotmail.com) (Y.-S. Zhang).

an intangible good that does not have a market price. In order to do this, CVM presents consumers with hypothetical opportunities to buy public goods and elicits preferences by asking people about their willingness to pay (WTP) for them, thus circumventing the absence of a real market (Mitchell and Carson, 1989). This approach enables individuals to take account of all factors (e.g. income level, socio-economic characteristics, consumption of non-market goods, etc.) that are important to them in the provision of the service. Within this study, the non-market good is the idea of air quality improvement in the city of Ji'nan.

CVM has been in use as a means of valuating a wide range of environmental goods and services for over 35 years, with over 2000 papers and studies using this method, most of which were from developed countries (Carson, 2000; Whittington, 2002). However, CVM has rarely been used in environmental valuation in China. Given the seriousness of air pollution in China, and a general lack of previous China-based valuation studies based on the CVM technique, practicing this valuation method has clear advantages.

CVM has been produced in several formats: open-ended, bidding game, dichotomous choice (DC) and payment card format. Among these methods, the open-ended format CV has its own advantages, including a much more efficient use of data, and absence of a starting-point and yea-saying bias (Carlsson and Johansson-Stenman, 2000). According to previous studies carried out by Langford, the open-ended format can be useful in providing information that can be obtained from smaller scale studies, which have been often undertaken as a precursor to a DC survey (Langford et al., 1998). Since there are few studies concerned with residents' WTP for the improvement of air quality in cities of northern China, it would be too difficult to design a bid-vector for dichotomous choice format questions or a scale and intervals for payment card questions. Finally, and most importantly, several studies have identified that the open-ended hypothetical format produced a more accurate estimate of actual payment than did other hypothetical formats (Brown et al., 1996; Onwujekwe and Uzochukwu, 2004). Thus, although uncertainties exist about several of the components of open-ended (OE) methodology (Carson, 2000), the results provide reasonable estimates of the range of residents' willingness to pay for air quality improvement.

Taking into account the multiple advantages of the open-ended question format and a lack of information from other formats, we finally chose to use OE CVM in our questionnaire. We hope that our research can determine residents' degree of satisfaction with air quality and provide useful information as guidance for establishment and implementation of environmental policy.

The remainder of this study is organized as follows. Section 2 gives a general description of the study design and data collection process. Section 3 describes the data analysis using a regression model. Finally, we briefly conclude the study by discussing the implications of the findings, limitations of the study, and potential directions for future research.

## 2. Study design and statistical method

### 2.1. Study site description

Ji'nan is located between latitude 36°10'–37°90'N and longitude 116°12'–117°35'E and is a typical land-locked city in northern China, with jurisdiction over four rural and six urban districts. Its urban area is approximately 3257 km<sup>2</sup>, with more than 3 million inhabitants at the end of 2005. Five urban districts (Licheng, Lixia, Huaiyin, Shizhong, and Tianqiao) were selected in our survey based on their development level.

Significant air pollution concentrations have been reported in Ji'nan, which is still listed as a city with some of the worst air pollution in China, and even in the world. According to a report

released in 1998 by the World Health Organization (WHO), seven of the 10 most polluted cities in the world can be found in China, with Ji'nan ranked in 8th place (Green Nature, 2004). The annual concentrations of air pollutants reported in the Ji'nan Environmental Protection Bureau (JNEPB) annual reports for 1992–2005, also confirmed this, based on the data averaged over five urban air quality monitoring substations<sup>1</sup> (Fig. 1).

PM<sub>10</sub> which is a combined expression of smog, industrial dust and natural dusts, is a major air pollutant in Ji'nan. The annual average PM<sub>10</sub> concentration in the city has exceeded the Class II national air quality standard guideline since 1992, and is far from meeting the WHO Air Quality Guideline of 20 µg/m<sup>3</sup> (WHO, 2006), though a decline in mean annual concentration was seen over the 1990s. Daily monitored data between 2002 and 2005 showed that the concentration of PM<sub>10</sub> days exceeded the Class II national air quality standard (100 µg/m<sup>3</sup>) on 478 (32.7%) of the 1461 days monitored (JNEPB, 1990–2005).

Due to the large urban population and high population density in Ji'nan, the number of people exposed to air pollution is quite large in this area (The World Bank and SEPA, 2007). Since air pollution causes serious economic losses, investments in air pollution control from government are increasing and public pressure is mounting on the local government to crack down on air pollutants. However, no significant changes have been observed since 2000. An earlier investigation conducted in Ji'nan indicated that more than 93% of respondents were concerned about urban air pollution. These facts laid the foundation for our investigation into the citizen's WTP for air quality improvement in the area.

