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# WILLINGNESS TO PAY FOR BETTER AIR QUALITY: THE CASE OF CHINA

Li-Qiu Liu    Zhong-Ling Yin    Bai-Chen Xie    Wei Zhou

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Air pollution is a big threat to human beings and has attract worldwide attention from governments and scholars. Based on the survey of happiness in China, this paper attempts to analyze the impact of local air quality on the happiness of individuals, and to evaluate the monetary value of mitigating air pollution. Through merging individual happiness data in a nationally representative survey with daily air quality index (AQI) according to the date and location of each respondent, it calculates the marginal rate of substitution (MRS) between air quality and income, and then estimates respondents' willingness to pay (WTP) for better air quality. Moreover, it has further explored the differences of WTPs among groups. This study reaches the conclusion that happiness is positively associated with income but negatively correlated with air pollution. Besides, individual happiness is heavily influenced by income, age, gender, health condition, marital status and other variables. Furthermore, WTPs differ greatly among groups and the estimated average WTP of whole sample is 549.36RMB(or 0.90% of annual household income) per year per family for one unit reduction in AQI.

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## EPRG Working Paper 2009

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**Keywords:** Happiness; Willingness to pay; Air pollution; China

**JEL Classification** L94



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# Willingness to Pay for Better Air Quality: The Case of China

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## Abstract

Air pollution is a major environmental health threat to human beings. The increasingly deteriorating air quality has attracted serious attention from the international community. Environmental regulations in many countries have been formulated to address the concerns surrounding air pollution and its impact on human welfare. Based on a survey in China, this study attempts to analyze the impact of local air quality on the happiness of individuals and to evaluate the monetary value of mitigating air pollution. Utilizing individual happiness data in a nationally representative survey with a daily air quality index (AQI), it calculates the marginal rate of substitution between air quality and income, and then estimates the respondents' willingness to pay (WTP) for better air quality. It further explored the group differences of WTP. It is concluded that happiness is correlated positively with income but negatively with air pollution. Moreover, individual happiness is strongly influenced by a range of variables including age, gender, health condition and marital status. Furthermore, whilst the estimated average WTP of the whole sample is 549.36 RMB (or 0.90% of

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annual household income) per year per family for a one-unit reduction in AQI, there exists substantial variation in WTP amongst surveyed groups.

**Keywords:** Willingness to pay; Happiness; Air pollution; China

# 1. Introduction

Air pollution poses a major threat worldwide, especially in some developing countries (Greenstone and Hanna, 2014; Tanaka, 2015). The negative effects of air pollution range from the loss of visibility and a reduction in agricultural productivity to putting stress on ecosystems (Ambrey et al., 2014). Meanwhile, the health risk attached to air pollution is an increasingly noticeable issue that is attracting unprecedented attention. According to the World Health Organization (WHO), nine out of 10 people breathe polluted air[1] and air pollution topped the 10 health threats facing humanity in 2019.[2] Air pollutants contain fine particles that can penetrate into the respiratory and cardiovascular systems, thus increasing tangible health risks such as respiratory diseases (Beatty and Shimshack, 2014) and cardiovascular diseases (Barnett et al., 2006; Gallagher et al., 2010). According to the latest estimates, approximately 7 million people worldwide die each year from air-pollution-related diseases, and more than 90% of deaths occur in low- and middle-income countries.[3] As well as the tangible health risks, air pollution has a negative effect on labor productivity (Marin and Mazzanti, 2013), human capital (Ebenstein et al., 2016), and mental health (Zhang et al., 2017a).

[1]See https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.
[2]See https://news.cgtn.com/news/3d3d674e3059544d32457a6333566d54/index.html.
[3]See https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.

In China, residential operating energy consumption has increased sharply which can be attributed to the acceleration of urbanization processes over past two decades (Ma et al., 2015), which has been aggravating air pollution and its impact on the economy. According to the "China Eco-Environment Report (2018)", only 121 out of the 338 cities at or above prefecture level complied with the Ambient Air Quality Standards (GB3095-2012) (Air Quality Index≤100) in 2018. Severe pollution (201≤AQI≤300) occurred in all the cities with an accumulative sum of 1,899 days, of which 822 days were characterized by extremely severe pollution (AQI≥301).[4] This has seriously affected the physical and mental health of the public and hampered daily social and economic activities. For example, air pollution has caused severe economic losses. A report by the Asian Development Bank and Tsinghua University revealed that the annual economic loss caused by air pollution in China was equivalent to 1.2% of GDP based on a cost-of-illness valuation, and it was projected to rise to 3.8% of annual GDP when measured against willingness to pay (WTP) (Zhang and Crooks, 2012). Therefore, having fully recognized the pressing need to address air pollution and its related impacts across health, environmental, social, and economic dimensions, the Chinese Government has issued and implemented a series of policies, measures, and programs at all levels. From the perspective of policy evaluation, one established practice is to compare the cost of regulations with the monetary value of improved air quality when they are introduced (Zhang et al., 2017b).

## 1.1 Research on air quality valuation

Estimating the monetary value of air quality is always a challenge because it is a public good

[4]See http://www.mee.gov.cn/hjzl/sthjzk/zghjzkgb/201905/P020190619587632630618.pdf.

and does not have a market price (Levinson, 2012). Of the several established methods for valuing better air quality, the main ones are typically classified as stated-preference approaches and revealed-preference approaches (Ferreira and Moro, 2010; Welsch, 2006). Stated-preference approaches are direct valuation methods, relying upon asking people questions to estimate their WTP under hypothetical markets. Among the stated-preference approaches, the contingent valuation method (CVM) introduced by Ciriacy-Wantrup in 1947 has been used most widely (Alberini and Krupnick, 1998; Carlsson and Johansson-Stenman, 2000; Yu and Abler, 2010; Wang et al., 2015; Sun et al., 2016). Contrastingly, revealed-preference approaches are indirect methods based on the actual behavior of individuals (Ferreira and Moro, 2010) such as the hedonic pricing (HP) method (Smith and Huang, 1995; Bayer et al., 2009).

As expected, each method has its own limitations. The CVM usually utilizes questionnaires to directly investigate the amount that respondents are willing to pay for non-market goods or services in hypothetical markets (Xie et al., 2019). For example, "How much would you like to pay for better air quality?". This method, mainly divided into open-ended (OE), payment card (PC), and dichotomous choice (DC) according to the framework of the questionnaire, has been widely adopted because of its convenience and flexibility. However, it has also been challenged for its lack of reliability. Using hypothetical markets (Welsch, 2006) and framed types of questions (Zhang et al., 2017b), this method has been found to be vulnerable to strategic responses (Zhang et al., 2017b), thereby resulting in the unexpected creation and overestimation of WTP under specific conditions.

The HP method values air quality by analyzing housing prices across regions with varying air quality. Compared with the CVM, its priority centers on data collected from real situations such as the housing market, which is objective and will not yield misleading WTPs. However, one issue associated with HP is that the benefits of clean air are incompletely capitalized if migration is costly (Luechinger, 2009). Some studies suggest that this approach will indeed underestimate the value of better air quality (Smith and Huang, 1995; Bayer et al., 2009).

## 1.2 Subjective well-being and happiness

Recently, there has been a growing body of literature targeting subjective well-being (SWB). Generally, SWB concerns how individuals perceive their lives according to their own standards; that is, whether a person is happy or not depends on how he/she evaluates his/her life subjectively. Diener (2006) defined SWB as "all the various types of evaluations, both positive and negative, that people make of their lives." He indicated that "happiness can mean a general positive mood, a global evaluation of life satisfaction, living a good life, or the causes that make people happy, with the interpretation depending on the context." A large amount of research considers SWB, life satisfaction, and happiness to be interchangeable.[5] The term "happiness" is often used as a substitution for SWB (OECD, 2013).

