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# Estimating the Young Generation's Willingness to Pay (WTP) for $PM_{2.5}$ Control in Daegu, Korea, and Beijing, China

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**Abstract:** This research aimed to examine the willingness to pay (WTP) of the young generation (the age group from 18 to 29) for the participatory solutions and actions on fine particulate matter ($PM_{2.5}$) pollution control and abatement in Daegu, Korea, and Beijing, China. This study found out that Korean respondents and Chinese respondents shared a wide range of similarities, both in terms of socio-demographic characters like age, family size, and house/apartment ownership, as well as a number of perceptions related to environmental and social responsibilities. Around one-third of the Korean respondents and one-fifth of the Chinese respondents expressed negative WTP due to primary reasons such as lack of trust in the effectiveness of $PM_{2.5}$ control measures (Korea) and limitation of budget (China). The mean estimated values of WTP with and without explanatory variables in Korea were merely slightly higher than those in China. The mean WTP without control variables in Korea was 11,882.97 KRW/month (10.61 USD/month) and the one in China was 65.09 CNY/month (9.48 USD/month). The mean WTP with explanatory variables for Daegu, Korea, was KRW 11,982.33 (USD 10.70) per person per month, and the one for Beijing, China, was CNY 64.84 (USD 9.40) per person per month. The annual total WTP for Daegu, Korea, was assessed around KRW 47572 million (USD 42.45 million), whereas the estimated total WTP for Beijing, China, was around CNY 3260.14 million (USD 474.94 million) per year. Based on the results and the findings, this study proposes to further strengthen the comprehensive cooperation between China and Korea in the field of air quality improvement, with a particular focus on $PM_{2.5}$ control and abatement and cooperation in academic circles and among the general public.

**Keywords:** willingness to pay; WTP; contingent valuation method; CVM; fine particulate matter; $PM_{2.5}$

## 1. Introduction

It is broadly recognized that air pollution is a major health risk and a primary obstacle to development [1], with aggravating public health consequences and economic costs. Among all the air pollutants, fine particulate matter ($PM_{2.5}$) is well acknowledged as the most robust and consistent predicator of mortality from respiratory diseases, and has become the sixth highest risk factor to cause premature death [2]. About 95% of the world's population resides in areas with $PM_{2.5}$ concentrations exceeding standards (10 $\mu g/m^3$ for annual mean and 25 $\mu g/m^3$ for 24 h mean) from the Air Quality Guideline established by the World Health Organization (WHO) [2]. If no stronger actions are put in place to effectively abate $PM_{2.5}$ concentrations, more severe consequences can be expected at both global and local levels. In one of its 2016 studies, the Organisation for Economic Co-operation and Development (OECD) projects an annual total of 6 to 9 million early deaths globally by 2060 as a result of current $PM_{2.5}$ concentration levels, with the largest death tolls in non-OECD economies and, in particular, India and China [3]. The most significant increase of death numbers in OECD members is forecasted to take place in Japan and Korea, with a tripling in Korea's number of $PM_{2.5}$-induced premature deaths by 2060. The research also estimates a global welfare cost of USD 18 trillion to 25 trillion in 2060 from air pollution-induced illness, with China having the highest per capita welfare costs, followed by Korea having the highest per capita welfare costs among OECD members.

Air pollution has gained growing attention in Korea over the past two to three years. Korea ranked 173rd in the air quality category in the 2016 Environmental Performance Index (EPI) out of 180 countries for EPI evaluation [4,5]. According to the Korean Ministry of Environment (MOE), fine dust (including $PM_{10}$ and $PM_{2.5}$) concentration and especially the ultra-fine dust ($PM_{2.5}$) concentration have been growing since 2013 [6]. In 2017, out of 197 air quality monitoring stations with valid data, 77 stations observed a $PM_{2.5}$ annual average concentration exceeding Korea's national standard (25 $\mu g/m^3$ for annual average) and 180 stations recorded a $PM_{2.5}$ 24 h mean concentration above the standard (50 $\mu g/m^3$ for 24 h average) [7]. The number of $PM_{2.5}$ warnings issued (when the $PM_{2.5}$ concentration surpasses 90 $\mu g/m^3$ and stays over 2 h) has continued to increase, from 72 in 2015 to 92 in 2017 [8]. With the growing public concern about the related health impact, $PM_{2.5}$ has turned into a big social issue in Korea [9]. The Korean government has taken various mitigation and responsive actions to deal with the $PM_{2.5}$ issue. In June 2016, the MOE issued "Special Countermeasures on Fine Dust" with the aim to reduce local $PM_{2.5}$ emissions by 14% by 2021. In September 2017, a much more stringent and ambitious Comprehensive Plan on Fine Dust Management was released to reinforce efforts in $PM_{2.5}$ control and abatement, with the goal of cutting local $PM_{2.5}$ emissions by 30% by 2022. It is obvious that greater efforts have to be made to achieve the intended outcomes.

Air pollution has been the biggest environmental issue in China in recent years, especially after 2012 when long-lasting haze and smog (with $PM_{2.5}$ as the dominant pollutant) hit the country more frequently. It has caused serious economic losses and a large public heath burden in China [10]. To address such severity, China has issued the most stringent environmental legislation and initiated powerful actions, and further launched a "War on Pollution". A wide range of measures have been taken to fight air pollution at various levels, under the framework established by China's overarching air pollution control strategy and action plan—the Action Plan on Air Pollution Prevention and Control issued in 2013. Over the past five years, positive progress in $PM_{2.5}$ concentration control and abatement has been achieved nationwide, especially in the Beijing–Tianjin–Hebei Region. From 2013 to 2016, the overall $PM_{2.5}$ concentration in China displayed a prominent decline and that in the Beijing–Tianjin–Hebei Region decreased substantially, from 100.1 $\mu g/m^3$ in 2013 to 72.5 $\mu g/m^3$ in 2016 [11]. However, the Beijing–Tianjin–Hebei Region remained one of the most $PM_{2.5}$ affected areas [12], and the $PM_{2.5}$ concentration changes were not evenly distributed nationwide, especially in the Beijing–Tianjin–Hebei Region, in which Beijing has witnessed the slightest $PM_{2.5}$ concentration drop, with high risks of rebound [11]. Both the central and local governments are determined to initiate enhanced measures to continue abating $PM_{2.5}$ concentration in the country, in the Beijing–Tianjin–Hebei Region, and in Beijing in particular.

Since clean air is a typical public good of which the sustainable provision must be guaranteed by collective actions [13], the government is usually deemed responsible for taking the lead in addressing air pollution and ensuring air quality improvement. The existing $PM_{2.5}$ concentration control actions and corresponding results in Korea and China are primarily attributed to the diversified measures taken by the government (e.g., restructuring the national energy mix, adjusting industrial layout and switching to a greener development mode, reducing emission sources and strengthening pollution treatment), underpinned by government investment and subsidies and with the intensive involvement of industries and the private sector. Because public participation is an integral part of collective action and as there is a growing trend towards bottom-up governance in environmental issues [14], the general public should be fully empowered to actively participate in $PM_{2.5}$ control and abatement actions. Governments in Korea and China have incorporated public participation in their $PM_{2.5}$

measures and put forward a number of participatory solutions that require positive support from the public, such as phasing out old diesel vehicles (Korea) and heavily polluting old and yellow-label vehicles (China) to cut mobile pollution sources; promoting the use of environmentally friendly vehicles such as liquefied petroleum gas (LPG) and electric cars (Korea), or low-emission and/or new-energy automobiles (China) to reduce automobile $PM_{2.5}$ emissions; and encouraging the use of high-quality cleaner fuels in automobiles (Korea and China), among others.