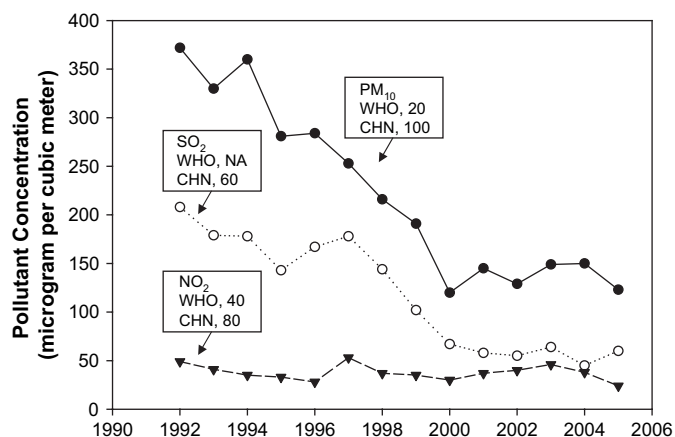
### 2.2. Questionnaire and survey design

Pretest and pilot studies were conducted to assess the effectiveness of the survey. A pretest was conducted in December 2005 which ascertained that all 20 respondents understood the question asked. Sixty people were interviewed in a pilot test a week later, which focused on the content of the WTP questions. After modifying the questionnaire, the final questionnaire consisted of three parts. The first section contained socio-economic questions, including those relating to gender, age, education, region of residence, occupation and annual income. The second part consisted of questions regarding respondents' subjective views on the current situation of air pollution status in their area of residence and the relationship between air pollution and health, respiratory diseases and expenditure on treatment of these diseases. The final section consisted of the contingent valuation survey.

A final survey was conducted in April 2006. Interviews were conducted on a face-to-face basis by trained student interviewers from the School of Environmental Science and Engineering, Shandong University. A random selection of 1500 adults who agreed to participate in the survey was chosen from the five urban areas of Ji'nan. The number of sampling units was determined according to the population in each district to ensure the samples were representative (Table 1). All the respondents were 18 years old or above.

Since air pollution may impact many aspects of society, it would be a failure to only consider health effects as a survey strategy (Carlsson and Johansson-Stenman, 2000). To avoid bias, we allowed the respondents themselves to judge the effects of air pollution from their subjective perspective. However, considering the lack of experience for respondents in dealing with this kind of survey, it was necessary to provide essential information. Our explanation involves three elements: (a) the detailed classification of the

<sup>1</sup> TSP and NO<sub>x</sub> were monitored between 1993 and 1999, but this changed to the daily monitoring of PM<sub>10</sub> and NO<sub>2</sub> since 2000. Annual NO<sub>2</sub> concentration data were obtained from government report of 1998–1999 (JNEPB, 1990–2005).



**Fig. 1.** Annual air pollutant concentrations in Ji'nan, 1992–2005. TSP data from 1992 to 1999 were converted into PM<sub>10</sub>, based on the experimental result that on average the PM<sub>10</sub> fraction was 0.60 of the TSP mass (JNEPB, 2004). Data from 1992 to 1997 were shifted from NO<sub>x</sub> to NO<sub>2</sub> using a ratio of 0.72 which was also obtained from experimental analysis. The standard annual mean concentration that was recommended by the updated WHO guideline (WHO, 2006) and the standard annual mean concentration for residential urban and rural areas in China (CHN) are also listed. NA, not available.

current ambient air quality standard<sup>2</sup>; (b) air quality status in Ji'nan, pictures of both “deteriorated” air and “improved” air in order to advance respondents’ understanding of current air pollution levels; and (c) payment objective and method. Interviewees were told that the payment would be charged to himself/herself annually in order to avoid confusion between personal and household payment.

The respondents were asked the following open-ended valuation question:

“Currently, the urban area in Ji'nan meets Class III air quality standards. In order to fulfill the stringent Class II air quality standards, a series of improved actions must be employed. Obviously, the implementation of these programs incurs cost, which would be directly or indirectly paid by us. When you consider your household’s income and expenditure are you willing to pay this cost so that this aim can be achieved?” (Note: you do not actually pay the money in our survey).

(1) Yes (2) No

If you are willing to pay for air quality improvement, what is the maximum amount you would be willing, and be able, to pay for it?\_\_\_\_\_

The respondents who reported a WTP value greater than zero were treated as positive WTP. Those who chose to answer ‘unwillingness to pay’ were treated as valid zero WTP. The latter were also asked a follow-up question to establish their reasons for rejection and who they believed should be responsible for covering the costs of air quality improvement.

### 2.3. Statistical tools and method

Statistical packages SPSS 14.0 and Stata 9.0 were applied to calculate the relationship between WTP and influential factors. After initial statistical analysis, we used the Probit model to identify the variables that affect the respondents’ final decision on WTP.

<sup>2</sup> At present, China has adopted three classes of ambient air quality standards. The Class I standard applies to tourist, historic and conservation areas. The Class II standard is used in residential urban and rural areas, while the Class III standard is a suitable guideline for industrial areas and heavy traffic areas.

