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# Citizens' Satisfaction with Air Quality and Key Factors in China—Using the Anchoring Vignettes Method

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**Abstract:** This study uses the anchoring vignettes method to accurately measure citizens' perceptions of air quality by correcting for the measurement errors which often exist in subjective satisfaction indexes. Our study shows that there is significant variation in satisfaction with air quality before and after using the anchoring vignettes method, especially when calculating and comparing satisfaction levels with the city-level air quality index. In addition, we found that the actual air pollution does indeed decrease citizens' satisfaction with it, but that the relationship between the two is non-linear. However, among the relevant pollution indicators, citizens are more easily influenced by PM2.5 rather than by $SO_2$ and dust emission concentrations. Finally, our research also found evidence to support the idea that public expectations of air quality in China affect satisfaction levels. Our findings therefore challenge the idea that the relationship between actual and perceived air quality is straightforward, and also confirm that expectation theory holds true for levels of satisfaction with air quality.

**Keywords:** anchoring vignettes; air quality; satisfaction; expectation

## 1. Introduction

Air pollution can cause different types of harm, including to individuals' levels of life satisfaction and general well-being [1–3]. In light of this, in order to ensure a clean and even beautiful environment, many countries such as United States and European Union countries, have formulated a range of public polices to enhance their air quality [4]. In addition, Campaign-Style Enforcement to protect environment, typically in China [5], is another important way to control air pollution, with APEC Blue [6] in 2014 being just one example. In other words, as the issue of air pollution is gaining increasing attention from China's central government [7], a campaign to control air pollution in and around Beijing was launched. As a result, citizens of Beijing have experienced the clearest air quality. In theory, public perceptions of air pollution—a subjective measure of environmental quality at the local level—are becoming an increasingly important indicator of the performance of this public service.

However, unlike objective air quality evaluation, which is based on a set of scientific indicators, such as PM2.5, PM10 [8], etc., perceptions of air pollution can be heterogeneous and are complicated by many cultural, historical, and institutional factors. Prior research efforts [9,10], normally using a five-level Likert table to measure air pollution by assuming that each respondent is in the same context, are unable to deal with the problem of Differentiate Item Functioning (DIF) [11,12] defined as "the circumstance in which two individuals of similar ability do not have the same probability of answering a question in a particular way" [13], thereby producing biased results. In other words,

although citizens in a given city may provide a "very satisfied with air quality" evaluation, they may well hold divergent ideas as to the meaning of "very satisfied". The existing research, based on directly asking respondents about their satisfaction with air quality and measuring this on a five-point scale, is limited in its ability to account for or to measure this variable.

The present study takes the innovate step of using the anchoring vignettes method to measure citizens' satisfaction with air pollution levels, and the Compound Hierarchical Ordered Probit (CHOPIT) model to ascertain which factors might influence variations in perceptions of air pollution. In doing so, it pays particular attention to the relationship between actual city-level air pollution and individual-level perceptions of air pollution. Additionally, we attempt to add public service expectations into the analytical framework to reflect the difference between individuals at the micro level. To this end, we use representative survey data, collected in December 2017 in Shandong Province and archival data regarding air pollution levels in 17 cities. The CHOPIT model was used so as to include the vignettes in the regression model using an R package in order to measure and determine the key factors influencing perceptions of air pollution.

This study thereby provides a unique and significant contribution to the literature on perceptions of air pollution and public service satisfaction levels. First, using the anchoring vignettes method (developed in the field of political science), allows us to overcome the shortcomings of the five-point Likert scale at both the individual and aggregate levels. Second, prior studies have predominantly focused on air pollution and public service satisfaction levels from the perspective of specific population groups, focusing on particular characteristics, such as gender, age, information sources and awareness of government policies. However, few attempts have been made to systematically study public perceptions of air pollution in dialogue with expectations of public services (air quality being considered a component of the public environment and thus the responsibility of the government to maintain). When the public believes that the government should deliver a high level of public service, they will very likely give a lower evaluation of air quality as compared to populations with low expectations of public services. Our study sheds light on the effects which expectations of public services can have at the individual level. This is particularly important because popular evaluations are considered a vital part of public administration, but to date, little attention has been given to the study of perceptions of environmental quality in China and other developing countries. Third, existing studies have understandably treated actual air pollution as an important predictor and have focused on its impact on perceptions of air pollution. However, there is little in the prior research which can provide solid evidence to support the relationship between these two variables. Our study adopts a robust research design to examine the effects of city-level indicators on individual-level perceptions using the anchoring vignettes method (non-parametric and parametric methods).