However, substantial gaps exist between the desired level and the existing level of public involvement in these participatory solutions to $PM_{2.5}$ issues in Korea and China. It is quite clear that all participatory solutions will either increase people's life costs or affect the conveniences of daily life to some extent. This may be a major reason for the insufficient public participation. No matter how stringent the control measures, if there are no supportive actions from the general public, the sustainability of existing treatment measures and results will be plagued. Thus, it is important to understand people's willingness to pay (WTP) for the participatory $PM_{2.5}$ control actions and associated influencing factors for WTP to help improve the overall $PM_{2.5}$ control performance in Korea and China.

It should be noted that both Korea and China are currently pushed to face the challenges of a declining birth rate and a rapidly aging population. Such growing demographic changes are anticipated to speed up shifts in the consumer market and the younger generations; in particular, the generations born after the 1990s are expected to become a strong consumption power in the near future. Their attitude towards $PM_{2.5}$ control and participation in the actions are highly likely to influence the attitude and the WTP of their family members, giving a further hint of the sustainability of public participation. It is believed in this study that estimating the WTP of the young generation will provide a unique perspective to understanding the whole WTP picture. Currently, there is limited literature and research on the public's and particularly the young generation's WTP for the participatory solutions in Korea and China to inform the government about initiating more effective and targeted programs. Further studies are therefore needed to contribute to enriching the knowledge pool about the WTP for $PM_{2.5}$ control in Korea and China.

As a result, this study was designed to find out the young generation's WTP for the participatory solutions on $PM_{2.5}$ control and abatement in Korea and China, respectively; to better understand the dominant factors that affect the young generation's WTP, and potential similarities and differences of situations in the two countries through comparison; and to propose targeted policy recommendations on possible approaches towards better public participation in $PM_{2.5}$ control and abatement actions, so as to inform government's decision-making. The following four sections of this article will explain the research methodology and present results, discussion, and conclusions, respectively.

## 2. Methodology

### *2.1. Evaluating Willingness to Pay for Air Pollution Control Using the Contingent Valuation Method (CVM)*

Defined as the maximum price at or below which a consumer will definitely buy one unit of a product, the concept of willingness to pay (WTP) was originally developed for establishing prices for public goods and services or valuing subjects that are not usually given monetary terms such as human life [15]. There are a wide range of methods to evaluate WTP, which can be broadly classified into either the category of revealed preference method or that of stated preference method. Revealed preference approaches are based on actual observable choices from which the value of environment or resources can be directly inferred. In contrast, with regard to values that are usually not directly observable, stated preference methods are applied, which use survey techniques to induce WTP for either enabling a marginal improvement or preventing a marginal loss. There are a number of approaches known as stated preference methods, including contingent valuation, conjoint analysis, choice experiments, contingent ranking, attribute-based models, etc. [16].

The contingent valuation method (CVM), the most direct approach among all stated preference methods towards WTP [16], is widely accepted by academic and political circles [17]. The CVM presents hypothetical opportunities for the consumers to buy public goods and services and then asks people's WTP for these goods and services, which enables individuals to consider all factors (e.g., income level, other key socio-economic characteristics) that are important to them in the supply of the goods and services [18]. The CVM is regarded as the single method that can interpret both user values and non-user values (e.g., bequest value and existence value) [19].

As the CVM is a survey-based tool for assessing non-market goods and services like environmental preservation or pollution impacts [20], questionnaire design is critical because all estimated values are contingent on the information collected from the survey [17]. There are generally three available approaches for WTP elicitation, namely, (1) via open-ended questions for the respondents to directly state their WTP; (2) via payment cards for the respondents to select the amount closest to their valuation from a range of possible payments; and (3) via dichotomous choice questions (including the single-bounded model and the double-bounded one) for the respondents to give Yes or No answers [21]. At present, the double-bounded dichotomous choice model is believed to have a higher efficiency in assessing WTP and is more frequently used in practice [21].

WTP has been extensively applied by researchers to evaluate environmental benefits or losses to address the challenges arising from the lack of a competitive market for environmental goods and benefits. Researchers have also identified a special strength of using the CVM on the environment, that is, the CVM can be applied to a wide spectrum of situations to gauge the benefits of environmental changes, and at the same time contribute to a better knowledge of the good and/or service being valued and the corresponding public preference to facilitate decision-making [17]. The CVM has proven to be the most popular method among all available ways for directly evaluating the environment in monetary terms [22,23]. A substantial number of CVM practices are used in determining WTP in many environment-related areas, ranging from areas related to outdoor recreation (such as national park or nature reserve management) to the reduction of risks from drinking water and ground water pollution, and from improving air and water quality to protecting wilderness areas and endangered species [20,24], indicating a constantly broadening application scope of the CVM in the environmental sector.

Researchers have been using the CVM to estimate the welfare impact of air pollution at high frequency [25]. A number of research studies were conducted to assess people's WTP for air pollution control and air quality improvement both in developed countries and the developing world [26]. These studies not only established a benchmark of monetary values for air quality improvements in different localities, but also identified a series of analysis models and major factors which may affect the amount of WTP. Existing CVM literature positively confirmed that level of income (both at the individual and household levels, including household assets such as ownership of house and car), education, knowledge of air pollution and $PM_{2.5}$, and risks of respiratory disease from air pollution are the most common and strong factors that significantly affect people's WTP for improved air quality [10,25,27–33].

### *2.2. Research Design*

#### 2.2.1. Research Hypotheses

Based on existing research and literature on WTP for environmental goods and services, this study assumed that the young generation's WTP for participatory solutions and actions to $PM_{2.5}$ control is influenced by three general categories of factors including socio-economic status, environmental awareness, and level of exposure to air pollution. The following three hypotheses are proposed.

1. Ha1: The higher the individual's socio-economic status, the higher the willingness to pay (H01: There is no relationship between socio-economic status and willingness to pay).
2. Ha2: Individuals with higher environmental awareness have a higher willingness to pay (H02: There is no relationship between environmental awareness and willingness to pay).

3. Ha3: Individuals who experience a higher level of air pollution exposure with a high income have a higher willingness to pay (H03: There is no relationship between the interaction between the level of air pollution exposure and income, and willingness to pay).

#### 2.2.2. Questionnaire Design

This research used a semi-structured questionnaire to collect primary data. The questionnaire consisted of three major question sections, namely, a section of general questions on the respondent's perception of air pollution and level of air pollution exposure to identify key influencing factors of WTP; a section of in-depth questions on specific WTP and the individual's willingness to participate in $PM_{2.5}$ reduction actions; and a section on personal information to collect basic demographic and socio-economic data. Two sets of questionnaires with differentiated initial bidding prices were prepared for Korea and China, respectively, to consider country differences. In addition, a brief narrative and photos were provided at the beginning to explain the negative health impacts of $PM_{2.5}$ and directly show the comparison between a clear day and a $PM_{2.5}$-hit day, so as to help respondents better understand the hypothetic scenarios.