**Table 1**  
Sampling statistics for the five urban districts in Ji'nan

Sample districts	Population (10 <sup>4</sup> person)	Area (km <sup>2</sup> )	Sample number (person)	Sample ratio (10 <sup>-4</sup> )
Licheng	90.57	1298	500	5.52
Lixia	59.88	101	400	6.68
Shizhong	56.22	280	250	4.45
Tianqiao	50.27	249	200	3.98
Huaiyin	35.85	151	150	4.18
Total	292.79	2079	1500	5.12

Source: Ji'nan Statistical Yearbook (2005, 2006).

Then, a stepwise model was constructed to determine factors affecting the amount of a positive WTP.

## 3. Results and discussion

### 3.1. Validation test

Because CVM uses hypothetical questions, it is a standard practice for the study to include tests on the internal and external validity of respondents.

In our study, the scenario presented was well accepted by the interviewees and achieved an 87.9% (1319/1500) completion rate by the closeout date. Interviewees (12.7%) did not answer the WTP questions, which was smaller than but consistent with Carson's report (1991) report that the typical number of non-responses in a CV study range from 20% to 30%. The relatively low non-response rate of 12.7% indicated that the questionnaire was constructed successfully.

The background and validity checking questions used in this study are listed in Table 2. Detailed descriptions of the variables are also given in the table. These variables include the respondents’ demographic characteristics, socio-economic status, health status of family members, and the air pollution status in their resident areas from a subjective perspective.

**Table 2**  
Descriptions of the independent variables, and the mean and standard deviation (S.D.) of the responses

Variables	Description	Mean	S.D.
Age	Respondents' current age	32	12
Agesq	Age square	1168	975
Gender	Male = 1, female = 0	0.562	0.496
Education	Categorical variable: 1 (below Primary school), 2 (Middle school), 3 (Technical middle school), 4 (College), 5 (University), and 6 (over University)	4.105	1.143
Family size	Number of family members	3.529	1.126
Workers	Number of workers in family: 1 (no workers), 2 (1 worker), 3 (2 workers), 4 (3 workers), and 5 (exceeding 4 workers)	2.345	0.928
Income	Family annual income (unit: 10 <sup>3</sup> CNY): 1 (below 2), 2 (2–5), 3 (5–8), 4 (8–10), 5 (10–20), 6 (20–30), 7 (30–50), 8 (50–100), 9 (over 100)	4.796	2.332
Expenditure	Expenditure on respiratory diseases treatment per year (unit: CNY): 1 (below 100), 2 (100–1000) 3 (1000–2000), 4 (2000–5000), 5 (over 5000)	1.947	0.945
Employment	Being employed in the formal sector = 1, other = 0	0.555	0.497
Pollution	Self-reported living in a severely air polluted area = 1, other = 0	0.643	0.479
Correlation	Self-reported air pollution and health having correlation = 1, other = 0	0.962	0.192
Diseases	Having respiratory symptoms = 1, other = 0	0.536	0.499
Questions	Respondents who were willing to pay = 1, other = 0	0.980	0.140

The average age of respondents was 32, and the average age for urban residents ranges from 32 to 36 years old, according to the Fifth Nationwide Population Census. Differences between data obtained from the survey and actual distribution of inhabitants (Ji'nan Statistical Yearbook 2005, 2006) are shown below. The mean household income of respondents participating in our survey was about 10,000 CNY, compared to the average household income of 14,920 CNY in 2005. The average education level of the respondents was about 12 years, while for city residents it averaged 8.52 years. The percentage of male respondents accounted for 56.2% of participants while the average ratio of males in the urban region was 50.4%. The number of family members in our survey was 3.529, compared to 3.317 in the 2000 national population census. In short, the respondents were more likely to be male, younger, more educated, and have a relatively lower annual household income, with more family members, than the overall population.

Of 1319 valid responses, 532 interviewees (40.3%) who were hypothetically unwilling to pay were treated as 'true zeros'. This, in turn, means that the distribution of the WTP in the sample is skewed unevenly and that the median value is much lower than the mean value. The respondents who were willing to pay 51–1000 Chinese Yuan (CNY) composed about 76.9% of all positive WTP ( $WTP > 0$ ). This phenomenon was also consistent with other studies carried out at home and abroad (Wang et al., 2006; Carlsson and Johansson-Stenman, 2000).

### 3.2. Characteristics of respondents with negative and positive WTP

In Table 3, the descriptive statistics of the WTP responses to the valuation questions can be seen, where the values are presented in CNY per year. The 692 respondents with positive WTP ( $WTP > 0$ ) were split into eight groups, according to the amount of money that they would be willing to pay (1–10, 11–50, 51–100, 101–200, 201–500, 201–1000, 1001–5000, and exceeding 5000 CNY). Since there is a rather large share of zero responses and most respondents stated a rather low WTP, the mean WTP is very sensitive to any extreme responses.