## 2. Literature Review and Research Hypotheses

Satisfaction with air quality is a subjective measure of air quality determined by the public, normally meaning by citizens of a particular location. It is different from actual air quality, which is measured by objective indicators such as PM2.5, PM10, $SO_2$, etc. However, people respond to their perception of reality, not to reality itself, which means that perception is both important and worthy of careful study. There is no doubt that air quality is one of the most important components of our environment, and it has increasingly become a focus of research in many social science disciplines and in institutes and agencies around the world.

### *2.1. Measuring Perceptions of Air Pollution*

The perception of environmental pollution can be complicated and multidimensional. Air, water, and solid waste can be sources of environmental pollution in a direct sense. Of these, air pollution is the most salient and prominent in China, given its profound influence on the country's economic sustainability, and because of the emotional and behavioral responses it evokes among

the population [14,15]. Therefore, how to measure perceptions of air pollution is critical to any China-focused environmental pollution perception study.

Within the existing literature, there are two principal methods which have been used to explore these issues. The first is direct—quite simply, one question is posed to each respondent. Research conducted by Peng et al. [10] and Shi [9] used data gathered from CGSS2013 and from just one single question—"How serious do you generally think the air pollution problem is in your city?"—in order to measure perceptions of air pollution. Answers were selected on a scale from "an extremely serious problem = 1" to "not a problem at all = 4". Environmental satisfaction research conducted by Wong et al. [16] similarly posed just one question to each respondent: "All things considered, how satisfied are you with the environment nowadays? 1 = extremely dissatisfied, 5 = extremely satisfied."

The other principal method of research in the existing literature is to employ several items and then perform a factor analysis [17–19]. We will take Pelletier et al. [17] as an example to illustrate this approach. In their research, several statements are presented to the respondents, such as: "local governmental conditions are excellent"; "Most of the time, the quality of the government's environmental programs is very good"; "Most of the time, the environmental conditions in my area are close to ideal"; "At the moment I'm content with the state of the environment", etc. Although several prompts are provided, this does not help to overcome the measurement problem, because each item is simply too vague to provide meaningful data. As such, existing studies cannot deal with the Difference Item Functioning problem highlighted by King and Wand [11].

However, the anchoring vignettes method, enhanced by Hopkins & King [12], aims to overcome the problem of incomparability by providing several vignettes to which respondents' perceptions can be compared. This method has been usefully applied in the fields of political science, management, and psychology, among others. Put simply, in the survey design, both the self-reported and the anchor questions will be asked and measurement errors can then be overcome using particular calculations in an R package (further details can be found in the method section).

The mechanism behind this is simple enough. As can be seen in Figure 1, above, self1, shown on the left, is higher than self2, shown in the middle, indicating that the level of satisfaction with perceived air quality was higher prior to the introduction of the anchoring vignettes method. Vignettes are (usually brief) descriptions of hypothetical people or situations that survey researchers can use to correct otherwise inter-personally incomparable survey responses. Survey questions are a function of the actual quantity being measured along with a dose of interpersonal in-comparability (i.e., different for each respondent). When measurement errors are overcome by using the anchoring method, shown on the right, self2's satisfaction with perceived air quality is actually higher than that of self1.

In light of this, we advance the following hypothesis.