Selection of Variables

In this research, WTP was the major dependent variable. Interdependent variables were selected under the above-mentioned three categories. Two key independent variables were selected for the category of socio-economic status, including (1) household income and (2) family assets in forms of house/apartment and car ownership. Environmental awareness was measured by five key sets of independent variables, namely, (1) perception of air quality status, (2) perception of air pollution control measures, (3) recognition of responsible actors for air pollution abatement and their duties, (4) knowledge of air pollution and its health risks, and (5) level of environmental education. Two independent variables were chosen to assess air pollution exposure level, namely, (1) residence's distance to the air pollution sources (such as manufacturing plants, coal-fired boilers, etc.) and (2) the frequency of hospital visits due to diseases triggered by air pollution (e.g., acute lower respiratory infections). The age and gender of the respondent were considered as control variables, and family size was examined as part of the demographic variables. General statements and questions were developed to measure or indicate the value/level of these variables.

Structure for Eliciting WTP

This study followed a typical double-bounded dichotomous choice contingent valuation method to guarantee the probability of accurate results. A hypothetical scenario was created and described to respondents in each country, that is, the amount of respondents' WTP to support the government-initiated programs to reduce the $PM_{2.5}$ emissions in their city by 30% (for the Korean respondents)/$PM_{2.5}$ concentration by 25% (for the Chinese respondents) over the next five years. An initial bid X (KRW/CNY) was proposed in the scenario for the respondents to simply give Yes/No answers (a dichotomous choice) based on their own WTP. A follow-up question was asked according to the respondents' reply. If the respondents answered YES to the initial bid, a higher amount (2X) was given to them to seek their maximum WTP; if otherwise, a lower amount (0.5X) was provided to encourage the expression of WTP. The initial X differed in the context of Korea and China to properly consider the national differences. The basic framework for WTP elicitation is displayed in Figure 1.

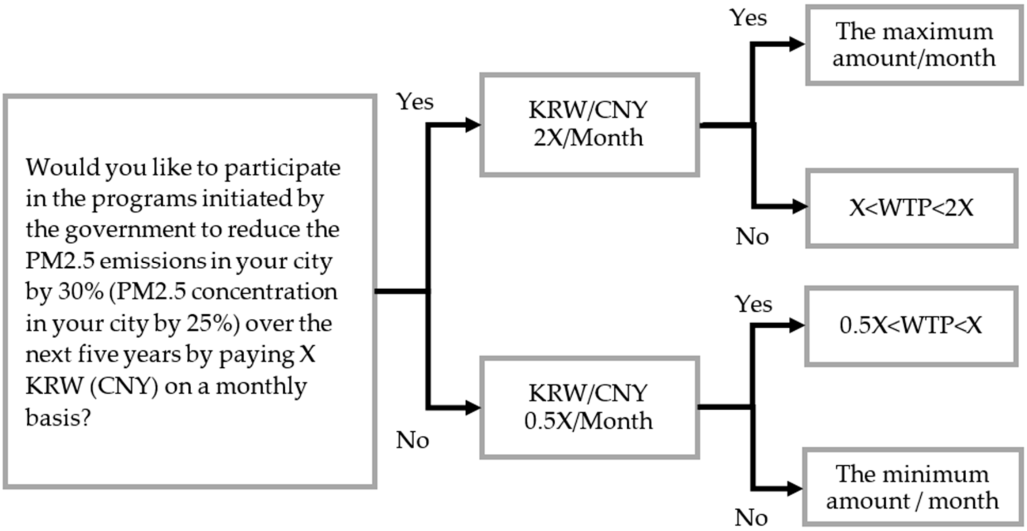


**Figure 1.** Basic framework of the contingent valuation method (CVM) question in the questionnaire.

## 2.3. Research Objects

### 2.3.1. Study Area

The study area was made up of two target cities in the two countries, one city from each country—Daegu, Korea, and Beijing, China.

Daegu Metropolitan City is the third largest metropolitan area in Korea. It is located in southeastern Korea with latitude between 35°36′ and 36°01′ N and longitude between 128°21′ and 128°46′ E, covering an area of 883.56 km$^2$. Daegu is generally known as a manufacturing city. Its GDP in 2016 hit KRW 49,757,725 million, including KRW 10,163,607 million contributed by the manufacturing sector. The registered population in Daegu reached 2,461,769 by the end of 2018, among which the 20s age group numbered 330,845 persons [34]. The number of motor vehicles in Daegu reached 1,176,887 by 2018, including 1,125,394 personal automobiles [35].

Beijing is the capital city of China and an integral part of the Beijing–Tianjin–Hebei Region, the biggest urban region in northern China. Beijing is situated at the northern edge of the North China Plain, with latitude between 39°26′ and 41°03′ N and longitude between 115°25′ and 117°30′ E and an area of 16,410.54 km$^2$. As of 2017, Beijing had a permanent population of 21.707 million, among which 4.19 million residents were between 20 and 29 years of age. Beijing's GDP in 2017 hit CNY 2800.04 billion, primarily underpinned by a consumer service-driven economy that contributed up to 86.7% of the total GDP. By the end of 2017, the number of automobiles in Beijing reached 5.909 million, including 4.672 million private cars [36,37].

### 2.3.2. Sampling

At the time of design, the aim was to collect 409 samples, which included 200 samples from Daegu, Korea, and 209 samples from Beijing, China, for comparison. For the questionnaire survey in Korea, conducted in Daegu in December 2018, 200 hard copies of the questionnaire were distributed to students and then collected. The survey in China employed an on-line survey and was carried out in collaboration with a professional on-line survey company named WJX.cn, the most renowned on-line survey service provider in China. Digital questionnaires were distributed among student WeChat users with IP locations in Beijing in December 2018. For that survey, 209 responses were collected. Finally, a total number of 409 samples were collected for analysis and comparison. In addition to the primary data collected through the questionnaire survey, secondary data were referred to as well to supplement the primary data.

This research applied Microsoft Excel for data coding, as well as IBM SPSS Statistics 22 (Armonk, NY, USA) and Stata SE 11 (College station, TX, USA) for statistical analysis, model construction, and WTP calculation.

### 2.4. Analysis Model

The doubleb command of Stata was particularly used to make the econometric estimation of WTP, which holds the basic assumption that WTP can be modelled with a linear function illustrated below [21]:

$$WTP_i(z_i, u_i) = z_i\beta + u_i, \tag{1}$$

$$u_i \sim \mathrm{N}\left(0,\ \sigma^2\right), \tag{2}$$

where $z_i$ represents a vector of explanatory variables, $\beta$ is a vector of parameters, and $u_i$ is an error term. In the double-bounded model, the respondents gave two answers to the closed WTP questions, in which the first bid amount was marked as $t^1$ and the follow-up bid was marked as $t^2$. Then, the WTP of each respondent fell into one of the following four categories:

- Yes-Yes answers: $t^2 > t^1$ and $t^2 \le WTP < \infty$.
- Yes-No answers: $t^1 \le WTP < t^2$.
- No-Yes answers: $t^2 < t^1$ and $t^2 \le WTP < t^1$.
- No-No answers: $0 \le WTP < t^2$.