#### 3.2.1. Negative WTP ( $WTP = 0$ )

A large proportion, as much as 40%, of respondents refused to pay for air quality improvement. We list five possible explanations here, and consider the likelihood that they could have influenced our survey results.

The first explanation is that open-ended survey questions can typically elicit a large number of protest zeros, which is often seen as a pitfall of the open-ended question format (Brown et al., 1996; Carson, 2000). In this method, it is more difficult for respondents to answer compared to other CV methods. Respondents were not

**Table 3**  
WTP responses for air quality improvement in Ji'nan

WTP (CNY)	Frequency	Percentage (%)
0	532	40.3
≤10	25	1.9
11–50	85	6.4
51–100	201	15.2
101–200	98	7.4
201–500	125	9.4
501–1000	108	8.2
1001–5000	42	3.2
>5000	8	0.6
<sup>a</sup>	95	7.2
Total valid	1319	100

<sup>a</sup> Ninety-five respondents were willing to pay but did not answer the valuation question, including 42 males, 44 females and 9 persons who did not record their gender.

**Table 4**  
Respondents' reasons for negative WTP ( $WTP = 0$ ),  $N = 532$

Reasons for rejection	Percentage (%)
It is the government's responsibility	40.9
Polluters should pay	26.4
Income is too low to afford it	15.9
Government and polluters should pay for it	12.6
Air quality is good	2.1
Other reasons	2.1

given a ready market price to choose, thus they had to provide a precise WTP amount themselves, which requires more time and attention and may result in their protest. Ninety-five respondents even skipped the WTP questions in our survey, though they showed positive attitudes towards air quality improvement.

A second explanation is that respondents with rejective attitudes had quite high expectations of the government. Since China is not entirely an open market economy, many people have much confidence in the government and regard it as omnipotent (Table 4). In contrast to their confidence in the government, one quarter of respondents believed that polluters should pay for air quality improvement. In other words, interviewees with negative responses did not regard ordinary citizens as being responsible for investments in air quality improvement, which indicates a relatively low awareness of environmental protection.

A third possible explanation is that wealthier respondents believed that, since they pay taxes, the government should use some of this money for air pollution control.<sup>3</sup>

The fourth potential explanation is that once the environmental protection activities affect routine life, the protest ratio will rise (Davies and Mazurek, 1998). If inhabitants believe that the money paid for air quality improvement is too high, and would affect their living standard without obvious benefits, a high rejection rate is expected.

Finally, there may be a potential explanation about the good which was asked to be paid for. Improved air quality is a pure public good which is non-excludible and non-competitive and therefore is generally more difficult to get people to pay for. Those who contribute nothing (or less than other respondents do) to improving air quality are able to enjoy the same benefits as those who do contribute to the costs of achievement. Respondents may conclude that they can enjoy the benefits of a group's success regardless of the extent of their own efforts – so why risk bearing the costs of what might turn out to be a failed investment of resources? Consequently, in the absence of any other factors, people frequently calculate that there is little incentive to bear the costs of attempting to achieve better air quality.

Of the five possible factors, we believe that residents' trust in the government is the most important factor that led to the high protest ratio. More than 50% of respondents regarded that the government should be responsible for the serious air pollution issue and cover the bill for air quality improvement (see Table 4). This reveals that inhabitants in Ji'nan still have relatively low environmental awareness.

#### 3.2.2. Determinants of the probability of positive WTP

T tests and regression models are often used to check the effects of various factors on the probability of a positive WTP. Since the T test can only determine the effect of a single factor on WTP, we

<sup>3</sup> At the time of the survey, only earners with an income more than 1600 CNY (about 200 US\$) per month pay income tax in China. The exchange rate at the time of the survey was 1 US\$ = 8.0 CNY.

**Table 5**Probit model for the probability of positive WTP,  $N = 973$ 

Variables	Model 1		Model 2		Model 3	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Gender	0.035	0.086	0.049	0.086	0.055	0.086
Age	0.009	0.022	0.005	0.022	-0.001	0.022
Agesq	-0.000	0.000	-0.000	0.000	-0.000	0.000
Education	0.095	0.039*	0.088	0.039*	0.080	0.039*
Family size	0.015	0.049	0.010	0.049	0.014	0.049
Income	0.055	0.018**	0.053	0.019**	0.053	0.019**
Pollution	-0.092	0.088	-0.112	0.090	-0.133	0.090
Workers	0.088	0.060	0.078	0.060	0.071	0.061
Region of residence	-0.011	0.032	-0.012	0.032	-0.006	0.032
Employment	-0.070	0.096	-0.069	0.096	-0.056	0.097
Respiratory symptoms			-0.083	0.097	-0.094	0.097
Expenditure on respiratory diseases treatment			0.122	0.052*	0.118	0.052*
Health correlation					0.469	0.227*
Pseudo $R^2$	0.022		0.027		0.030	

\*\* $P \leq 0.01$ ; \* $P \leq 0.05$ .

adopted the latter method and established a sequence of Probit models to establish the quantitative relationships between endogenous variables and people's WTP. The results of these calculations are presented in Table 5.