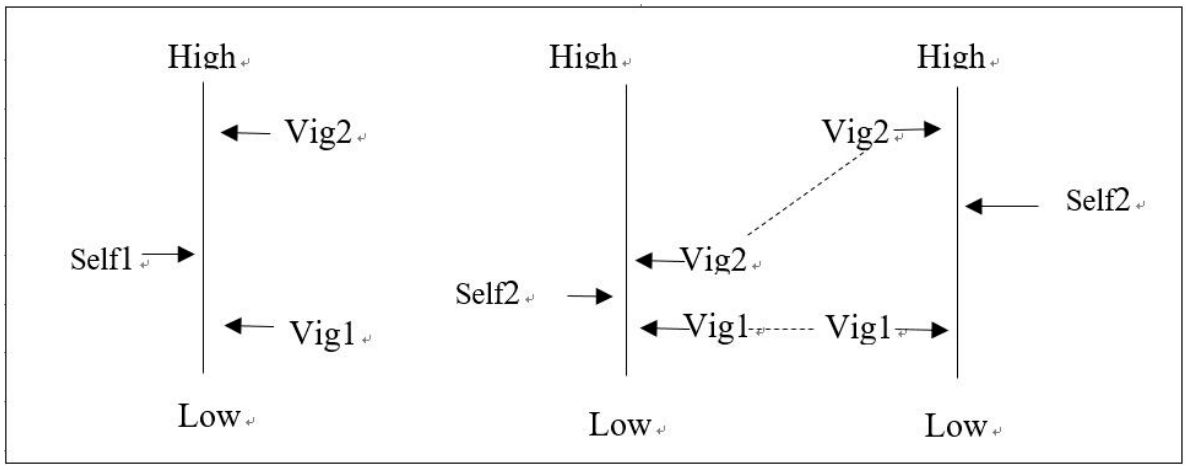


**Figure 1.** Anchoring vignettes method.

**Hypothesis 1.** *There will be significant variation in terms of satisfaction with air quality before and after the anchoring vignettes method is used.*

### *2.2. The Relationship between Actual and Perceived Air Pollution: Beyond Congruence*

The existing scholarship on the relationship between actual and perceived air pollution can be broken into two main phases. The first phase might be called the significant association period, during which a significant relationship was found between actual and perceived air quality in developed countries. As early as the 1980s, Malm et al. [20] found that the visibility as well as the unpleasant odors of air pollution constituted the basis of public perceptions, which was independent of the effects of individual characteristics. Atari, Luginaah and Fung [21] found that exposure to high $NO_2$ and $SO_2$ concentrations significantly increased individual dissatisfaction scores. The same conclusion was reached by Oglesby et al. [22], who found that Nitrogen Dioxide concentrations outdoors (measured in 1993), as well as smoking, workplace dust exposure, and respiratory symptoms, were all predictors of individual dissatisfaction scores.

The second phase in the scholarship has focused on inconsistency. Research undertaken by Graves [23] found that significant environmental advances had been made in the United States between 1970 and 1997, leading to a reduction of 77 million tons of air pollutants per year (defined according to the Environmental Protection Agency criteria of six specific pollutants). This represented a 34% nationwide reduction, yet, despite this demonstrable achievement, public perceptions of air quality worsened during this period. Much the same evidence can be found in the work of Schwartz [24]. At the same time, Williams and Bird [25] found that the public's perception of air quality can't be predicted by actual air quality measured by data provided by monitoring station in London. In addition, a similar study has also been done in Asian Country. Kim et al. [26] found that measured air quality had a negative or neutral impact on perceived air quality in Seoul.

When it came to explaining this inconsistency between actual and perceived air pollution, two main perspectives have emerged among scholars: media framing and social construction. The former holds that a biased and pro-environmental media has consciously or unconsciously misinformed the public by focusing on bad news, for the sake of attracting a wider audience in a competitive media marketplace [23,24]. This is done by providing various framing components, such as metaphors, news descriptions, examples, word selection, arguments, and visual images [10,27]. By contrast, those scholars who favor the social construction perspective argue that, when assessing the objective measurement, the public tends to localize information into specific contexts wherein goals, values, and motives are also embedded. In other words, subjective evaluations of air quality are the combined outcome of direct pollution-related experiences and a series of individual or localized contextual factors, such as physical health conditions and sensitivity, the neighborhood environment, and cultural and social senses of belongs [28,29]. Therefore, the neighborhood environment, as well as cultural and social senses of belonging, should be controlled for in all environmental satisfaction research.

With this existing scholarship in mind, it seems that a nonlinear relationship might exist between actual and perceived air quality.