Easterlin (1974) found that economic development does not necessarily lead to improvements in happiness, which is known as the "Easterlin Paradox," marking the birth of happiness economics. With the development of happiness economics, individual SWB is receiving more and more attention. Gradually, a booming research stream aimed at exploring the determinants of SWB has emerged. Previous studies focused mainly on income and indicated that happiness is positively associated with household annual income (Sekulova and van den Bergh, 2013). According to Cummins (2000), personal income is a very important element in the maintenance of SWB,

[5] Subjective well-being is often measured by happiness and life satisfaction and economists often use them interchangeably (Ferreira and Moro, 2010; Ferreira et al., 2013).

especially for poor people. Easterlin (2005) further pointed out that happiness is related to economic circumstances, family life, health, and work. Good health (Steptoe et al., 2005) has a positive impact on SWB, while unemployment (Winkelmann, 2009) has a negative effect. Marital transitions have different implications for individuals (Lucas et al., 2003). Later studies have included the effect of demographic characteristics such as gender, age, and education (Michalos, 2007; Frijters and Beatton, 2008; Baetschmann, 2011).

The emergence of happiness research has been a highlight in environmental economics. Some research endeavors have placed their emphasis upon actively exploring the impact of environmental quality on people's happiness and found a robust negative impact of air pollution on happiness (Welsch, 2006, 2007; Rehdanz and Maddison, 2008; Levinson, 2012; Du et al., 2018). This finding is fundamental because the negative effects of worsening environmental quality on well-being provide a major rationale for pollution control (Welsch, 2006). Inspired by happiness economics, a new assessment method from the perspective of happiness has been developed to derive information on individual preference on air quality. This happiness approach is based on the assumption that self-reported happiness can be explained by a series of observable characteristics such as income, air quality, and other factors (Sekulova and van den Bergh, 2013). Theoretically, the logic of the happiness approach is concise and clear. It has been well documented that happiness is positively affected by income and negatively affected by air pollution. There is a trade-off between increasing income and worsening air quality (Ferreira and Moro, 2010; Zhang et al., 2017b). With the happiness method, happiness is regressed on air pollution, income and other covariates. By holding happiness constant, we can obtain the marginal rate of substitution (MRS) between income and air pollution, and then estimate the WTP to reduce air pollution.

The happiness approach is considered to have an inherent ability to address the methodological limitations that the aforementioned methods are subject to. First, by utilizing the self-reported happiness index as a utility and not directly asking about WTP, this approach avoids the necessity of addressing strategic responses sometimes found in CVM. Secondly, the concern of incomplete capitalization having strong implications for analysis results can be ruled out because housing market data is not used as in the case for HP. Thirdly, the happiness approach enables the exploration of WTP difference amongst groups of respondents. Therefore, all these advantages of the happiness approach make it a promising alternative tool for valuing air quality with a strong potential for wider applications.

## 1.3 Application of the happiness method

An important application of happiness economics is how pollution affects human welfare and the value of better air quality. A burgeoning body of studies relating to happiness or life satisfaction is concerned with both. The use of happiness data in economic studies is based on the assumption that happiness scores should be both a good approximation of individual utility and be interpersonally comparable (Welsch and Kühling, 2009; Menz, 2011; Frey et al., 2010).

A growing body of international and national surveys concerns self-reported happiness. The high transparency and accessibility of survey data makes it possible for further research based on the data. For example, China's most representative surveys are the China Family Panel Studies (CFPS) and the Chinese General Social Survey (CGSS). In the U.S. and Germany, the most popular surveys are the General Social Survey (Levinson, 2012) and the German Socio-Economic Panel (SOEP) (Schmitt, 2013), respectively.

However, usually, air quality data are derived from monitor stations rather than these surveys. For example, the air pollution measures come from the daily air quality report published by the Ministry of Environmental Protection of China (MEP) (Zhang et al., 2017a). Considering that a specific national survey takes place on different days and covers many areas, a methodological challenge due to practical constraints is to match air pollution data with individual happiness at the moment a survey is conducted (Li et al., 2018). To get around this issue, previous studies typically merged the average annual air pollution data on a country or regional level with panel happiness data in order to analyze their relationship (Welsch, 2007; Schmitt, 2013).

Early studies typically used cross-sectional air-quality data collected on a country level to investigate the impact of air quality on self-reported well-being (Welsch, 2002, 2006, 2007; Luechinger, 2010; Schmitt, 2013). For example, Welsch (2002) and Welsch (2007) conducted a cross-sectional analysis of 54 countries and found a robust negative impact of environmental pollution on SWB. These studies also estimated the WTP for better air quality. For example, by combining a set of panel data of happiness with air pollution data, Welsch (2006) found that the values of reducing $NO_2$ and lead pollution in Western Europe in the 1990s were approximately $750 and $1,400 per capita per year, respectively. The paper further pointed out that the value of simultaneously reducing $NO_2$ and lead was slightly higher than the sum of these values due to interaction among the pollutants (Welsch, 2006). Luechinger (2010) studied 13 European countries over the 1979-1994 period and indicated a negative and robust relationship between individual life satisfaction and annual $SO_2$ emissions. To identify the relationship between current pollution and current life satisfaction, Schmitt (2013) applied average daily rather than yearly country-level air pollution data in Germany to examine the effect of air pollutants (CO, $NO_2$, and $O_3$) on individual life satisfaction. Only $O_3$ was proven to be a significantly negative factor.

Luechinger (2009) avoided the concern associated with inter-country comparisons by using more spatially disaggregated air pollution data from only one country. The paper indicated a marginal WTP of \$232 for a 1 μg/m$^3$ reduction in $SO_2$ in Germany. Similarly, Ferreira and Moro (2010) used average annual PM10 in Ireland and found a negative effect of air pollution on SWB, and they computed a shadow cost of €945 for a 1 μg/m$^3$ reduction in PM10. Such studies focusing on one country have also taken place in China (Smyth et al., 2008).

In previous research, monitoring stations often recorded pollutant concentrations at the frequency of every few days (Levinson, 2012). Therefore, most studies relied on aggregated air quality data covering a long period (Welsch, 2002, 2006, 2007; Luechinger, 2009, 2010; Ferreira et al., 2013). Few studies use spatially disaggregated air pollution data that focused on the individual level. As an inherent limitation, the aggregated long-term air pollution used in analyses is highly unlikely to be able to accurately reflect the actual exposure level at the time of an interview, thereby resulting in biased estimates.

MacKerron and Mourato (2009) utilized monthly average PM10 and $NO_2$ to analyze the relationship between air pollution and individual life satisfaction in London. Only local $NO_2$ concentrations were proven to significantly reduce life satisfaction. Some studies used personal subjective perceptions of air pollution (Rehdanz and Maddison, 2008; Li et al., 2014) and also found a negative correlation between air pollution and personal well-being. However, people's perceptions of air pollution, being completely subjective, can by no means represent real air quality data and can therefore only play a limited role in reflecting the impact of air quality on happiness. Moreover, as far as estimating monetary value is concerned, only objective air pollution can be applied. In a recent study, Zhang et al. (2017a) merged happiness data and air quality on a daily and a local level. Their study found that overall life satisfaction is immune from bad daily air quality, while hedonic happiness is reduced by air pollution. Considering that different groups of people may hold different ideas toward air pollution, some studies identified the heterogeneous effects of air pollution (Zhang et al., 2017a, 2017b), with the overall finding that vulnerable populations are more susceptible to air pollution (Zhang et al., 2017a).

From the perspective of measuring air quality, some studies focus on a single pollutant, while other studies select multiple air pollutants, as shown in Table 1. It is worth noting that, for those covering multiple pollutants, a particular type of pollutant is often the focus of analysis at the authors' discretion. For example, out of the six major air pollutants studied, Zhang et al. (2017b) highlighted PM2.5 due to its high concentration and the significant public concern surrounding it. As a general observation, when several pollutants were involved in a study, it was quite usual that not every pollutant was found to have a significant influence on happiness.