To use these responses in the model for estimating WTP, the answers from individual i were coded as the dichotomous variables $y_i^1$ (response to the first WTP question) and $y_i^2$ (response to the second WTP question), respectively, where value 1 was given to the variables if the individual answered yes and 0 if the answer was no. Given that the WTP and the error term $u_i$ are normally distributed, the probability of the individual's response is described by the following expressions borrowed from Lopez-Feldman [21]:

$$y_i^1 = 1 \text{ and } y_i^2 = 1: \tag{3}$$

$$\Pr\left(y_i^1 = 1, y_i^2 = 1 \mid z_i\right) = \Pr(Y, Y) = \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right),$$

$$y_i^1 = 1 \text{ and } y_i^2 = 0: \tag{4}$$

$$\Pr\left(y_i^1 = 1, y_i^2 = 0 \mid z_i\right) = \Pr(Y, N) = \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right),$$

$$y_i^1 = 0 \text{ and } y_i^2 = 1: \tag{5}$$

$$\Pr\left(y_i^1 = 0, y_i^2 = 1 \mid z_i\right) = \Pr(N, Y) = \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right),$$

$$y_i^1 = 0 \text{ and } y_i^2 = 0: \tag{6}$$

$$\Pr\left(y_i^1 = 0, y_i^2 = 0 \mid z_i\right) = \Pr(N, N) = 1 - \Phi\left(z_i'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right).$$

Then, the maximum likelihood estimation was applied to infer parameters such as $\beta$ and $\sigma$. The following log-likelihood (LL) function was developed to maximize [21]:

$$\begin{aligned}&\textstyle\sum_{i=1}^{n}\Big[d_i^{Y,Y}\ln\Big(\Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^2}{\sigma}\big)\Big) + d_i^{Y,N}\ln\Big(\Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^1}{\sigma}\big) - \Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^2}{\sigma}\big)\Big) + \\ &d_i^{N,Y}\ln\big(\Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^2}{\sigma}\big) - \Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^1}{\sigma}\big)\Big) + d_i^{N,Y}\ln\big(1 - \Phi\big(z_i'\tfrac{\beta}{\sigma} - \tfrac{t^2}{\sigma}\big)\Big),\end{aligned} \tag{7}$$

where i = 1, ..., n, while $d_i^{Y,Y}$, $d_i^{Y,N}$, $d_i^{N,Y}$, and $d_i^{N,N}$ are regarded as indicator variables that have the value of 1 or 0 according to the specific case for each respondent.

## 3. Results

### 3.1. General Profile of the Respondents

#### 3.1.1. Socio-Economic Status of the Respondents

Table 1 summarizes the average demographic and socio-economic status of the 409 respondents, including their gender, age, family size, household income, and household asset status in forms of house and car ownership.

**Table 1.** General social-economic profile of respondents in Korea and China.

| Variables | | Korea ($n$ = 200) | | China ($n$ = 209) | |
|---|---|---|---|---|---|
| | | **Freq.** | **Ratio (%)** | **Freq.** | **Ratio (%)** |
| Gender | Female | 100 | 50.0 | 138 | 66.0 |
| | Male | 100 | 50.0 | 71 | 34.0 |
| Mean Age | | 22.38 | | 21.02 | |
| Mean Family Size | | 3.88 | | 3.73 | |
| Average Household Income | | KRW 60 million/year (USD 53,556/year) | | CNY 150,000/year (USD 21,847/year) | |
| House Ownership | Yes | 183 | 91.5 | 181 | 86.6 |
| | No | 17 | 8.5 | 28 | 13.4 |
| Car Ownership | Yes | 173 | 86.5 | 118 | 56.6 |
| | No | 27 | 13.5 | 91 | 43.5 |
| Average Car Quantity | | 1.59 | | 0.68 | |

Among all the 200 Korean respondents, the number of female respondents in Korea was same as that of the male respondents. The respondents' average age was 22.38. A majority of respondents were second-year (31.5%) and third-year (38.5%) university students. The average family size was 3.9 persons per household and the average household income was around KRW 60 million annually (around USD 53,556.13 per year). Of the respondents, 91.5% and 86.5% were from households with ownership of house and car(s), respectively. The respondents' families owned 1.59 cars on average.

As for the 209 Chinese respondents, 66% of them were female and the remaining 34% were male. Their average age was 21.02. Of the respondents, 78.5% were university undergraduates, whereas 11.5% were in their master degree programs. The average family size was 3.7 persons and the yearly household income averaged around CNY 150,000 (about USD 21,846.78 per year). Of the respondents, 86.6% lived in their own apartments and 56.6% were from families that owned at least one car. The average number of cars in these respondents' families was 0.68, below half of the Korean average.

In general, the Korean respondents and Chinese respondents were relatively similar in terms of age, family size, and house/apartment ownership, whereas the Chinese respondents were slightly younger and had a smaller family size (probably as a result of China's family planning policy). However, the household income level and car quantity for respondents in Korea numbered more than twice the level in China, which reflects the national difference in economic conditions and indicates a possibly stronger financial capacity of the Korean respondents.

#### 3.1.2. Environmental Awareness of the Respondents

A total of 15 questions were included in the questionnaire related to the five sets of variables regarding respondents' environmental awareness. A set of 12 questions was prepared for respondents to state their perceptions on air quality status, air pollution control measures, responsible actors and their duties for air pollution control, as well as air pollution's health risks using a Likert scale. Given that environmental education is a key source to developing environmental awareness, this study involved one question on environmental education that the respondents received in their academic curriculum. Table 2 presents the average responses.

**Table 2.** Comparison of environmental awareness level in Korea and China.

| Variable | Statements | Korea | China |
|---|---|---|---|
| (1) Perception of air quality status | I-1. I am satisfied with the air quality in my surroundings. | × | × |
| | I-2. The air quality is gradually improving. | × | – |
| | I-3. The air quality is degrading. | – | – |
| (2) Perception of air pollution control measures | I-4. Proper measures are in place to control and treat air pollution. | – | – |
| | I-5. The current air quality control measures need to be improved. | √ | √ |
| | I-6. The current air quality control measures are too severe. | – | × |
| | I-7. The existing pollution control measures should be continued. | √ | √ |
| (3) Recognition of responsible actors and their duties | I-8. Government should take the lead in addressing air pollution. | √ | √√ |
| | I-9. Only the industries should pay for the air pollution treatment. | √ | × |
| | I-10. Residents need to participate in pollution reduction actions. | √ | √ |
| (4) Knowledge of air pollution and its health risks | I-11. I believe it is important to control and prevent air pollution. | √ | √√ |
| | I-12. Air pollution has negative impacts on health. | √ | √√ |
| (5) Environmental education | III-5. Have you ever taken any environment-related courses? | 44.0% Yes | 38.8% Yes |

Note: ×× = Strongly disagree; × = Disagree, – = undecided, √ = Agree, √√ = Strongly agree.