**Hypothesis 2.** *There will be a mixed relationship between actual and perceived air quality.*

### *2.3. Public Service Expectation and Its Impact on Perceptions of Air Pollution*

As we can see from the literature reviewed above, there is an inconsistent relationship between actual and perceived environmental conditions. However, when considering this topic within a broader literature, we will greatly benefit from existing Public Administration scholarship. A current hot topic in Public Administration concerns the association between citizens' levels of satisfaction and the provision of government services. After several decades of inquiry, it is becoming the consensus view

that citizen satisfaction is not only the result of the objective performance of a government service, but that it also depends on the implicit, pre-existing performance expectation of that service [30]; this is the fundamental concept of the Expectancy Disconfirmation Model (EDM).

EDM was first developed by Oliver [31] to explain customer decision-making; the theory was then applied to and confirmed in the field of public management. EDM is premised on three relationships, which can be seen in Figure 2. The first link is the direct effect of perceptions of performance on citizens' levels of satisfaction, which has been proven by Van Ryzin [32]. The second link predicts a direct effect of expectations on satisfaction. This link is less apparent and requires some explanation. Expectations are people's baseline from which they form a judgment about a government service [32]. However, evidence supporting the relationship between expectations and satisfactions is mixed [30]. The third relationship in the EDM is the role played by disconfirmation, but this is not the focus of this paper.

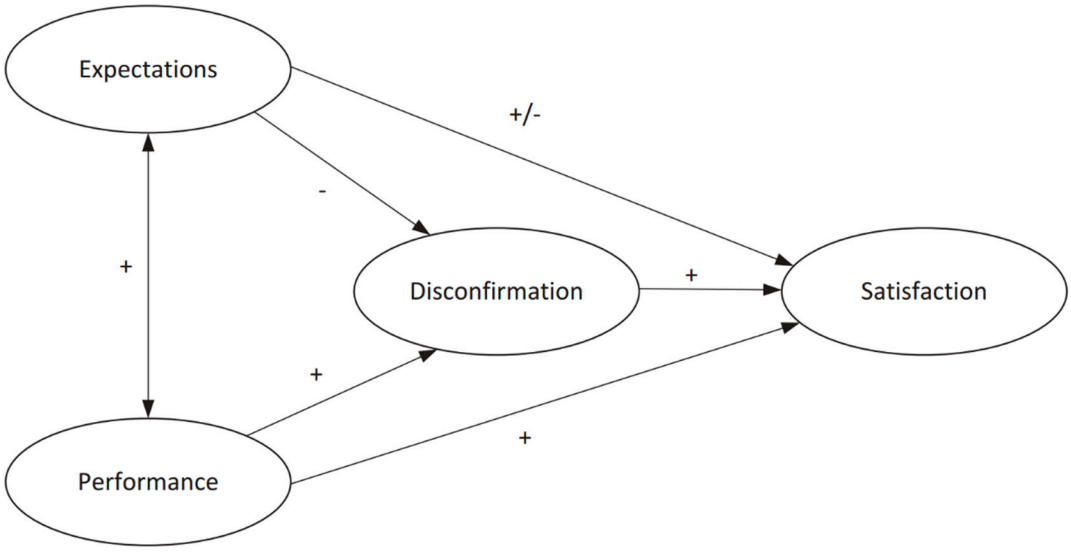


**Figure 2.** Expectancy Disconfirmation Model [32,33].

Although the effect of expectation on satisfaction has been examined in relation to public services, only limited research has thus far been done with regard to air pollution. Drawing on the findings of the existing, broader research, we can hypothesize that, when the public has a high expectation of air quality, they will report a low level of satisfaction with it; in turn, when the public has a low expectation of the ambient air quality, they will report a high level of satisfaction with it.

**Hypothesis 3.** *The higher the public's expectation of the public service of air quality regulation, the lower their satisfaction with air quality will be.*

## 3. Data Collection and Variable Specification

### *3.1. Data Collection*

This study intends to measure public satisfaction with air quality and to use the anchoring vignettes method to determine the factors underlying these assessments. To that end, we set out to collect a random sample across 17 cities in Shandong province in December 2017. This sample data was collected by telephone and the sample size was 5145. Therefore, the targeted population were mobile phone users in 17 cities in Shandong Province. In order to perform suitable quality control for the survey, we only accepted as valid respondents who were over 18 years old and who had lived in the city for more than six months. Further, we attempted to make a comparison between the data we collected and the Sixth China Population Census. The results can be found in the Table 1 below.