**Table 1**
Air quality data in studies

| Pollutants | Authors | Main results |
|---|---|---|
| $SO_2$ | Luechinger (2009, 2010) | Negative |
| $SO_2$ | Ferreira et al. (2013) | Negative |
| PM10 | Ferreira and Moro (2010) | Negative |
| PM10 | Levinson (2012) | Negative |
| PM10 | Ambrey et al. (2014) | Negative |
| PM2.5 | Zhang et al. (2017b) | Negative |
| $SO_2$, $NO_2$ and particulate | Welsch (2007) | Negative with all |
| $NO_2$, particulate and lead | Welsch (2006) | Negative with $NO_2$ and lead |
| CO, $NO_2$ and $O_3$ | Schmitt (2013) | Negative with $O_3$ only |
| $NO_2$ and PM10 | MacKerron and Mourato (2009) | Negative with $NO_2$ only |
| Air pollution index ($SO_2$, $NO_2$ and PM10) | Zhang et al. (2017a) | Negative |

In summary, although there have been a wide range of research attempts targeting air quality and happiness, it is clear that there are several common methodological limitations in this area that need to be addressed. One major limitation is the common use of aggregated air quality data covering a rather long period. A related limitation is that most studies focused on a single pollutant or several single air pollutants across the studied geographical locations. Considering that the main air pollutants in different cities are themselves different, using a specific pollutant concentration as a universal indicator of air pollution may cause substantial estimation bias.

In an effort to address these limitations, we utilize happiness data from a novel national survey in China (Chinese General Social Survey, CGSS) combined with well-matched air quality data at the time and place of an interview. To measure air quality, we choose the Air Quality Index (AQI), a comprehensive index which has been less studied in the literature, to ensure the comparability between different geographical locations. The results show that individual happiness is negatively associated with air pollution. On average, people are willing to pay 549.36 RMB per year per family for a one-unit AQI reduction. To the best of our knowledge, the work presented in this paper is among the first attempts to estimate WTP for AQI reduction in China.

The rest of the paper is organized as follows. Section 2 describes the data, and Section 3 covers the empirical method. Section 4 introduces the results, and Section 5 concludes the paper.

# 2. Data

## 2.1 Happiness and demographic data

For individual survey data, we rely on the CGSS, which is the first national, comprehensive, and continuous academic investigation project in China.[6] Respondents of the 2015 wave come from 134 counties across 31 provinces of China.[7] Information on geographic locations and dates of the interviews is fully recorded, enabling a precise match to be made between individual happiness responses and air quality data.

One survey question, which is "All things considered, how happy are you with your life?" is designed to understand respondents' happiness. The scale ranges from 1 to 5, where 1 corresponds to "very unhappy" and 5 to "very happy". The answers to this question form the basis of the dependent variable. In addition to asking about happiness level, the CGSS collects a wide range of information on families and individual characteristics, making it possible for us to include the usual demographic information.

Previous studies show that individual happiness is affected by absolute income (Cummins, 2000), relative income (Luttmer, 2005; Dorn et al., 2007), personal characteristics such as gender (Alesina et al., 2004; Sekulova and van den Bergh, 2013) and age (Dolan et al., 2008; Schmitt, 2013; Ferreira et al., 2013; Zhang et al., 2017a), socially developed characteristics such as education level (Zhang et al., 2017a, 2017b), employment status (Ferreira et al., 2013) and health state (Ferreira et al., 2013), and family relationships such as marriage state (Ferreira et al., 2013; Schmitt, 2013) and whether there is a child in the family (Zhang et al., 2017a). In addition to these commonly studied factors, we also include other variables that we believe may affect happiness. For example, we include housing area, an indicator of living conditions, so as to investigate whether it contributes to

[6] The CGSS, a continuous cross-sectional survey covering society, community, families, and individuals, is executed by the China Survey and Data Center of Renmin University of China. In compliance with international standards, a survey of more than 10,000 households from various provinces of mainland China has been conducted annually since 2003. We take the latest public data to conduct our research.

[7] The CGSS utilizes three-stage Probability Proportionate to Size Sampling (PPS) to better represent Chinese society. For the required layer (Shanghai, Beijing, Guangzhou, Shenzhen, and Tianjin), the sample is selected by street, neighborhood, and household. For other cities, the sample is selected by county, neighborhood/village, and household.

happiness. As literature suggested that income inequality is negatively correlated with individual well-being in China (Smyth et al., 2008), we include personal attitudes toward society equality to explore its effect on happiness. Meanwhile, considering that self-rated status is a reflection of one's self recognition to some extent, we also include status as a variable in our study.

## 2.2 Air quality data

As a general observation, different regions may differ in WTP for the same pollutant, whereas the WTP for various pollutants may be different even in the same region. For example, a study by Levinson (2012) focused on America and indicated that a 1 $\mu g/m^3$ increase in PM10 reduces individual stated happiness by an amount equal to a \$459 decrease in annual income, on average. He also estimated alternative measures of air quality. The WTP for 1 $\mu g/m^3$ reduction in $O_3$, $SO_2$, and CO is \$143, \$126, and \$495, respectively. Considering that the main air pollutants may be different across cities, it may cause an estimation bias when using a specific pollutant or several pollutant concentrations as an indicator of air pollution. This study employs a comprehensive AQI to serve as air quality data.

Regarding China, the main pollutant is PM10 or PM2.5 in some cities, while it is $SO_2$, $NO_2$, or $O_3$ in other cities according to the records of air quality in recent years. Considering these inter-city variations, applying a specific pollutant concentration as a universal indicator of air pollution to different cities in a country may result in a substantial estimation bias. As a solution, AQI aggregates the air pollution level of several pollutants, including $SO_2$, $NO_2$, PM10, PM2.5, $O_3$, and CO according to the new "Ambient air quality standards" (GB3095-2012). The AQI ranges from 1 to 500, with higher values indicating worse air quality. Compared with the air pollution index (API), AQI monitors six pollutants rather than three, therefore presenting a more comprehensive and objective account of local air conditions. Daily observations of AQI are collected from the city-level air quality report published by the Ministry of Ecology and Environment of China.

Of the 2015 wave of CGSS, all 134 counties are within a specific AQI reporting city, allowing us to precisely match city-level AQI with the survey samples. The 2015 wave of CGSS has 10,968 individuals. After eliminating missing data, the final database includes 9,634 observations.[8] Table 2 gives a general description of the sample. First, the overall happiness level is relatively high, with respondents reporting "very happy" or "happy," collectively accounting for nearly 79% of the total observations. This is in line with the conclusion drawn in previous literature that the majority of people feel happy, with the possible exception of very poor societies (Cummins, 1995; Diener and Diener, 1996). Second, higher income comes with a higher level of happiness, as expected. The average annual household income of the unhappiest group is 30,690 RMB, while the happiest group is nearly three times higher, reaching 91,400 RMB. This is a salient trend that requires further empirical study. Third, in general, residents in areas with better AQIs are happier.

**Table 2**
Household income and AQI of different happiness groups.

| Happiness level | Very happy | Happy | Fair | Unhappy | Very unhappy | Total |
|---|---|---|---|---|---|---|
| Number | 1,714 | 5,845 | 1,392 | 570 | 113 | 9,634 |
| Proportion (%) | 17.79 | 60.67 | 14.45 | 5.92 | 1.15 | 100.00 |
| Average annual household income (thousand CNY) | 91.40 | 74.34 | 67.54 | 34.57 | 30.69 | 73.53 |
| Average AQI | 65.98 | 70.02 | 82.52 | 75.53 | 109.25 | 71.47 |

[8]Owing to 1,110 missing data for household income and 224 missing data for demographics information (including 15 for happiness), the final database includes 9,634 observations.

# 3. Empirical Method

Before conducting empirical research, we take stock of the possible elements that influence happiness. Other than air pollution, demographic variables and their impacts on happiness were also investigated by existing studies. For example, including both age and its square term as variables, a U-shaped effect of age on SWB is found (Dolan et al., 2008; Ferreira et al., 2013; Zhang et al., 2017a). Better health and marriage have a significantly positive impact on happiness (Zhang et al., 2017b), whereas separation and divorce have a negative impact on happiness (Ferreira et al., 2013). Unemployment negatively affects happiness (Smyth et al., 2008; Ferreira and Moro, 2010; Zhang et al., 2017b). Families with small children are likely to be more concerned about bad air quality (Zhang et al., 2017a). In addition, lower education may restrict an individual's ability to recognize and digest information on air quality (Levinson, 2012; Greenstone and Hanna, 2014; Li et al., 2014; Zhang et al. (2017b).