As shown in Table 2, Korean respondents were not quite satisfied with the air quality in their surroundings and did not observe any improvement in air quality. On average, they thought that the current air quality control measures needed to be continued and further strengthened. They believed that government, polluter industries, and the public should jointly work on air pollution control measures and actions, where government takes the lead, industries pay, and the public participates. The average Korean respondents agreed that air pollution has negative health impacts and that it is important to control and prevent air pollution. With regard to the Chinese respondents, they expressed slightly stronger non-satisfaction with their surrounding air quality. Similar to the Korean respondents, Chinese respondents agreed with the continuation and further enhancement of current air quality control measures. They strongly believed that government should take the lead in these measures and the public should participate. The average Chinese respondents strongly agreed that air pollution brings health risks and that air pollution control is crucial.

There was one multiple choice question on the causes of air pollution, with nine possible causes and one open choice for respondents to specify their own ideas. It is quite impressive that there exists a consensus between Korean and Chinese respondents on the top three major causes (Table 3). Both the majority of the Korean (43.5%) and Chinese (95.2%) respondents ranked industrial emissions as the primary air pollution cause. Next, 31.5% of the Korean and 80.4% of the Chinese respondents voted emissions from the excessive use of cars as another major cause. The open burning of wastes became the third major cause, with votes from 16.0% of the Korean and 64.1% of the Chinese respondents. This result shows that respondents from the two countries do share certain common perceptions concerning air problems.

**Table 3.** Comparison of perception of air pollution causes in Korea and China.

| Top Causes | Korea ($n$ = 200) | China ($n$ = 209) |
| --- | --- | --- |
| 1 | Pollution from factories/industries (43.5%) | Pollution from factories/industries (95.2%) |
| 2 | Excessive use of cars (31.5%) | Excessive use of cars (80.4%) |
| 3 | Open burning of wastes (16.0%) | Open burning of wastes (64.1%) |

In conclusion, the environmental awareness level of respondents in the two countries was quite close. However, the Chinese respondents had stronger feelings about air pollution's effects and a higher supportive attitude towards air pollution programs (Table 2), which is likely attributed to China's prevailing air pollution issues and the extensive abatement efforts (including awareness campaigns).

#### 3.1.3. Air Pollution Exposure Level of the Respondents

Figure 2 displays the major statistics indicating the respondents' level of exposure to air pollution in Korea and China. It shows that a majority of Korean respondents (around 58%) lived in areas which were not close (between 3.1 km to 5 km or above 5 km) to air pollution sources such as highways and factories, and only 15% of the respondents lived in places where pollution sources were located less than 1 km away. By contrast, 37.3% of the Chinese respondents lived in places with air pollution sources in a 1 km neighborhood. This may explain the higher percentage of Chinese respondents (or their family members) experiencing increased occurrence of air pollution-induced diseases (46.9% of the respondents) and visiting hospital more frequently (45.9% of respondents having 1 to 3 hospital visits per month), compared with the situation in Korea (24.0% of the respondents with growing sickness frequency and 20.0% with 1 to 3 hospital visits per month). It can be concluded that Chinese respondents had a higher exposure level than their Korean counterparts. Such an exposure difference may probably lead to a difference in WTP.

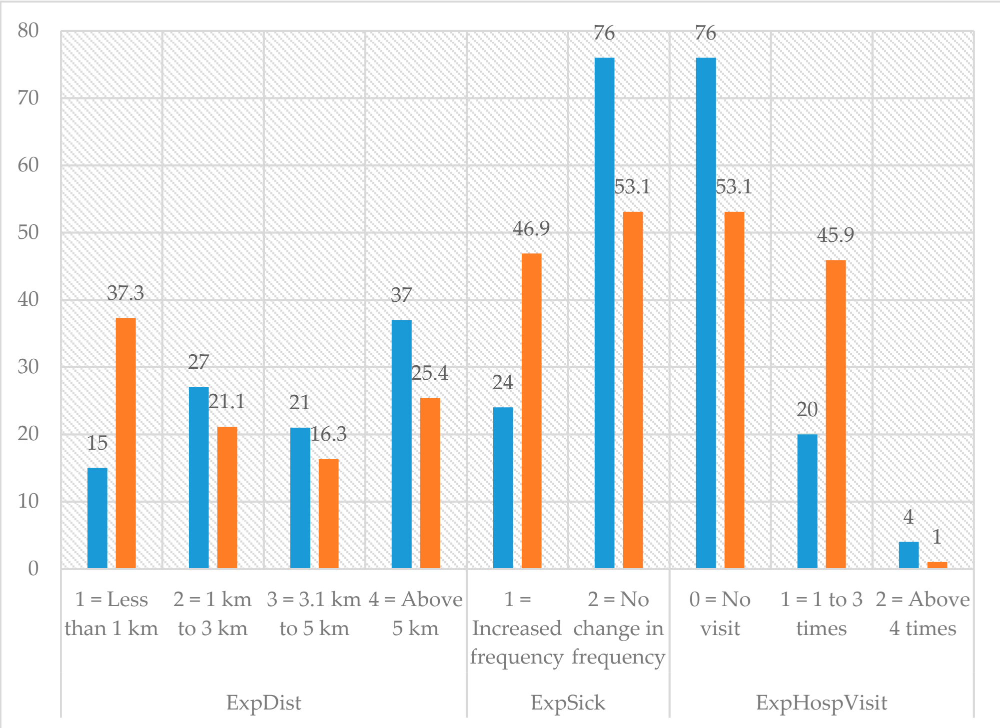


**Figure 2.** Comparison of air pollution exposure level in Korea and China.

## 3.2. *Estimation of WTP*

### 3.2.1. Overview

Two sets of questionnaires were created for the two countries. For each set, four initial bids were chosen to produce "reasonably efficient and robust estimates" [38], the value of which was determined with reference to the findings from previous studies. According to Kim et al. [9], the estimated mean WTP for enforcing $PM_{2.5}$ concentration reduction policy in Korea is KRW 5591 (USD 4.97) per household per year, whereas Wei and Luo [31] assessed an average WTP for $PM_{2.5}$ control in the Beijing–Tianjin–Hebei Region as CNY 65 (USD 9.47) per person per month. Therefore, initial bids for Korea started from KRW 5000 (USD 4.46) with an incremental amount of KRW 5000 for the next initial bid, and those for Chinese respondents started from CNY 20 (USD 2.91), with CNY 20 as the incremental amount for the next initial bid. Table 4 describes the payment plans for each country.

**Table 4.** Payment plans for Korea and China.

| Payment Plan | Korea (KRW/Month) | | | China (CNY/Month) | | |
|---|---|---|---|---|---|---|
| | Initial Bid | Upper Bound | Lower Bound | Initial Bid | Upper Bound | Lower Bound |
| 1 | 5000 | 10,000 | 2500 | 20 | 40 | 10 |
| 2 | 10,000 | 20,000 | 5000 | 40 | 80 | 20 |
| 3 | 15,000 | 30,000 | 7500 | 60 | 120 | 30 |
| 4 | 20,000 | 40,000 | 10,000 | 80 | 160 | 40 |

A portion of respondents answered "Yes" to the initial bids to express their positive WTP for the $PM_{2.5}$ emission/concentration reduction programs. In Korea, 85 out of the 200 respondents answered yes to the initial bids, accounting for 42.5% (Table 5). In China, 123 out of 209 Chinese respondents agreed to pay the initial bids, taking up to 58.85% of the total interviewed population (Table 6).