In the first model, only social and economical variables have been included. Not surprisingly, family annual income had a strong positive impact on positive WTP probability ( $r = 0.055$ ) with a 0.01 level of significance. Education level ( $r = 0.095$ ) also has a positive relationship with the probability of positive WTP, at a 0.05 level of significance. In addition, gender, family size and number of workers in the family displayed positive effects on the probability of any WTP, which is consistent with expectations, but not statistically significant. The results demonstrate that age has a generational impact on the probability of a positive WTP. Up to 27.7 years old, as age increased, a person's probability of having any WTP for air quality improvement increased, but after age 27.7 it began to decrease. The results indicate that young people were more sensitive to air pollution threats than their parents.

In the second Probit model (Table 5) the results were not affected by adding disease variables as regressors except that the turning point for the age variable lowered to 19 years old. Expenditure on the respiratory diseases treatment ( $r = 0.122$ ) variable showed a significant relationship with the probability of having a positive WTP. People without respiratory symptoms were more willing to pay for air quality improvement than those who had symptoms, but the correlation was not at the significant level.

In the final Probit model, a subjective view on the correlation between air pollution and health variables was included and a significant correlation was found. The age variable effect in the third model turned out to be negative, whereas it was positive in the first and second regression models. A comparison of outcomes and probabilities showed that 65% of an exact prediction could be achieved.

Overall, it appears that the main factors affecting a positive WTP for air quality improvement are household income ( $P \leq 0.01$ ), a respondents' opinion regarding the relationship between health and

air pollution ( $P \leq 0.05$ ), education level ( $P \leq 0.05$ ) and expenditure on respiratory disease ( $P \leq 0.05$ ). Surprisingly, factors which were hypothesized to increase the probability of a positive WTP such as gender, age and household size were statistically insignificant (Table 5).

### 3.3. The determinants of the amount of WTP

The 95 respondents with a positive attitude towards air quality improvement but who skipped the elicitation questions (generally due to their inability to provide a precise WTP estimate) were eliminated, leaving 692 valid samples in the next stage of analysis.

Partial correlation analysis was first applied to avoid co-linear effects. The procedure computes partial correlation coefficients that describe the linear relationship between two variables, while controlling the effects of additional variables.

By applying partial correlation analysis, it was found that money used for respiratory diseases treatment, annual household income and education level, as well as the number of workers in a family, have positive correlations with the amount of WTP, although they are not statistically significant. Gender and age display negative relationships with WTP. The number of family members suffering respiratory symptoms showed a relatively small influence on WTP value (Table 6).

The impacts of the independent variables on WTP were also analyzed by linear regression. Since the WTP distribution is skewed with a long tail towards high amounts, we chose to use the log-transformation approach to bring the distribution closer to the normal and to restrict the WTP to positive values. A stepwise regression model was constructed and variables including expenditure on respiratory diseases treatment, annual household income and number of workers in the family were chosen at the significance level of 0.05 (Table 7). Analysis of the model shows that residues of WTP are normally distributed, thus reflecting a better estimation of the WTP value. Goodness of fit tests also show that the models are suitable for predicting WTP values.

**Table 6**

Partial correlation matrix of positive WTP and nine variables (two tailed)

	Gender	Age	Education	Family size	Income	Residence	Workers	Expenditure	Diseases
WTP	0.049	-0.044	0.106	-0.003	0.148	0.038	0.073	0.236	0.023
$P$ value	0.272	0.324	0.016	0.951	0.001	0.395	0.099	0.000	0.600

**Table 7**  
Results of stepwise regression of WTP and socio-economic variables,  $N = 692$

Step	Explanatory variable	Regression coefficients		T value	P value	95% CI		Co-linearity statistics	
		B	S.D.					Tolerance	VIF <sup>b</sup>
1	Constant	2.079	0.059	35.447	0.000	1.964	2.195	1.000	1.000
	Expenditure <sup>a</sup>	0.129	0.027	4.810	0.000	0.076	0.181		
2	Constant	1.918	0.076	25.117	0.000	1.768	2.068	0.991	1.009
	Expenditure	0.121	0.027	4.532	0.000	0.068	0.173		
	Income	0.035	0.011	3.252	0.001	0.014	0.056		
3	Constant	1.701	0.112	15.216	0.000	1.481	1.921	0.990	1.010
	Expenditure	0.118	0.027	4.465	0.000	0.066	0.171		
	Income	0.034	0.011	3.188	0.002	0.013	0.055		
	Workers	0.101	0.038	2.650	0.008	0.026	0.175		

<sup>a</sup> Expenditure on treatment of respiratory diseases.