**Table 1.** Sample data vs. the Sixth China Population Census.

| Variable | Value | Sixth China Population Census (%) | Sample Data (%) |
|---|---|---|---|
| Gender | male | 50.58 | 58.9 |
| | female | 49.42 | 40.1 |
| Chinese Citizen? | Yes | 62.45 | 52.29 |
| | No | 37.55 | 47.71 |
| Age | 18–23 | 16.29 | 17.31 |
| | 24–45 | 45.41 | 66.13 |
| | 46–60 | 24.14 | 12.57 |
| | 61 and above | 14.16 | 4 |

As shown in the table, our sample data is a little over-sampled in the male, non-citizen, and 24–45 age bracket groups when compared to the Sixth China Population Census data. However, it remains acceptable to make parameter estimations using the sample data, given its randomized nature.

### 3.2. Variable Specification

Dependent variable: Satisfaction with air quality. Existing research has usually relied on self-reported perceptions of air quality. In this literature [11,12,34], measurement errors cannot be accounted for using the self-reported 5- or 7-point Likert scale because each citizen can define what is very satisfied or very unsatisfied. According to prior research, the anchors that can be used to attach the answers of different individuals should be the same standard scale [11,12]. Although vignettes have been designed in political efficacy, self-reported health, and corruption perception, there are no vignettes that can be referred to in the air pollution domain. Following the rule that anchors should create a context that can be understood without confusion, we designed two vignettes to anchor the respondents to a particular situation in order to correct their self-reported answers. Details can be seen in Table 2 below.

**Table 2.** Satisfaction with air quality.

| Question | Option | Category |
|---|---|---|
| Generally speaking, how satisfied are you with the ambient air quality in your city? | A.1 B.2 C.3 D.4 E.5 F. unknown G. reject answer | Self-reported |
| Vignette 1: There is a person called Qiang li (male) or Juan li (female). According to statistics, the city he or she lives in has 9 months a year of clear weather, which means blue skies, white clouds, and high-visibility. If you were Qiang li, how would you rate the air quality in your city? [hint: if the respondent is male, then read Qiang li; if female, read Juan li] | A.1 B.2 C.3 D.4 E.5 F. unknown G. reject answer | Anchoring vignettes |
| Vignette 2: Still using Qiang li or Juan li. The city he or she lives in only has 3 months a year in which there is a chance of blue skies, white clouds and high visibility. If you were him or her, how would you rate the air quality in your city? | A.1 B.2 C.3 D.4 E.5 F. unknown G. reject answer | |

Note: according to King and Wand [11], the two vignettes should produce varied levels of satisfaction. As can be seen from the table above, vignette 2 would produce a lower satisfaction than vignette 1 because it describes only three months of good weather each year whereas the latter has nine months.

The questions posed for both self-reporting and for the vignettes cover the same issue and ask for the same kind of evaluation. The bigger the value given by the respondent, the higher their satisfaction with the air quality. The self-reported question was asked first, followed by the vignette questions [12]. Also, using the *anchor* package in R Language, we tested the order of the two vignettes according to the assumption that on average the level of satisfaction in vignette 1 is higher than that in vignette 2, indicating that the two vignettes we designed were appropriate for correcting the DIF problem in measuring the air quality satisfaction.

Independent variable: actual air quality. To measure actual air quality, we chose the PM2.5, $SO_2$, and dust emission concentrations as indicators [10,35]. The data were collected from the Shandong Statistical Year Book (2017). This means we used data for 2016 rather than 2017, which we did in order to compare the impact of actual air quality on perceived air quality. The survey data were collected after 2016.

Independent variable: public service expectations. We follow the specification elaborated by Van Ryzin [31], who adopted several items by which to measure expectations of a public service. For our research, we used the following five items to measure this variable. We recode the answers given by respondents, A as 1, C as 3, and E as 5. The big value means high expectation for public service.

A. The level of public service currently delivered by the government is far better than what I expected three years ago (I have a very low level of expectation for public services).
B. The level of public service currently delivered by the government is a little better than what I expected three years ago (I have a low level of expectation for public services).
C. The level of public service currently delivered by the government is the same as what I expected three years ago (My expectation for public services is fairly neutral).
D. The level of public service currently delivered by the government is worse than what I expected three years ago (I have a high level of expectation for public services).
E. The level of public service currently delivered by the government is far worse than what I expected three years ago (I have a very high level of expectation for public services).