Following the study by Zhang et al. (2017b), we employ happiness as a substitution of utility. We estimate the following happiness function using ordinary least squares (OLS)[9]:

$$H_{ijt} = \alpha P_{jt} + \beta_1 LnI_i + \beta_2 R_i + X'_{ijt}\gamma + \delta_j + \eta_t + \varepsilon_{ijt} \quad (1)$$

The dependent variable *H* is individual happiness. *P* reflects the air quality measured by the *AQI*. Despite absolute income gains, income inequality may cause people to find themselves in a relatively more disadvantaged position (Brockmann et al., 2009). Thus, for income variables, we include both the log form of annual household income *I* and the self-rated relative income status *R*.

[9]What counts in the estimate results is allowing for fixed effects, while the form assumption of happiness scores, ordinality, or cardinality, makes little difference (Ferrer-i-Carbonell and Frijters, 2004). One key advantage of the liner regression approach over the ordered probit is that the former can easily include fixed effects (Levinson, 2012). Therefore, we adopt OLS to conduct the estimation in this paper.

The index $i$ refers to the respondent, $j$ refers to the county, and $t$ refers to the interview date. The vector $X$ contains a set of demographic variables of happiness, including age and its square term, gender, education, whether one has children younger than 18, health status, marital and employment experience, housing area, view toward equality, and self-rated social status. $\delta$ represents county fixed effect, and $\eta$ indicates the month and day-of-week fixed effects. The set of factors which influence well-being is far larger and can be extended to various aspects (Sekulova and van den Bergh, 2013). Factors that cannot be easily captured usually remain hidden in the error term $\varepsilon$. Table 3 describes the main variables employed and Table 4 presents their summary statistics.

**Table 3**

Description of main variables

| Variable | Description |
|---|---|
| Happiness | The answer to "Taking all things together, how happy you are with your life?", ranging from 1 (very unhappy) to 5 (very happy) |
| AQI | Air quality index: ranging from 0 to 500, with higher number represents worse air quality |
| Household income | Total household income of last year for the respondent |
| Relative income | Self-rated relative income status at his/her location, ranging from 1 (far below average) to 5 (far above average) |
| Age | Age/10 |
| Gender | Gender of the respondent |
| Education | Current qualifications, from 0 (none) to 13 (master and above) |
| House | Housing area |
| Health | Self-reported health status, ranging from 1 (very bad) to 5 (very good) |
| Equality | View towards equality, ranging from 1 (not at all) to 5 (quite equal) |
| Status | Self-reported social status, ranging from 1 to 10, with higher number represents higher status |
| Medicare | Dummy: 0 = have taken out health insurance policy, 1= have not taken out health insurance policy |
| Child | Dummy: 0 = no child younger than 18, 1= have children younger than 18 |
| Marriage | 4 categories: never married (reference); married; divorced or separated; widowed |
| Work experience and status | 6 categories: paid work (reference); farmers retired from paid work; always farming; retired farmer; unemployed or retired from paid work; never worked |

**Table 4**
Summary statistics of main variables

| Variable | Obs. | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| AQI/100 | 9,634 | 0.71 | 0.35 | 0.26 | 2.72 |
| Happiness | 9,634 | 3.88 | 0.82 | 1.00 | 5.00 |
| Household income/1000 | 9,634 | 61.04 | 1.20 | 71.69 | 500.00 |
| Relative income | 9,634 | 2.62 | 0.98 | 1.00 | 5.00 |
| Gender | 9,634 | 0.48 | 0.50 | 0.00 | 1.00 |
| Age/10 | 9,634 | 5.03 | 1.66 | 1.80 | 9.40 |
| Education | 9,634 | 4.88 | 3.13 | 0.00 | 14.00 |
| House/100 | 9,634 | 1.14 | 0.77 | 0.15 | 4.50 |
| Health | 9,634 | 3.62 | 1.10 | 1.00 | 5.00 |
| Equality | 9,634 | 3.21 | 1.00 | 1.00 | 5.00 |
| Status | 9,634 | 4.33 | 1.63 | 1.00 | 10.00 |
| Medicare | 9,634 | 0.92 | 0.28 | 0.00 | 1.00 |
| Child | 9,634 | 0.30 | 0.46 | 0.00 | 1.00 |
| Marital status (Ref: never married) | | | | | |
| Married | 9,634 | 0.79 | 0.41 | 0.00 | 1.00 |
| Divorced or separated | 9,634 | 0.02 | 0.15 | 0.00 | 1.00 |
| Widowed | 9,634 | 0.09 | 0.28 | 0.00 | 1.00 |
| Work experience and status (Ref: paid work) | | | | | |
| Farmer retired from paid work | 9,634 | 0.05 | 0.22 | 0.00 | 1.00 |
| Always farming | 9,634 | 0.16 | 0.37 | 0.00 | 1.00 |
| Retired farmer | 9,634 | 0.13 | 0.33 | 0.00 | 1.00 |
| Unemployed or retired from paid work | 9,634 | 0.24 | 0.43 | 0.00 | 1.00 |
| Never worked | 9,634 | 0.04 | 0.20 | 0.00 | 1.00 |

When focusing on the valuation of environmental pollution, we can temporarily assume that demographic variables affecting utility remain unchanged; that is, $dX = 0$. By totally differentiating Eq. (1) and setting $dH = 0$, we can obtain the MRS between income and air pollution: $\frac{\partial I}{\partial P} = -I\frac{\hat{\alpha}}{\widehat{\beta_1}}$. The MRS is the amount of income that the individual should pay in exchange for a one-unit decrease in pollution to keep utility (represented by happiness) unchanged. This is also known as WTP (Zhang et al., 2017b).

# 4. Results

## 4.1 Baseline Results

Table 5 presents the estimated results. The overall observation is that air pollution diminishes happiness significantly. Both absolute income and relative income have a positive impact on happiness. Column (1) estimates the baseline specification. The coefficient of age is negative while the coefficient of age square form is positive, indicating a U-shaped relationship between age and happiness, which supports previous studies (Dolan et al., 2008; Ferreira et al., 2013; Zhang et al., 2017a). The trough for happiness appears at about 44-year-old. On average, females report a higher level of happiness. Consistent with the study by Ferreira et al. (2013), individuals in good health are happier than those in poor health. By the same token, people who have taken out a health insurance policy reported a higher happiness level, implying a positive role of the health insurance system in guaranteeing living standards. As we would expect, a housing area, as an indicator of living standards, has a positive impact on happiness. Those viewing society as being equal are substantially happier, suggesting that social equality is an important element in maintaining people's happiness. When it comes to social status, people who reported to be in higher status are substantially happier than those in a lower status. Here, the underlying logic is that self-rated social status is closely related to happiness (Price, 2008; Xu and Li, 2016).