<sup>b</sup> Variance inflation factor.

The regression equation is

$$\log_{10} \text{WTP} = 1.701 + 0.118 \times \text{Expenditure} + 0.034 \\ \times \text{Household income} + 0.101 \\ \times \text{Number of workers in family}$$

Based on the estimated WTP function, we can calculate that the predicted WTP for air quality improvement, using sample means for all the variables in the logistic functions and the predicted mean value obtained from the model, is 217 CNY (27 US\$). The range calculated from the regression model is 71–3206 CNY which was limited to real scope.

The two variables of education level and respondents' subjective opinion on the correlation between air pollution and health did not enter into the stepwise model. Thus, these variables are correlated with the decision to state a positive WTP, but not with the level of WTP.

Our results were in line with what has been noted by Sherrod and Downs (1974), that WTP is inevitably associated with ability to pay. Such an association with income is positive since it means that WTP is behaving in a way that would be expected a priori; thus confirming the internal validity of the technique.

#### 3.4. The estimation of WTP for different districts

The average residents' WTP for the five different districts can be seen in Table 8. Predicted WTP using the estimated WTP function is also presented.

According to Table 8, residents of the Tianqiao District have the highest predicted WTP, when compared with other districts, when residents' own complaints of poor air quality are also taken into account. Respondents living in the Shizhong District, where complaints of respiratory problems were more frequent than in the four other districts, had the largest average and median WTP.

The chi-square test showed that the residents of the districts chosen did not have significant differences in their attitudes about air quality improvement. This is consistent with their social and economic development level, which reflects that the respondents

chosen were representative, and thus the WTP value obtained from the survey is reliable.

#### 3.5. Comparison of other studies

The results of the few prior studies in China focused on eliciting residents' WTP and opinions on air quality are listed in Table 9. Differences in survey time and samples, the healthcare system, and experiences with surveys contribute to differences in the results, and a different question format may also lead to differences, as confirmed by investigations conducted in developed countries. Yet, it is still interesting to compare our results with those obtained in previous studies which can provide useful insights on the method.

Surveys in Beijing (Wang and Mullahy, 2006) and Chongqing (Wang et al., 2006) which adopted open-ended CVM have similar ratios between WTP and income level as our results in Ji'nan. Surveys carried out in Beijing (Cai and Zheng, 2007; Hammitt and Zhou, 2006), Shanghai (Peng and Tian, 2003), Tianjin (Yang and Xu, 2004) and Taiwan (Chien et al., 2005) using DC CVM have relatively higher ratios ranging from 0.5% to 4.1% which are consistent with survey results in Malaysia (Afroz et al., 2005). The comparison shows that the WTP values of the respondents do not differ significantly across different question formats though the DC method showed a somewhat higher ratio than the OE method. We also found that WTP questions referring to air pollution related diseases increased the ratios between WTP and income.

In other words, residents' WTP for air pollution related good were mostly determined by their income level. For example, when comparing previous findings with this study, it can be seen that ratios between WTP and mean annual income are similar, with magnitudes ranging from 0.4% to 2.1%. This, in turn, confirmed the theory that residents' WTP is related to their economic development level. Since social and economic development in Ji'nan lags behind that of Beijing and Shanghai, the obtained WTP (100 CNY) indicated a reasonable scope.

The conservative estimate of aggregate WTP values of the residents was CNY 0.37 billion for air quality improvement in urban areas of Ji'nan, which accounts for about 15% of air pollution control

**Table 8**  
WTP in different districts

District	Valid sample	Positive WTP (%)	Self-reported air quality <sup>a</sup>	Respiratory symptom <sup>b</sup>	Mean WTP	Median WTP	Predicted mean WTP	S.D.
Licheng	446	59.0	0.66	0.62	264	50	213	620
Lixia	368	60.9	0.63	0.65	514	50	230	3000
Shizhong	206	63.6	0.61	0.69	544	100	222	1902
Tianqiao	180	53.3	0.69	0.60	331	0	233	1228
Huaiyin	119	61.3	0.56	0.60	199	50	216	366

<sup>a</sup> Self-reported air quality: 0 = air quality is good, 1 = air quality is bad.

<sup>b</sup> Respiratory symptom: 0 = no respiratory symptom, 1 = at least one respiratory symptom.