**Table 5.** Distribution of responses to initial bid offers in Korea.

| Response (Answer 1) | Initial Bid (Bid 1) (KRW/Month) | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5000 | | 10,000 | | 15,000 | | 20,000 | | | |
| | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio |
| Yes | 28 | 56.00 | 19 | 38.00 | 22 | 44.00 | 16 | 32.00 | 85 | 42.50 |
| No | 22 | 44.00 | 31 | 62.00 | 28 | 56.00 | 34 | 68.00 | 115 | 57.50 |
| Total | 50 | 100.00 | 50 | 100.00 | 50 | 100.00 | 50 | 100.00 | 200 | 100.00 |

**Table 6.** Distribution of responses to initial bid offers in China.

| Response (Answer 1) | Initial Bid (Bid 1) (CNY/Month) | | | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | 40 | | 60 | | 80 | | | |
| | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio | Freq. | Ratio |
| Yes | 42 | 80.77 | 27 | 51.92 | 27 | 50.94 | 27 | 51.92 | 123 | 58.85 |
| No | 10 | 19.23 | 25 | 48.08 | 26 | 49.06 | 25 | 48.08 | 86 | 41.15 |
| Total | 52 | 100.00 | 52 | 100.00 | 53 | 100.00 | 52 | 100.00 | 209 | 100.00 |

### 3.2.2. Negative WTP

A relatively large portion of respondents in both countries gave No-No answers to all the WTP questions, including 62 Korean respondents (accounting for 31.00% of the total Korean respondents) and 48 Chinese respondents (taking up to 22.97% of the total Chinese respondents). For respondents with negative WTP, they were asked to give one reason. The questionnaire provided six possible reasons and one option for respondents to specify their own justifications for rejection. Table 7 outlines an overview of primary reasons for negative WTP in Korea and China.

**Table 7.** Reasons for negative WTP in Korea and China.

| Reasons for Negative WTP | Korea ($n$ = 62) | | China ($n$ = 48) | |
|---|---|---|---|---|
| | Freq. | Ratio (%) | Freq. | Ratio (%) |
| (1) Air pollution control programs are not important to me. | 4 | 6.5 | 1 | 2.1 |
| (2) I am on a limited budget. | 20 | 32.3 | 17 | 35.4 |
| (3) I do not think that the programs would be effective. | 23 | 37.1 | 6 | 12.5 |
| (4) I do not think that I should be responsible for the programs. | 1 | 1.6 | 15 | 31.3 |
| (5) I have been greatly affected by the existing programs and I do not want to suffer further losses caused by similar programs. | 3 | 4.8 | 4 | 8.3 |
| (6) I think the current air pollution control and treatment programs are adequate. | 2 | 3.2 | 0 | 0 |
| (7) Others. Please specify: ________________. | 1 | 1.6 | 5 | 10.4 |
| No explanation of reasons | 8 | 12.9 | 0 | 0 |
| Total | 62 | 100.0 | 48 | 100.0 |

In regard to Korea, 23 respondents out of 62 (37.1% of the total protest respondents) expressed "I do not think that the programs would be effective", making it the most significant reason for rejection. It partially responds to an MOE statement on the inefficacy of "Special Countermeasures on Fine Dust" [8]. The second most prominent reason was limitation of budget, explained by 32.3% of the protest respondents. The third biggest reason was the indifferent attitude towards air pollution control programs, accounting for 6.5%. Around 12.9% of the respondents did not give any reasons for their rejection, probably to show their protest attitude.

As for China's case, limitation of budget ranked top of the list as the biggest reason for negative WTP, selected by 17 respondents out of 48 (35.4% of the total protest respondents). The second biggest reason was the perception that individuals should not be responsible for the $PM_{2.5}$ control programs, chosen by 15 individuals (31.3%). The third biggest reason was attributed to the perception of ineffectiveness of programs, voted by 12.5% of the protest respondents. Of the respondents, 10.4% explained their justifications, including "government should be responsible for funding the programs", "polluters should pay", and "lack of trust and confidence in government measures", among others. According to these results, it could be inferred that a certain portion of people with negative WTP may have the preference for $PM_{2.5}$ control but are limited by their financial capacity.

Wang and Zhang [29] identified very similar reasons for negative WTP in their study in Jinan, China. They found out that the most popular reasons included, among others, (1) air quality improvement is the government's responsibility, which was supported by 40.9% of 532 respondents with negative WTP in their research (versus "I don't think that I should be responsible for the programs" in this study); (2) income is too low to afford it, chosen by 15.9% of their protest respondents (versus "I am on a limited budget" in this study); and (3) polluters should pay (26.4%) and government and polluters should pay for it (12.6%). All of these justifications for negative WTP may give some hints to the government for further action, for example, building people's ownership for programs to fight $PM_{2.5}$.

### 3.2.3. Economic Estimation

#### WTP without Control Variables

This study applied the doubleb command in Stata to build the double-bounded model and carry out the WTP-related evaluation. Because the doubleb command is able to estimate $\hat{\beta}$ directly, the WTP is calculated by the simple formula $\widetilde{z}' \hat{\beta}$ [21]. Therefore, the WTP with no control variables is regarded as the constant. The following tables explain the basic calculation. The mean WTP without control variables in Korea was around 11,882.97 KRW/month (10.61 USD/month) at the individual level (Table 8), whereas the mean WTP without control variables in China was around 65.09 CNY/month (9.48 USD/month) per person (Table 9). In this sense, the mean WTP amounts in the two countries are quite similar, and Korea's level is slightly higher than the one in China (Table 10).

**Table 8.** WTP model with no control variables in Korea. SE, standard error; LL, log likelihood.

| Attributes | Coefficient | SE | $p$-Value |
|---|---|---|---|
| Constant | 11,882.97 | 1289.957 | 0.000 |
| $n$ | | 200 | |
| LL | | −303.919 | |

**Table 9.** WTP model with no control variables in China.

| Attributes | Coefficient | SE | $p$-Value |
|---|---|---|---|
| Constant | 65.08991 | 5.07871 | 0.000 |
| $n$ | | 209 | |
| LL | | −301.677 | |

**Table 10.** Comparison of mean WTP with no control variables in Korea and China.

| Country | WTP with No Control Variables | |
|---|---|---|
| | Local Currency | USD |
| Korea | 11,882.97 KRW/month | 10.61 USD/month |
| China | 65.09 CNY/month | 9.48 USD/month |

WTP with Explanatory Variables

Calculating the mean WTP with explanatory variables needs the prior determination of significant variables to establish a proper model for WTP estimation. The significant variables were selected by following two steps. First, variables under each general category were examined in the doubleb command to identify all the significant ones; and second, all the significant variables were reviewed and the common strong variables in the two countries were selected to create the final model. Given the different national conditions in Korea and China, significant variables that strongly affect the WTP in the two countries were anticipated to be different.