**Table 5**
Regression results

| | Baseline version | Only AQI and income | Add average pollution | Omit relative income | Omit absolute income |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| AQI/100 | -0.060** | -0.056* | -0.060** | -0.058* | -0.063** |
| | (0.030) | (0.033) | (0.030) | (0.030) | (0.030) |
| Monthly average AQI/100 | | | 0.061 | | |
| | | | (0.287) | | |
| Ln (household income) | 0.067*** | 0.100*** | 0.067*** | 0.078*** | |
| | (0.009) | (0.009) | (0.009) | (0.009) | |
| Relative income | 0.058*** | 0.140*** | 0.058*** | | 0.069*** |
| | (0.008) | (0.009) | (0.008) | | (0.008) |
| Gender | -0.046*** | | -0.046*** | -0.044*** | -0.045*** |
| | (0.016) | | (0.016) | (0.016) | (0.016) |
| Age/10 | -0.158*** | | -0.158*** | -0.164*** | -0.164*** |
| | (0.032) | | (0.032) | (0.032) | (0.032) |
| Age squared/100 | 0.018*** | | 0.018*** | 0.019*** | 0.018*** |
| | (0.003) | | (0.003) | (0.003) | (0.003) |
| Education | 0.004 | | 0.004 | 0.005 | 0.008*** |
| | (0.003) | | (0.003) | (0.003) | (0.003) |
| House/100 | 0.021** | | 0.021** | 0.025** | 0.029*** |
| | (0.011) | | (0.011) | (0.011) | (0.011) |
| Health | 0.141*** | | 0.141*** | 0.146*** | 0.144*** |
| | (0.008) | | (0.008) | (0.008) | (0.008) |
| Equality | 0.178*** | | 0.178*** | 0.181*** | 0.177*** |
| | (0.008) | | (0.008) | (0.008) | (0.008) |
| Status | 0.085*** | | 0.085*** | 0.093*** | 0.090*** |
| | (0.005) | | (0.005) | (0.005) | (0.005) |
| Medicare | 0.119*** | | 0.119*** | 0.123*** | 0.123*** |
| | (0.027) | | (0.027) | (0.028) | (0.028) |
| Child | -0.050*** | | -0.050*** | -0.053*** | -0.050*** |
| | (0.021) | | (0.021) | (0.028) | (0.021) |
| Marital status (Ref: Never married) | | | | | |
| Married | 0.167*** | | 0.167*** | 0.171*** | 0.195*** |
| | (0.036) | | (0.036) | (0.036) | (0.036) |
| Divorced or separated | -0.128** | | -0.128** | -0.125** | -0.126** |
| | (0.060) | | (0.060) | (0.060) | (0.060) |
| Widowed | 0.076* | | 0.076* | 0.078* | 0.095** |
| | (0.043) | | (0.046) | (0.046) | (0.046) |
| Work experience and status (Ref: paid work) | | | | | |
| Farmer retired from paid work | 0.084** | | 0.084** | 0.087** | 0.058 |
| | (0.037) | | (0.037) | (0.037) | (0.037) |
| Always farming | -0.001 | | -0.001 | -0.003 | -0.032 |
| | (0.028) | | (0.027) | (0.027) | (0.027) |
| Retired farmer | 0.076*** | | 0.076*** | 0.077*** | 0.044 |
| | (0.029) | | (0.029) | (0.029) | (0.029) |
| Unemployed or retired from paid work | 0.028 | | 0.030 | 0.029 | 0.030 |
| | (0.022) | | (0.022) | (0.022) | (0.022) |
| Never worked | 0.053 | | 0.059 | 0.056 | 0.045 |
| | (0.040) | | (0.040) | (0.040) | (0.040) |
| County fixed effects | Yes | Yes | Yes | Yes | Yes |
| Month, day-of-week fixed effects | Yes | Yes | Yes | Yes | Yes |
| Adjusted R-squared | 0.222 | 0.090 | 0.220 | 0.218 | 0.218 |
| Observations | 9,634 | 9,634 | 9,634 | 9,634 | 9,634 |
| Mean household income (CNY) | 6,1040.31 | 61,040.31 | 61,040.31 | 61,040.31 | 61,040.31 |
| %income to pay for a one-unit reduction per year per family (%) | 0.90 | 0.56 | 0.90 | 0.74 | |
| WTP for a one-unit reduction per year per family (CNY) | 549.36 | 341.83 | 549.36 | 451.70 | |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.

Family life is identified as an important factor of happiness (Easterlin, 2005). Regarding marital status, people who are married report a higher level of happiness, while people who are divorced or separated are unhappier. Those who have children younger than 18 usually under more pressure, and are thus more negatively affected in terms of happiness. As a largely unexpected outcome, education level does not have a significant influence on happiness. With regard to work experience and status, we mentioned in Section 3 that previous studies have found a negative effect of unemployment on happiness. Our findings provide further insights into this aspect. Either farmers retired from paid work or retired farmers are found to be happier. These two groups are mostly characterized by low education levels, as shown in Fig. 1 - Fig. 4. This may elicit an interesting perspective in a broader context; namely, whether people's happiness differs significantly along with their work experience and status in urban and rural areas.

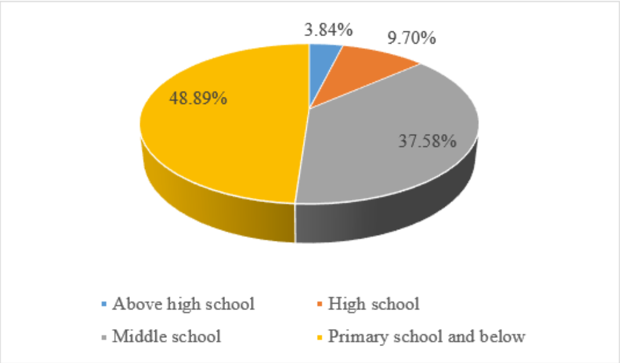


**Fig. 1.** Education structure of farmers retired from paid work.

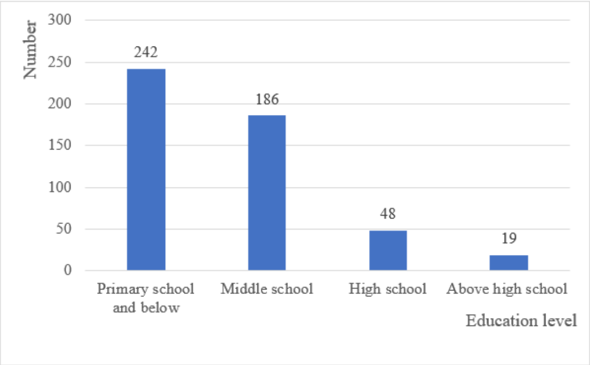


**Fig. 2.** Numbers of different education level of farmers retired from paid work.

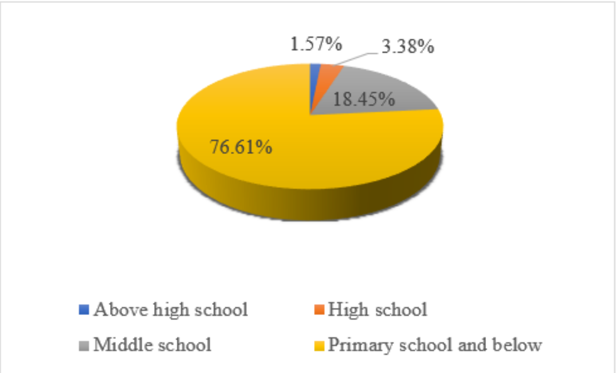


**Fig. 3.** Education structure of retired farmers.

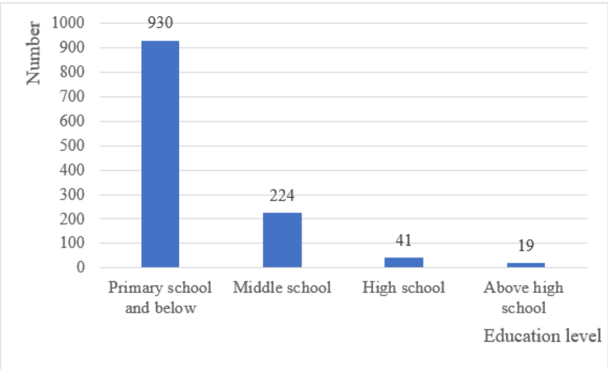


**Fig. 4.** Numbers of different education level of retired farmers.

As explained in Section 3, we can obtain WTP from the estimated coefficients. Column (1) of Table 5 suggests that a one-unit increase in AQI is associated with a decline in happiness by 0.06% (on a 5-point scale), and a one-unit increase in the log form of annual household income raises happiness by 0.067 (on a 5-point scale). By plugging in -0.060% for $\hat{\alpha}$, 0.067 for $\widehat{\beta_1}$, and 61,040.13 for the mean annual household income (in CNY), it can be calculated that the WTP is 549.36 RMB, which means that a one-unit reduction in AQI contributes to an average person's happiness by an amount equivalent to 549.36 RMB per year, or 1.51 RMB (= 549.36/365) per day. In other words, people are on average willing to pay 549.36 RMB per household per year in exchange for a one-unit reduction of AQI. Considering that the average annual household income is 61040.31 RMB, the WTP accounts for 0.90% (=549.36/61040.31) of their annual household income. To put this into context, the standard deviation of AQI is 35.190, which results in a WTP of 53.14 RMB (= 35.190 × 1.51 RMB) for a one-standard-deviation reduction in AQI per household per day.