Control variables: information sources. As noted, experience will significantly influence the public's perception regarding government trustworthiness [36], satisfaction [37] and corruption perception [38,39]. Prior research has also argued that social media usage and the official media are the most significant two factors to impact on citizens' perceptions [40]. In this paper, we control all the three variables by one multiple choice question. Data for these three variables are collected from this survey, which are all considered to be dummy variables. To be specific, whether respondents' satisfaction with air quality was based on their own experiences or not; social media is operationalized as whether they use Wechat or not; the official media usage was specified as whether they use government websites or not.

Control variables: demographic variables. Researchers have previously found evidence that gender [41], age [42], education [10], and citizenship will at various levels significantly impact people's perceptions of, satisfaction with, and other attitudes towards government. Party affiliation has also been shown to have a significant effect on the public's perception of government performance [43]. We take this variable as a categorical variable, also dummied. The gender can be male and female. The age variable was divided into four groups, "18–23, 24–45, 46–60, and 60 and above". The education variable was divided into 6 groups, "primary and below, middle school, high school, college, undergraduate, and postgraduate". Citizenship referred to whether respondents are registered residence in the city they stay. The party affiliation was categorized as six types, "CPC member, semi-CPC member, Democratic Parties, League member, Independents, and the Unaffiliated".

Table 3 gives the summary statistics of the dependent and independent variables, both at the individual and city level.

**Table 3.** Descriptive analysis of variables.

| Variables | Observation | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|
| Satisfaction with air quality | 4081 | 3.45 | 1.19 | 1 | 5 |
| Vignette 2 | 4081 | 1.91 | 0.95 | 1 | 5 |
| Vignette 1 | 4081 | 4.33 | 0.77 | 1 | 5 |
| Expectation | 4081 | 2.67 | 0.97 | 1 | 5 |
| Satisfaction with air quality at city level | 17 | 3.304 | | 0.388 | |
| PM2.5 | 17 | 81.353 | | 21.723 | |
| $SO_2$ | 17 | 89,745.410 | | 33,676.160 | |
| Dust emission concentration | 17 | 63,707 | | 43,766.34 | |
| Categorical Variables | value | proportion (%) | | | |
| Gender | male | 0.587 | | | |
| | Female | 0.413 | | | |
| Citizenship | yes | 52.29 | | | |
| | no | 47.41 | | | |
| Party Affiliation | CPC member | 16.47 | | | |
| | Semi-CPC member | 1.13 | | | |
| | Democratic parties | 14.09 | | | |
| | League member | 0.2 | | | |
| | Independents | 0.38 | | | |
| | The Unaffiliated | 67.72 | | | |
| Age group | 18–23 | 17.31 | | | |
| | 24–45 | 66.13 | | | |
| | 46–60 | 12.57 | | | |
| | 61 and above | 4 | | | |
| Education | Primary and below | 3.49 | | | |
| | Middle school | 14.52 | | | |
| | High school | 22.73 | | | |
| | College | 22.29 | | | |
| | Undergraduate | 32.91 | | | |
| | Postgraduate | 4.05 | | | |
| Wechat | yes | 29.89 | | | |
| | no | 70.11 | | | |
| Government website | yes | 11.66 | | | |
| | no | 88.34 | | | |
| Experience | yes | 67.46 | | | |
| | no | 32.54 | | | |

## 4. Results

### *4.1. Perception of Air Quality before and after Anchoring Vignettes*

As can be seen in Figure 3, most of the respondents in Shandong Province were satisfied with the air quality. The proportion might be as high as 80.5% (28.6% + 29.8% + 22.1%), which is very high and close to what was reported by Statistia in 2011. Some 22.1% of respondents were very satisfied with the ambient air quality of their city of residence in 2017. Those who stated they were satisfied accounted for 29.8% of the total, while 28.6% of respondents said they were somewhat satisfied with the ambient air quality of their cities. However, 8.1% of respondents were not at all satisfied with their air quality, and a further 11.4% were not satisfied.