The WTP model was then developed as the following function:

$$WTP_i = \hat{\beta_0} + \hat{\beta_1}x_1 + \hat{\beta_2}x_2 + \hat{\beta_3}x_3 + \hat{\beta_4}x_4 + \epsilon, \tag{8}$$

where $WTP_i$ indicates the WTP of respondent i, $x_1$ represents age, $x_2$ represents household income in KRW in Korea and CNY in China, $x_3$ represents the respondent's level of perception about public participation in $PM_{2.5}$ control actions, and $x_4$ represents the interaction between household income and distance to pollution sources.

Tables 11 and 12 show the estimated coefficients and effects of variables on the dependent variable for Korea and China, respectively. For Korea, the variable of age is significant at a 10% level, those of income are significant at a 5% level, whereas the variable indicating the respondent's public participation perception is significant at a 1% level (Table 11). With regard to China, the variable denoting the respondent's perception of public participation in $PM_{2.5}$ control programs is significant at a 1% level (Table 12).

**Table 11.** WTP model with explanatory variables for Korea.

| Attributes | Coefficient | SE | *p*-Value |
|---|---|---|---|
| Edu | −3806.41 ** | 1801.302 | 0.050 |
| Income | 2814.455 ** | 1226.331 | 0.045 |
| PubPart | 4299.548 *** | 1274.321 | 0.001 |
| Income*Distance | −167.691 | 216.418 | 0.312 |
| Constant | −38,275.40 | 1,926,412 | 0.049 |
| *n* | | 200 | |
| LL | | −293.179 | |

* = significant at 10% level, ** = significant at 5% level, *** = significant at 1% level.

**Table 12.** WTP model with explanatory variables for China.

| Attributes | Coefficient | SE | *p*-Value |
|---|---|---|---|
| Age | −0.89835 | 2.52175 | 0.735 |
| Income | 6.23321 | 6.32141 | 0.364 |
| PubPart | 18.53124 *** | 7.13616 | 0.009 |
| Income*Distance | −0.56226 | 0.61276 | 0.381 |
| Constant | −15.68916 | 61.6589 | 0.801 |
| *n* | | 209 | |
| LL | | −297.247 | |

* = significant at 10% level, ** = significant at 5% level, *** = significant at 1% level.

Applying the respective equation for the two countries, the mean WTP for $PM_{2.5}$ control actions were estimated, as listed in Tables 13 and 14. The mean WTP for Daegu, Korea, was assessed as KRW 11,982.33 (USD 10.7) per person per month, and the mean WTP for Beijing, China, was CNY 64.84 (USD 9.4) per person per month. As the results show, the mean estimated amount of WTP with explanatory variables in Korea was merely slightly higher than the one in China. Taking into account the big differences in national economic conditions and household income level, it may indicate that the Chinese respondents have relatively stronger WTP than their Korean counterparts, as the average annual household income in China is half of that in Korea yet the mean WTP almost reaches the same level as that in Korea. This may be partially due to the Chinese respondents' intensive experience and awareness of severe $PM_{2.5}$ pollution in China.

**Table 13.** Mean WTP for Korea (KRW/month).

| Attributes | Coefficient | SE | Z | $p > \|z\|$ |
|---|---|---|---|---|
| WTP | 11,982.33 | 1201.984 | 9.97 | 0.000 |

**Table 14.** Mean WTP for China (CNY/month).

| Attrubutes | Coefficient | SE | Z | $p > \|z\|$ |
|---|---|---|---|---|
| WTP | 64.82965 | 5.047281 | 12.85 | 0.000 |

Although the above mean individual level WTP represents ideas of the young generation of the 20s age group, it can still give a broad picture of people's preference to and potential benefits from $PM_{2.5}$ control in Daegu and Beijing. Based on the population of the 20s age group and their proportion in the entire population of the two cities, the total annual WTP for Daegu and Beijing was calculated (Table 15). The annual total WTP for Daegu, Korea, was estimated at around KRW 47572 million (USD 42.45 million), whereas the assessed total WTP for Beijing, China, was around CNY 3260.14 million (USD 474.94 million) per year.

**Table 15.** Total estimated WTP in Daegu, Korea, and Beijing, China.

| Study Area | | Mean WTP (Per Person Per Month) | | Population Information | | Total WTP (Per Year) | |
|---|---|---|---|---|---|---|---|
| Country | City | KRW/CNY | USD | 20s Age Group | Ratio (%) | KRW/CNY (million) | USD (million) |
| Korea | Daegu | 11,982.33 | 10.7 | 330,845 | 13.4 | 47,571.53 | 42.45 |
| China | Beijing | 64.84 | 9.4 | 4,190,000 | 19.3 | 3260.14 | 474.94 |

Population data source: Daegu Metropolitan City Statistics [34], Beijing Municipal Bureau of Statistics [36].

## 4. Discussion

### 4.1. WTP Level

The estimated values of WTP in this study exhibit a certain difference from the previous research findings in Korea but a similarity with those in China. With regard to the case in Korea, the mean WTP estimate of KRW 12,012.55 (USD 10.72) per person per month from this study is substantially higher than that of KRW 5591 (USD 4.97) per household per year from Kim et al. [9]. Such a big gap may arise from the great difference in target group and research scope. In their study, Kim et al. selected 1000 respondents via stratified random sampling from different cities in Korea, without targeting any age group. This study focused on the young generation of the 20s age group, who may have a more ambitious plan with their WTP. As for the case in China, the assessed mean WTP value of CNY 65.01 (USD 9.47) per person per month is very close to the average WTP of CNY 65 from the findings of Wei and Luo [31].

The estimation of mean WTP with and without explanatory variables reveals similar values in Korea and in China, despite the differentiated national economic conditions and household income levels in the two countries. As mentioned before, it can be considered that Chinese respondents have a relatively stronger WTP for $PM_{2.5}$ control programs than their Korean counterparts. This may be partially due to the higher air pollution exposure level and stronger feelings towards air pollution issues among respondents in China.

### 4.2. Major Influencing Factors for WTP

Based on the existing literature, this study proposed three hypotheses to examine the strong influencing factors for WTP of the young generation in Daegu, Korea, and Beijing, China, in the area of $PM_{2.5}$ control, assuming that the individual's socio-economic status, level of environmental awareness, and air pollution exposure level were positively correlated with one's WTP for air pollution control.

Analyses showed that the statistically significant variables differed in the Korean context from the Chinese one. In Korea, there were 7 strong influencing factors for WTP, among which age, number of cars owned by the household, and two perceptions under environmental awareness were positively correlated with WTP; on the other hand, family size and household ownership showed a negative correlation with WTP. As for the Chinese case, only two variables under environmental awareness were strongly positively correlated with WTP (see Appendix A for details).

A comparison between statistical analysis results and hypotheses gives the following findings. With respect to the socio-economic category, in the Korean case for instance, income is positively correlated with WTP at a 5% significance level; however, in China, none of the socio-economic variables are statistically significant to WTP. As a result, Ha1 can be partially rejected.

In terms of the environmental awareness category, although strong variables might differ in the two countries, a powerful indicator for environmental awareness—the variable denoting public participation perception—is significant at a 1% level both for Korea and China, showing that higher environmental awareness may lead to higher WTP for air pollution control. Ha2 can be accepted.