Column (2) of Table 5 includes AQI and income only as independent variables. Happiness decreases with AQI and increases with absolute household income and self-reported relative income. By plugging in -0.056% for $\hat{\alpha}$, 0.100 for $\widehat{\beta_1}$, and 61,040.13 for the mean annual household income (in CNY), WTP is calculated to be 341.83 RMB. The coefficient of household income increases significantly and the WTP decreases from 549.36 RMB to 341.83 RMB when omitting demographic variables. This indicates that unobserved individual characteristics may be related to both income and happiness, which may cause an omitting error. This finding suggests some consistency with a previous study pointing out that adding individual factors will offset some of the income effects (Ferrer-i-Carbonell and Frijters, 2004). However, in our study, the coefficient of AQI changes very slightly, implying its relative insensitivity to unobserved variables.

Column (2) of Table 5 adds to the regression the monthly average pollution for each respondent's location in which the interview was taken. The coefficient of income and pollution both remain unchanged, indicating an equal WTP with the baseline specification. The monthly average pollution coefficient is insignificant and even wrong-signed. One possible reason maybe that the monthly data cannot reflect daily pollution, which is what respondents really cared about when being interviewed. Another interpretation is that people become habituated to the environments and respond only to daily situations (Levinson, 2012).

We further estimate another two versions to investigate the impact of absolute income and relative income. In Column (3) and (4) of Table 5, we omit relative income and absolute income, respectively. Compared with the baseline specification in Column (1), omitting relative income (Column (3)) does not result in any fundamental change in the main findings. However, the coefficient of household income increases from 0.067 to 0.078 and the WTP decreases from 549.36 RMB to 451.70 RMB. In contrast, compared with the version where all demographic variables are omitted (Column (2)), there is a decrease in the coefficient of household income from 0.100 to 0.078 and an increase in WTP from 341.83 RMB to 451.70 RMB. These differences tend to suggest that relative income is an important factor in explaining happiness. As a plausible explanation, despite an absolute increase in income, it is likely to be the gap between income and aspirations that makes people unhappy. In Column (4), where the absolute income is omitted, one variable representing education level stands out. Education is not significant when absolute income is in the regression. However, it is very different if absolute income is omitted. A plausible explanation may be that absolute income absorbs part of the effect of education. A previous study has demonstrated that the return on income from education is obvious (Brunello et al., 2017). We also explore the education level of different income groups and find a positive relationship between education and income, as shown in Table 6.

**Table 6**

Education level of different income groups.

| Income level | 0-25% | 25%-50% | 50%-75% | 75%-100% |
|---|---|---|---|---|
| Average annual household income (thousand CNY) | 11.83 | 32.69 | 60.11 | 158.65 |
| Average education level | 3.27 | 4.16 | 5.31 | 7.23 |

Among the main variables, health and income are highly correlated. Table 7 shows that the average annual household income of the unhealthy and healthy respondents is 34,782.98 RMB and 96,541.04 RMB, respectively. Health is also highly related to happiness. The average happiness level of the unhealthy and healthy is 3.27 and 4.12 on a 5-point scale, respectively. If health and air pollution are also closely related, neglecting the health variable will lead to a severe estimation bias. It is necessary to substantiate that air pollution poses a direct effect on happiness, not simply because of health condition. We conduct two estimations in Table 8 to explore this health concern.

**Table 7**

Happiness and household income of different health status groups.

| Health status | Very good | Good | Fair | Bad | Very bad | Total |
|---|---|---|---|---|---|---|
| Average happiness | 4.12 | 3.94 | 3.79 | 3.61 | 3.27 | 3.88 |
| Average annual household income (thousand CNY) | 96.54 | 78.66 | 66.37 | 43.64 | 34.78 | 73.53 |

In Column (1) of Table 8, we use health as the dependent variable to investigate whether reported health status differs as a function of daily air pollution. Results show that the coefficient of AQI is insignificant, indicating strong evidence of a direct impact of air pollution on happiness. This finding also supports the conclusion made by Levinson (2012) that respondents' self-reported health status is not affected by pollution at the time of interview day, but is rather an objective answer in accordance with reality.

We make another estimation of Eq. (1) by omitting the health variable. As shown in Column (2) of Table 8, the air pollution coefficient does not increase, and even decreases slightly compared with the baseline specification in Column (1) of Table 5, demonstrating that including the health variable in the estimation does not affect the impact of air pollution on happiness. As expected, due to the high correlation between health and income, the income coefficient becomes higher than the baseline results, which leads to a smaller WTP (439.49 RMB) than the baseline specification in Table 5 (549.36 RMB).

**Table 8**
Exploration about health

| | Health as dependent variable | Happiness as dependent variable (Omit health) |
|---|---|---|
| AQI/100 | 0.029 | -0.056** |
| | (0.040) | (0.031) |
| Ln (household income) | 0.074*** | 0.078*** |
| | (0.012) | (0.009) |
| Relative income | 0.097*** | 0.072*** |
| | (0.011) | (0.008) |
| Gender | 0.134*** | -0.027* |
| | (0.021) | (0.016) |
| Age/10 | -0.320*** | -0.203*** |
| | (0.042) | (0.032) |
| Age squared/100 | 0.012*** | 0.020*** |
| | (0.004) | (0.003) |
| Education | 0.004 | 0.004 |
| | (0.004) | (0.003) |
| House | 0.000*** | 0.000** |
| | (0.000) | (0.000) |
| Equality | 0.057*** | 0.186*** |
| | (0.010) | (0.008) |
| Status | 0.052*** | 0.092*** |
| | (0.007) | (0.005) |
| Medicare | -0.013 | 0.117*** |
| | (0.037) | (0.028) |
| Child | 0.081*** | -0.038* |
| | (0.028) | (0.021) |
| Marital status (Ref: never married) | | |
| Married | -0.014 | 0.165*** |
| | (0.048) | (0.037) |
| Divorced or separated | -0.078 | -0.139** |
| | (0.080) | (0.061) |
| Widowed | 0.032 | 0.081* |
| | (0.061) | (0.047) |
| Work experience and status and status (Ref: paid work) | | |
| Farmer retired from paid work | -0.103** | 0.070* |
| | (0.050) | (0.038) |
| Always farming | -0.135*** | -0.020 |
| | (0.036) | (0.027) |
| Retired farmer | -0.237*** | 0.043 |
| | (0.039) | (0.030) |
| Unemployed or retired from paid work | -0.127*** | 0.013 |
| | (0.029) | (0.022) |
| Never worked | -0.200*** | 0.031 |
| | (0.053) | (0.041) |
| County fixed effects | Yes | Yes |
| Month, day-of-week fixed effects | Yes | Yes |
| Adjusted R-squared | 0.238 | 0.206 |
| Observations | 9,634 | 9,634 |
| Mean household income (CNY) | | 61,040.31 |
| %income to pay for a one-unit reduction per year per family (%) | | 0.72 |
| WTP for a one-unit reduction per year per family (CNY) | | 439.49 |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.