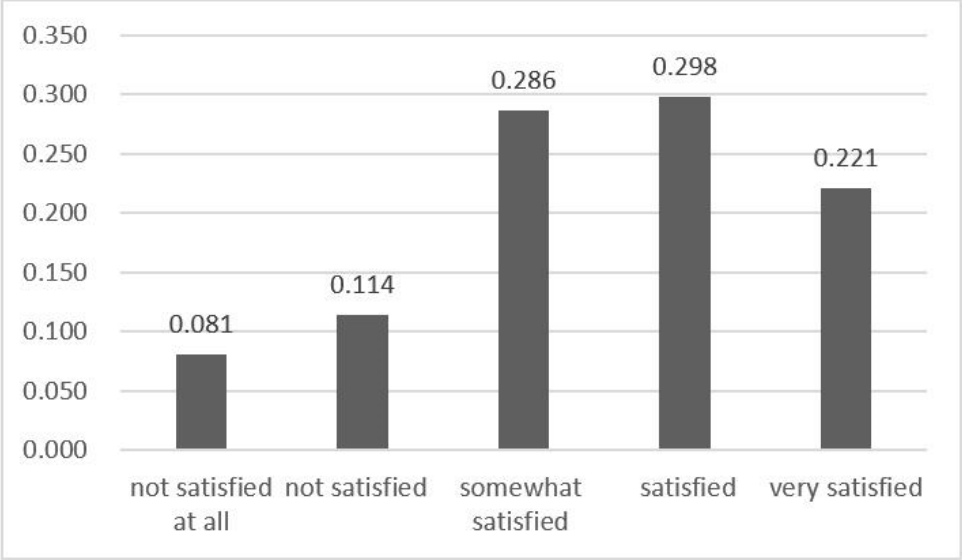


**Figure 3.** Perception of air quality before anchoring vignettes.

However, after the anchoring vignettes method was applied, we see quite different results.

The mechanism for estimating satisfaction with air quality using non-parametric methods is as follows:

We let $y_i$ be the self-reported response $i(i = 1, 2, \ldots, n)$ and $Z_{i1}, \ldots, Z_{iJ}$ be the j vignette responses (in this article $J$ = 2, because we designed two vignettes) for the $i$th respondent. For respondents with consistently ordered rankings for both vignettes ($Z_{ij} < Z_j$, for j = 2, ... , $J$), $C_i$, stands for DIF-corrected self-assessment.

$$C_i = \begin{cases} 1 & \text{if} \quad y_i < Z_{i1}, \\ 2 & \text{if} \quad y_i < Z_{i1}, \\ 3 & \text{if} \quad Z_{i1} < y < Z_{i2}, \\ \vdots & \\ 2J+1 & \text{if} \quad y_i > Z_{iJ}. \end{cases} \tag{1}$$

Respondents who gave tied or inconsistently-ordered vignette responses would have an interval value of C if this resulted in multiple conditions appearing to be true. A more general definition of C is the minimum to maximum values among all the conditions that hold true. Values of C that are intervals, rather than scalar, represent the set of inequalities over which the analyst cannot distinguish without making further assumptions. King and Wand (2007) provide four methods by which to deal with this problem: omiting, uniform, cpolr, and Minentropy. For the sake of simplicity, we chose only

to report the results calculated with the widely-used cpolr method. The four results are very similar, as can be seen in Appendix A.

The results in Figure 4 are very different to those shown in Figure 3. Some 78.4% (37.8% + 28.5% + 12.1%) of respondents were satisfied with the air quality in their city. To be more specific, there are only 12.1% of respondents who were very satisfied with the air quality compared to the 22.1% we see in Figure 3, representing an almost 10% gap. Intuitively, this 10% of respondents shifted into the categories of those who are somewhat satisfied with air quality, the proportion of which rose to 37.8%.