With regard to the interaction between income and air pollution exposure level, unlike the previous studies (e.g., Mu and Fan [30]), statistics in this study fail to reveal any significant correlation between interaction between air pollution exposure level and income, and WTP. Therefore, Ha3 is rejected.

### 4.3. Limitations of the Study

Since a number of studies have identified the positive correlation between WTP and income, and air pollution exposure level, the insignificant correlation between these factors and the young generation's WTP revealed in this study may be attributed to two major limitations listed below.

First, limitations arise from the insufficient understanding of the target group. The research focused on the 20s age group who were born after the 1990s and before the early 2000s. People from this generation are usually referred to as late "millennials" and regarded to have unique characteristics that are very different from their former generations [39]. For instance, they emphasize convenience and on-demand access to goods and services, cherish information transparency, and have a willingness to tackle global issues [39]. Such unique features of this generation may as well affect other significant influencing factors WTP like income, and lead to biased results, which may therefore undermine the researcher's extrapolation.

Second, survey administration and formats used by this study may create limitations. The on-line survey offsets the possibility of explanation whenever needed, and biased or even incoherent answers might possibly emerge due to respondents' misunderstanding of the questions.

## 5. Conclusions

This study found that Korean respondents and Chinese respondents share a wide range of similarities, in terms of socio-demographic characters like age, etc., and a number of perceptions related to environmental and social responsibilities. On average, both Korean respondents and Chinese respondents are not quite satisfied with the current air quality in their surroundings and agree that it is necessary to continue and further enhance the existing air quality control measures. They both emphasize the government's leading role in $PM_{2.5}$ control programs and recognize the necessity and importance of public participation in these solutions. They have similar awareness of the negative health impacts and major causes of air pollution. Nevertheless, Chinese respondents have higher air pollution exposure level than their Korean counterparts and express stronger feelings about air pollution's effects, higher expectations regarding government's roles, and a greater supportive attitude towards air pollution programs.

The majority of the respondents expressed preference and positive WTP for the $PM_{2.5}$ control measures and participatory solutions. However, 31.00% of the Korean respondents and 22.97% of the Chinese respondents displayed negative WTP, due to such primary reasons as lack of trust in the effectiveness of $PM_{2.5}$ control measures (Korea) and limitation of budget (China).

This study applied the doubleb command in Stata to build the double-bounded model for the WTP-related evaluation. The mean WTP without control variables in Korea was estimated at 11,882.97 KRW/month (10.61 USD/month) and the one in China was 65.09 CNY/month (9.48 USD/month). The estimated mean WTP with explanatory variables for Daegu, Korea, was KRW 11,982.33 (USD 10.70) per person per month, and the one for Beijing, China, was CNY 64.84 (USD 9.40) per person per month. The annual total WTP for Daegu, Korea, was assessed around KRW 47572 million (USD 42.45 million), whereas the estimated total WTP for Beijing, China, was around CNY 3260.14 million (USD 474.94 million) per year. As the results show, the mean estimated amount of WTP in Korea was merely slightly higher than the one in China. Considering that the average annual household income in China is half of that in Korea, this may indicate a relatively stronger sense of WTP among Chinese respondents.

Gaps between findings of this study and those in the existing literature must be reconsidered with the limitations of this study, including limitations in the sampling size and group, limitations arising from the insufficient understanding of the target group, and the potential misunderstanding of the questions from the respondents. It is thus suggested that a larger scale face-to-face interview survey with the young generation be conducted to further examine those commonly accepted correlations and at the same time to identify how the unique features of the young generation affect WTP and other influencing factors.

Results of the environmental awareness evaluation and opinions from the respondents on negative WTP strongly prove the importance of raising awareness. Thus, it is also recommended (1) to conduct routine public awareness and visibility campaigns via multiple channels and integrate environment courses into regular school curriculum; and (2) to further strengthen the comprehensive cooperation between China and Korea in the field of air quality improvement, with a particular focus on $PM_{2.5}$ control and abatement.

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## Appendix A Definition of Variables and Correlation between Variables and WTP

Based on the general design of the questionnaire, a total of 28 variables (including 2 bid variables, 2 indicator variables, and 24 explanatory variables) were finally created and coded for the data analysis in Stata SE 11 and IBM SPSS Statistics 22. All the variables used in this study and the corresponding definitions and values are listed in Table A1.

**Table A1.** Definition of variables used in Stata and SPSS.

| Variables | Definition |
|---|---|
| Bid1 | Initial amount (bid) in KRW (for Korea)/CNY (for China) |
| Bid2 | Second bid in KRW (for Korea)/CNY (for China) |
| Ans1 | Answer to the first WTP question (= 1 if the answer is "yes"; = 0 if the answer is "no") |
| Ans2 | Answer to the second WTP question (= 1 if the answer is "yes"; = 0 if the answer is "no") |
| Gender | Respondent's gender (= 1 if the individual is a female; = 2 if male) |
| Age | Respondent's current age |
| FamilySize | Number of family members |
| Income | Respondent's household annual income (categorical variable):<br>For Korea (KRW): 1 = less than 40 million; 2 = 40 million to 60 million; 3 = 60 million to 80 million; 4 = 80 million to 100 million; 5 = over 100 million<br>For China (CNY): 1 = less than 50,000; 2 = 50,001 to 150,000; 3 = 150,001 to 250,000; 4 = 250,001 to 350,000; 5 = 350,001 to 500,000; 6 = over 500,000 |
| FAHouse | Ownership of house/apartment (= 1 if the family owns a house/apartment; = 2 if the family is currently using a rental house, indicating no house ownership) |
| FACar | Ownership of car (= 1 if the family owns a car; = 2 if not) |
| FACarNo | Number of cars owned by the family |
| AQSat | Respondent's satisfaction with the current air quality (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQImp | Respondent's perception that air quality is improving (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQDeg | Respondent's perception that air quality is degrading (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQMFun | Respondent's perception that proper measures are in place to control and treat air pollution (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQMEnh | Respondent's perception that the current air quality control measures need to be enhanced (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQMSev | Respondent's perception that the current air pollution control measures are too severe (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQMCont | Respondent's perception that the existing pollution control measures should be continued (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| GovLed | Respondent's perception that government should take the lead in addressing air pollution treatment (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| IndPay | Respondent's perception that only the industries should pay for the air pollution treatment (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| PubPart | Respondent's perception that residents need to participate in pollution reduction actions (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| AQCSig | Respondent's perception that air pollution control is important (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| NegHImpact | Respondent's perception that air pollution has negative impacts on health (1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree) |
| ExpDist | Distance between respondent's residence to the air pollution sources (1 = less than 1 km; 2 = 1 km to 3 km; 3 = 3.1 km to 5 km; 4 = above 5 km) |
| ExpSick | Frequent occurrence of air pollution-induced disease in heavily polluted seasons (= 1 if the respondent or their family members visit the hospital more frequently; = 2 if otherwise) |
| ExpHospVisit | Average number of visits to the hospital per month due to diseases triggered by air pollution (0 = no visit; 1 = 1 to 3 times; 2 = above 4 times) |
| EnvEdu | Access to environmental education (= 1 if the individual has taken any environment-related courses; = 2 if not) |

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