**Table 9**

Results from similar studies in Chinese cities

Survey location and date	Sample	Goods	WTP (per year)	Income (CNY/year)	Ratio (%)	Reference
Ji'nan <sup>b</sup> (2006)	1500	Reduction of air pollution to meet residential area air quality standard	CNY 100	14,286	0.7	This work
Beijing <sup>b</sup> (1999)	1500	50% reduction of harmful substances in the air	CNY 143 <sup>a</sup>	20,429 <sup>a</sup>	0.7 <sup>a</sup>	Wang and Mullahy (2006)
Chongqing <sup>b</sup> (1998)	500	Air pollution control	CNY 14.3	3575	0.4	Wang et al. (2006)
Beijing <sup>c</sup> (2005)	880	50% reduction of harmful substances in the air	CNY 652.3 <sup>a</sup>	56,646 <sup>a</sup>	1.1 <sup>a</sup>	Cai and Zheng (2007)
Shanghai <sup>c</sup> (1999–2000)	568	Reducing respiratory illness caused by air pollution	CNY 146.4–483.6	11,802	1.2–4.1	Peng and Tian (2003)
Tianjin <sup>c</sup> (2000)	678	Medical treatment that would prevent a person from developing respiratory diseases	CNY 147.3	7014	2.1	Yang and Xu (2004)
Beijing <sup>c</sup> (1999)	>1200	Prevent an episode of cold	CNY 149–422 <sup>d</sup>	10,654	1.4–4.0	Hammit and Zhou (2006)
Anqing <sup>c</sup> (1999)	>1200	Prevent an episode of cold	CNY 25–50 <sup>d</sup>	5319	0.5–0.9	Hammit and Zhou (2006)
Taiwan <sup>c</sup> (1996)	938	Health benefits of air quality improvement	CNY 501 <sup>e</sup>	NA	0.6	Chien et al. (2005)

NA, not available.

<sup>a</sup> Using household as units.<sup>b</sup> Open-ended CVM.<sup>c</sup> Dichotomous choice CVM.<sup>d</sup> Converted with an exchange rate of 827.84 in 1999.<sup>e</sup> Converted with a calculated exchange rate of 3.78 NT\$ to 1 CNY (for 1996).

investments from government, as well as 0.3% of GDP in 2006. However, in contingent evaluation studies, residents' true WTP is always lower than what they claim (Brown et al., 1996). This issue will certainly arise in our survey and lead to an even lower ratio of WTP to investment in air pollution control. The conclusion drawn from the evaluation is that the WTP for air quality improvement can only be considered as an effective supplement of investments from government and enterprises. The survey in Beijing also confirmed this result (Wang et al., 2006).

#### 4. Conclusion

This survey adopted open-ended CVM to measure individual's WTP for air quality improvement, for respondents living and working in Ji'nan and revealed interesting information regarding the WTP of residents, in terms of improving air quality.

Of the 1500 questionnaire sheets that were filled in, 87.9% were valid which indicated urban residents' great concern about the issue of air quality. More than 40% of respondents have no incentive to bear the costs of air quality improvement. Most of them think the government should cover the bill, thus indicating a low awareness of environmental protection. Four important factors (household income, expenditure on respiratory illness treatment, education level and opinions on correlation between air pollution and health) all have significantly positive influences on respondents' decision to pay. The analysis also revealed that gender, age and household size differences, which were hypothesized to explain the results, did not actually have a significant influence on the probability of a positive WTP.

The research shows that annual income and WTP have a close correlation. Furthermore, WTP was larger for men and younger people. Although the estimated WTP is not significantly related to many other explanatory variables, there is a degree of internal consistency in the econometric analysis. The mean WTP for improving air quality in Ji'nan was estimated to be 100 CNY (12.5 US\$) per person per year in 2006, which is a conservative estimate since respondents who did not give a precise value were excluded from the statistical analysis. Aggregate WTP for all urban inhabitants accounted for about 15% of government investments in air pollution control, so WTP can only be regarded as a useful supplement.

The results showed that CVM is feasible in urban China, and the characteristics of urban residents' WTP obtained from this study are quite useful since the resulting information records both the direction and the strength of a respondent's preferences. The results can provide important implications to convince researchers and decision-makers to select better air pollution control projects

and practical insights into how to effectively and efficiently implement environment policies. More studies of this kind will be needed, with the growing demand for higher air quality and attention regarding the relationship between poor health and air pollution in China.

#### Acknowledgments

This study has been supported by the Natural Science Foundation of Shandong Province (No. Y2005E01) and Environmental Protection Science and Technology Project of Shandong Province (No. 2006-025). We would also like to thank students from the School of Environment Science and Engineering, Shandong University, for their hard work during the investigation. We thank Dr. Pamela Holt for editing the manuscript.