We interact pollution with income to test whether the results truly measure reactions to air pollution. To ensure that the pollution coefficient can be interpreted in the same way as previously, at the average income, we choose the difference between the respondent's log household income and the average log household income (Levinson, 2012).

$$H_{ijt} = \alpha_1 P_{jt} + \beta_1 LnI_i + \alpha_2 P_{jt}(LnI_i - \overline{LnI}) + \beta_2 R_i + X'_{ijt}\gamma + \delta_j + \eta_t + \varepsilon_{ijt} \quad (2)$$

Results are presented in Column (1) of Table 10. The interaction coefficient is negative and significant, suggesting that people with higher income are willing to pay more for better air quality. The marginal rate of substitution between income and air quality in this case, for the average level of pollution and log income, is

$$\frac{\partial I}{\partial P} = -I\,\frac{\widehat{\alpha_1} + \widehat{\alpha_2}(LnI - \overline{LnI})}{\widehat{\beta_1} + \widehat{\alpha_2}P}. \quad (3)$$

As shown at the bottom of Table 10, the point estimates in Column (1) are such that people in the 25th percentile of the income distribution are willing to pay 60.97 RMB for a one-unit reduction in AQI, and people in the 75th percentile appear to be willing to pay 891.85 RMB.

Another variable we might expect to be correlated with WTP for daily air quality is the local average air quality. This could go in one of two directions. People in polluted areas could be relatively less sensitive to pollution, either because they become habituated to the poor air quality or because people less concerned with air quality sort into polluted areas in the first place. A one-unit change in AQI would then affect people less in polluted areas than in clean areas. Or, if the marginal disutility from pollution increases, we could find the opposite. In Column (2) of Table 9, we estimate a version of

$$H_{ijt} = \alpha_1 P_{jt} + \beta_1 LnI_i + \alpha_2 P_{jt}(P'_{jt} - \overline{P}') + \beta_2 R_i + X'_{ijt}\gamma + \delta_j + \eta_t + \varepsilon_{ijt} \quad (4)$$

where $P'_{jt}$ refers to the local monthly average AQI. The coefficient is positive and significant, indicating that people in more polluted areas are more affected by air pollution. The marginal rate of substitution is

$$\frac{\partial I}{\partial P} = -I\frac{\widehat{\alpha_1}+\widehat{\alpha_2}(P'-\overline{P'})}{\widehat{\beta_1}}. \tag{3}$$

WTP appears to fall from 287.62 RMB at the 25th percentile of the AQI distribution to 265.30 RMB at the 75th percentile, suggesting that habituation or sorting may overcome rising marginal damages.

**Table 9**
Interactions

| | Income | Local monthly average pollution |
|---|---|---|
| AQI/100 | -0.021 | -0.006 |
| | (0.033) | (0.045) |
| Ln (household income) | 0.115*** | 0.067*** |
| | (0.018) | (0.009) |
| Interaction | -0.068*** | -0.289* |
| | (0.022) | (0.175) |
| Interacted variable: | | |
| Income | | |
| Local monthly AQI/100 | | -0.268 |
| | | (0.314) |
| WTP for a one-unit reduction per year per family when interaction=25th percentile (CNY) | 60.97 | 287.62 |
| WTP for a one-unit reduction per year per family when interaction=75th percentile (CNY) | 891.85 | 265.30 |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.
All regressions contain the other covariates and fixed effects as same as those in Column (1) of Table 5.

### 4.2 Heterogeneous Effects

It is widely acknowledged that people differ in WTPs for air quality. Taking forward the general analysis of the whole sample, we further analyze group data to evaluate WTP differences across subgroups. The whole sample is first categorized by annual household income and air pollution, and then by education, gender, age, view toward society equality, and the interview date. Tables 9 to 11 show the results of these group analyses.[10]

### 4.2.1 The effect of income and AQI

We divide the sample into four groups by income quartile.[11] Column (1) of Table 10 shows that AQI has a significant impact on the poorest, which indicates that they are more affected by the negative effects caused by air pollution. According to Column (4) of Table 10, AQI significantly reduces the happiness of the richest too. With a relatively high material life standard, rich people are less concerned with basic needs and pay more attention to pursuing better environmental quality in order to further improve their quality of life. The WTP toward air quality differs substantially among the income groups, ranging from 140.81 RMB to 3,236.41 RMB. Results in Columns (1) through (4) of Table 10 also support the viewpoint that income has a larger impact on the happiness of lower income groups (Diener and Diener, 1995). Generally, there is common understanding among researchers that income and SWB have a curvilinear relationship; a rising income leads to great gains in happiness for people at a low living standard, but the gains progressively attenuate and eventually stabilize as income continues to increase (Brockmann et al., 2009).

To investigate the effect of local air quality, we divide the sample into two groups according to AQI.[12] Columns (5) and (6) of Table 10 show that people living in more polluted areas are more sensitive to air pollution. The coefficient of AQI is significant and almost the same as the baseline regression in quantity. The annual household incomes of low-AQI and high-AQI groups is 62,561.67 RMB and 59,945.65 RMB, respectively. The gap between these two groups is relatively small. However, the proportion of WTP of the high-AQI group (1.19%) is about twice that of the

[10]We focus on the WTP difference in this part. Therefore, only the main variables are presented in these three tables. The complete regression results are available upon request.
[11]Following Zhang et al. (2017a), we divide the sample into four groups according to income quartile.
[12]If AQI ≤100, it meets the Ambient Air Quality Standards (GB3095-2012). We divide the sample into two groups according to whether this standard is met.

low-AQI group (0.59%). Thus, the estimation of WTP also satisfies this quantitative relationship; specifically, people facing worse air quality (713.35 RMB) are willing to pay about twice as much as the other group (369.11 RMB).

**Table 10**

Heterogeneous results by income and AQI.

| Variable | Income | | | | AQI | |
|---|---|---|---|---|---|---|
| | 0-25% | 25%-50% | 50%-75% | 75%-100% | Less polluted | More polluted |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| AQI/100 | -0.064** | -0.074 | -0.052 | -0.112** | -0.049 | -0.057* |
| | (0.100) | (0.078) | (0.051) | (0.046) | (0.039) | (0.034) |
| Ln (household income) | 0.054** | 0.102** | 0.029 | 0.055 | 0.083*** | 0.048*** |
| | (0.023) | (0.093) | (0.074) | (0.035) | (0.014) | (0.011) |
| Mean annual household income (CNY) | 11,832.82 | 32,692.60 | 60,110.39 | 158,647.39 | 62,561.67 | 59,945.65 |
| %income to pay for a one-unit AQI reduction per year per family (%) | 1.19 | 0.73 | 1.79 | 2.04 | 0.59 | 1.19 |
| WTP for a one-unit reduction per year per family (CNY) | 140.81 | 238.66 | 1,075.98 | 3,236.41 | 369.11 | 713.35 |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.

All regressions contain the other covariates and fixed effects as same as those in Column (1) of Table 5.

### 4.2.2 The effect of demographic characteristics

In this part, we select four variables to group the sample, including gender, age, education, and view toward social equality. In order to ascertain whether the interview date influences the responses, we also choose it as a classification variable.

We group the sample by gender to investigate happiness and WTP differences between males and females. As shown in Columns (1) and (2) of Table 11, factors affecting the happiness of males and females are different. Specifically, air pollution significantly affects the happiness of females, but this is not the case for males. There is evidence that bad air quality does great harm to skin (Mancebo and Wang, 2015), which can directly affect the happiness of females. Women have the dominant buying power and businesses would be wise to target female consumers (Silverstein and Sayre, 2009). Therefore, it is not hard to understand that when it comes to improving air quality, females seem to be much more positive. In addition, whether a child younger than 18 is present in the family does not have a significant influence on the happiness of men. However, it is totally different when it comes to females, who generally pay more attention to taking care of children and are therefore likely to have a higher WTP.

People have various experiences and may change their opinions at different stages of life. Thus, age may be an important factor that affects people's happiness. Columns (3) and (4) of Table 11 indicate that air quality has a significant effect on the happiness of people aged 60 or below, who are expected to have access to more information about air pollution and are concerned more about its implications on their future lives. Regarding older people (aged above 60), despite having a lower average income, they still show a slightly higher WTP (555.36 RMB) compared with the other age group (515.20 RMB). It is not surprising to find that older respondents seem to be willing to pay a much larger share of their income (1.23%) to improve air quality than those who are relatively young (0.76%). There are two possible reasons for this. On the one hand, they have experienced the changes in air quality over the past decades. Therefore, they have a strong desire for good air quality, which they attach a greater monetary value to and are willing to pay for. On the other hand, the elderly are more sensitive to air quality than the younger generation due to the decline in physical function, and the issue of health is one of the foremost priorities in their daily lives.

The education level may also have an impact on happiness. By separating the respondents by whether they have a bachelor's degree or higher, we find that the happiness of those who are more educated is insensitive to AQI. One plausible explanation from a practical perspective is that respondents in this group mostly work indoors and are exposed to conditioned air with less pollution. In contrast, less education may restrict an individual's ability to acquire information on air quality (Levinson, 2012; Greenstone and Hanna, 2014; Li et al., 2014). As revealed in Columns (5) and (6) of Table 11, people who are more educated are willing to pay much more to reduce AQI than those who are less educated in terms of the share of WTP in personal income. The reason for this may lie in the fact that those who are more educated have more disposable income share to pay for better air quality.

**Table 11**

Heterogeneous results by gender, age and education.

| Variable | Gender | | Age | | Education | |
|---|---|---|---|---|---|---|
| | Male | Female | ≤60 | >60 | Less educated | More Educated |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| AQI/100 | -0.033 | -0.081** | -0.067* | -0.058 | -0.053* | -0.059 |
| | (0.040) | (0.040) | (0.037) | (0.050) | (0.032) | (0.059) |
| Ln (household income) | 0.076*** | 0.064*** | 0.088*** | 0.047*** | 0.072*** | 0.038 |
| | (0.013) | (0.012) | (0.012) | (0.014) | (0.009) | (0.035) |
| Child | -0.043 | -0.057* | -0.042** | -0.026 | -0.033 | -0.145** |
| | (0.030) | (0.029) | (0.020) | (0.068) | (0.022) | (0.061) |
| Mean annual household income (CNY) | 63,524.28 | 58,773.01 | 67,788.80 | 45,003.31 | 54,418.22 | 127,589.24 |
| %income to pay for a one-unit AQI reduction per year per family (%) | 0.43 | 1.27 | 0.76 | 1.23 | 0.74 | 1.56 |
| WTP for a one-unit reduction per year per family (CNY) | 273.15 | 746.42 | 515.20 | 555.36 | 402.69 | 1,977.63 |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.

All regressions contain the other covariates and fixed effects as same as those in Column (1) of Table 5.

We also divide the sample according to attitudes toward equality. Columns (5) and (6) in Table 12 report the results. Obviously, those who view society as being equal are more concerned about air quality. In contrast, air quality is found to have no significant effect on the happiness of those who regarded society as being unequal. Regarding WTP, although those holding a positive attitude toward equality reported a lower average income, they are willing to pay more to reduce AQI. To the best of our knowledge, viewing society as being equal may indicate an active and optimistic life attitude. Therefore, it makes intuitive sense to presume that they are more enthusiastic about making the environment better.

Considering that the opinion of an individual may differ with working status, we further divide the sample into weekday interviews and weekend interviews. Similar with other groups, income is shown to have a significant impact on happiness, regardless of whether the interview take place on a week day or at a weekend. However, it is interesting to note that the people interviewed on a weekend are more sensitive to air pollution and willing to pay a considerably higher WTP than those interviewed on week days. A possible reason lies in the fact that people interviewed on week days have multiple work- and life-related priorities on their to-do lists and it is highly unlikely that air pollution is amongst those topmost priorities that would be attended to immediately and seriously.

**Table 12**
Heterogeneous results by view towards equality and interview date.

| Variable | View towards equality | | Interview date | |
|---|---|---|---|---|
| | Low | High | Weekend | Weekday |
| | (1) | (2) | (3) | (4) |
| AQI/100 | -0.049 | -0.057* | -0.084** | -0.024 |
| | (0.039) | (0.034) | (0.041) | (0.046) |
| Ln (household income) | 0.083*** | 0.048*** | 0.062*** | 0.071*** |
| | (0.014) | (0.011) | (0.017) | (0.011) |
| Mean annual household income (CNY) | 62,561.67 | 59,945.65 | 65,589.21 | 59,008.78 |
| %income to pay for a one-unit AQI reduction per year per family (%) | 0.60 | 1.19 | 1.35 | 0.34 |
| WTP for a one-unit reduction per year per family (CNY) | 369.34 | 712.15 | 884.84 | 201.15 |

Note: * 10% significance level. ** 5% significance level. *** 1% significance level.
All regressions contain the other covariates and fixed effects as same as those in Column (1) of Table 5.

In conclusion, disadvantaged groups, including those who have lower incomes, faced more polluted air, and are less educated, are found to be more vulnerable to air pollution. This observation is broadly consistent with the viewpoint of Zhang et al. (2017a). Furthermore, females and those showing a positive attitude toward society are more concerned about air pollution.

# 5. Conclusions

This paper focuses on the impact of air pollution on happiness and the value of better air quality. By matching the happiness data with air quality data according to the date and the interview location, it employs OLS to explore the possible factors that affect happiness. The results shed light on several important points.

First, pollution directly diminishes people's self-reported happiness. Also, females, lower income populations, those who are less educated, and those living in polluted areas are more susceptible to air pollution. We also explored whether other related factors affect happiness levels. Being in a better health condition and taking out health insurance policies both have a positive and significant impact on happiness. Holding a positive attitude toward equality and having a higher level of social status help to maintain happiness. In addition, marital status also affects happiness. For example, divorce and separation decreases happiness.

Second, the findings demonstrate that a substantial trade-off exists between absolute income and local air pollution. The estimated average WTP is 549.36 RMB, or 0.90% of annual household income per year per family for a one-unit AQI reduction. People differ significantly in their WTPs for better air quality. Specifically, those who are more sensitive to pollution show higher WTPs for better air quality. Vulnerable groups such as females or people living in more polluted areas show a higher WTP. Those who are more educated and those viewing society as equal are more willing to pay for better air quality.

Controlling air pollution effectively is a highly challenging mission, which depends not only on the decision-making ability of the government but also on the acceptance of the public. There certainly exists a long-term dynamic interplay between these two issues. The estimate of WTP provides useful information on the benefits of formulating and implementing regulations to reduce air pollution. In addition, the conclusions on individual preferences can serve as targeted recommendations to raise people's environmental awareness, which is integral to the collective efforts in reducing air pollution.

Improving income is an effective way to stimulate WTP. Currently, household income is still a dominant factor of WTP in China. The lowest-income group bears most of the negative effects but will pay a larger share of their income compared with the whole sample; however, their WTP is the smallest due to their limited income. Furthermore, WTPs range widely from 140.81 RMB to 3,236.41 RMB for different income groups. This implies that if an environmental tax is considered as a policy option, it should be formulated by duly taking people's financial positions and WTPs into account and it should be implemented in a reasonable and prudent manner.

Promoting social equality and improving the healthcare system should be further prioritized and provided with more resources. Those viewing society as inequal are less willing to bear the expense, despite having a higher income level compared with the other group. The results of equality may reflect concerns of vulnerable groups, so it is necessary to narrow gaps. Improved social equality will help people to achieve a high level of happiness.

We believe that our work provides a valuable perspective in order to obtain a high-level understanding of the public's WTP for better air quality in China. Underlying the described landscape of the WTP, what shall be fully recognized is the heterogeneity with regard to people's awareness of air-quality-related issues and their actual exposure to the negative effects of air pollution. Proactive measures should be taken to raise people's awareness of air pollution, particularly those who were found during surveys to have less awareness and knowledge on this subject such as males and the less-educated population. Meanwhile, capacity building and training that targets all stakeholders will be critical to ensure concerted efforts to mitigate air pollution while maintaining the desired strong momentum of social and economic development.

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