#### References

- Afroz, R., Hassan, M.N., Awang, M., Ibrahim, N.A., 2005. Willingness to pay for air quality improvements in Klang Valley Malaysia. *American Journal of Environmental Sciences* 1 (3), 194–201.
- Brown, T.C., Champ, P.A., Bishop, R.C., McCollum, D.W., 1996. Which response format reveals the truth about donations to the public good? *Land Economics* 72 (2), 152–166.
- Cai, C.G., Zheng, X.Y., 2007. Application of contingent valuation method in valuing health gains from air quality improvement. *Research of Environmental Sciences* 20, 150–154 (in Chinese).
- Carson, R.T., 1991. Constructed markets. In: Braden, J.B., Kolstad, C.D. (Eds.), *Measuring the Demand for Environmental Quality*. Elsevier, Amsterdam, pp. 121–162.
- Carlsson, F., Johansson-Stenman, O., 2000. Willingness to pay for improved air quality in Sweden. *Applied Economics* 32, 661–669.
- Carson, R.T., 2000. Contingent valuation: a user's guide. *Environmental Science and Technology* 34 (8), 1413–1418.
- Chien, Y.L., Huang, C.J., Shaw, D., 2005. A general model of starting point bias in double-bounded dichotomous contingent valuation surveys. *Journal of Environmental Economics and Management* 50, 362–377.
- China Statistical Yearbook 2006, 2007. National Bureau of Statistics of China, China Statistics Press, Beijing.
- Davies, J.C., Mazurek, J., 1998. *Pollution Control in the United States: Evaluating the System. Resources for the Future*.
- Green Nature, 2004. Air Pollution in China Available from: <http://greennature.com/article354.html>.
- Hammit, J.K., Zhou, Y., 2006. The economic value of air-pollution-related health risks in China: a contingent valuation study. *Environmental and Resource Economics* 33, 399–423.
- HEI International Scientific Oversight Committee, 2004. *Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review*. Health Effects Institute, Boston, MA. Special Report 15.
- Ji'nan Environmental Protection Bureau (JNEPB), 1990–2005. *Environmental Quality Briefing of Ji'nan*. JNEPB (in Chinese).
- Ji'nan Environmental Protection Bureau (JNEPB), 2004. *Atmospheric Environmental Capacity Calculation in Ji'nan City*. JNEPB, Jinan (in Chinese).
- Ji'nan Statistical Yearbook 2005, 2006. Jinan Statistics Bureau, China Statistics Press, Beijing.

- Langford, I.H., Kontogianni, A., Skourtos, M.S., Georgiou, S., Bateman, I.J., 1998. Multivariate mixed models for open ended contingent valuation data: willingness to pay for conservation of monk seals. *Environmental and Resource Economics* 12, 443–456.
- Mitchell, R.C., Carson, R.T., 1989. *Using Surveys to Value Public Goods: the Contingent Valuation Method*. Resources for the Future, Washington, DC.
- Onwujekwe, O., Uzochukwu, B., 2004. Stated and actual altruistic willingness to pay for insecticide-treated nets in Nigeria: validity of open-ended and binary with follow-up questions. *Health Economics* 13, 477–492.
- Peng, X.Z., Tian, W.H., 2003. Study on willingness to pay about air pollution on economic loss in Shanghai. *World Economic Forum* 3, 32–44 (in Chinese).
- Sherrod, D.R., Downs, R., 1974. Environmental determinants of altruism: the effects of stimulus overload and perceived control on helping. *Journal of Experimental Social Psychology* 10, 468–479.
- State Environmental Protection Administration (SEPA), 2006. Report on the State of the Environment in China-2005, Section on Atmospheric Environment. State Environmental Protection Administration, Beijing. Available from: <http://english.sepa.gov.cn/ghjh/hjzkgb/200701/P020070118528407141643.pdf>.
- State Environmental Protection Administration (SEPA), Chinese Academy of Social Sciences (CASS), 2006. Report of Survey on Cities Residents' Environmental Consciousness in China. Available from: <http://www.wenkoo.cn/wendang/quanguo-chengshi-2410> (in Chinese).
- The World Bank, State Environmental Protection Administration, 2007. *Cost of Pollution in China: Economic Estimates of Physical Damages*. The World Bank.
- Wang, H., Mullahy, J., 2006. Willingness to pay for reducing fatal risk by improving air quality: a contingent valuation study in Chongqing, China. *Science of the Total Environment* 367, 50–57.
- Wang, X.J., Zhang, W., Li, Y., Yang, K.Z., Bai, M., 2006. Air quality improvement estimation and assessment using contingent valuation method, a case study in Beijing. *Environmental Monitoring and Assessment* 120 (1–3), 153–168.
- Wang, Y., 2004. Environmental degradation and environmental threats in China. *Environmental Monitoring and Assessment* 90, 161–169.
- Watts, J., 2005. China: the air pollution capital of the world. *Lancet* 366, 1761–1762.
- Whittington, D., 2002. Improving the performance of contingent valuation studies in developing countries. *Environmental Resources Economy* 22, 323–367.
- WHO, 2006. *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen dioxide and Sulfur dioxide: Global Update 2005*. WHO.
- Xia, G., 1998. *An Economic Estimation for Environmental Pollution Losses in China*. China Environmental Science Press, Beijing (in Chinese).
- Yang, Z., Xu, L., 2004. Valuing health effects from the industrial air pollution in rural Tianjin, China. *Journal of Environmental Sciences* 16, 157–160.