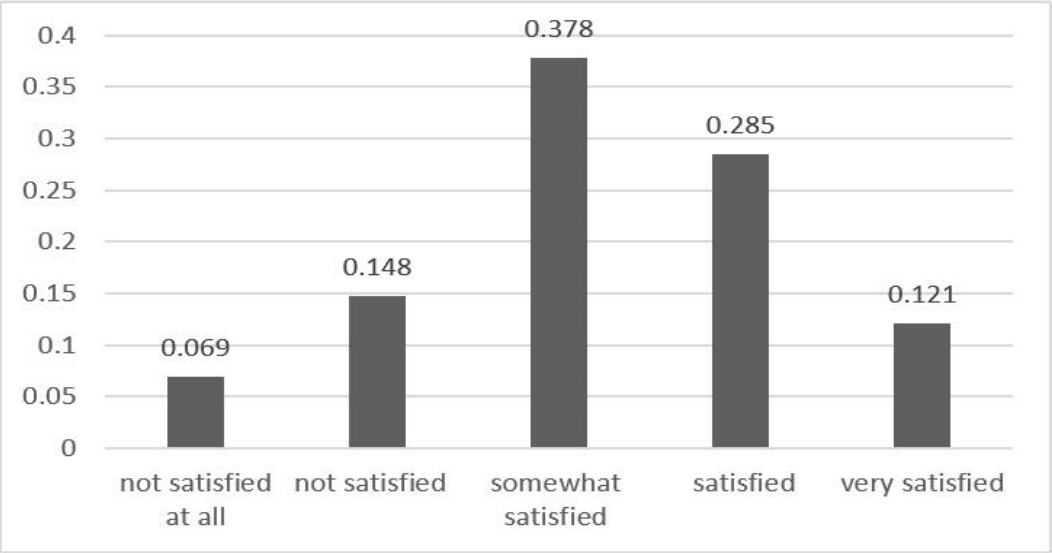


**Figure 4.** Perception of air quality after anchoring vignettes.

In order to demonstrate the satisfaction variation with air quality before and after using the anchoring vignettes method, we also compared the results at aggregate city level. The results can be seen in Figure 5, below.

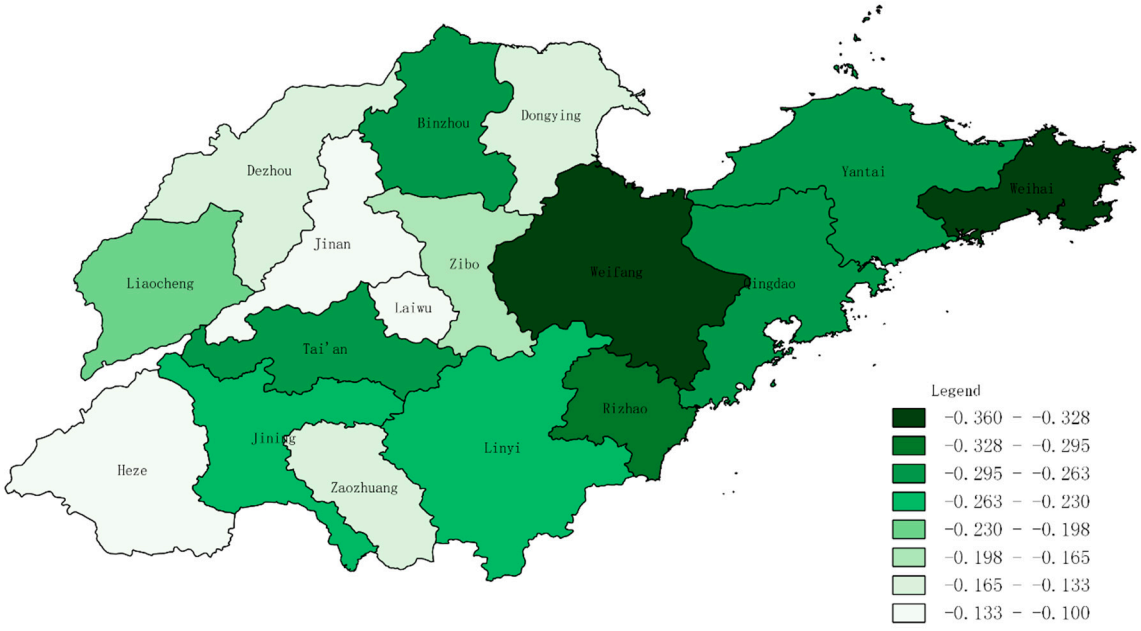


**Figure 5.** Difference of air quality satisfaction between before & after anchoring.

The difference of satisfaction score (retrieved from Appendix B) in cities such as Weifang, Weihai, and Rizhao, is over 0.3 in absolute value, which is large enough to change the satisfaction rank if there is an evaluation for air quality perception among 17 cities in Shandong Province.

Therefore, it is clear that levels of satisfaction with air quality before and after the anchoring vignettes method was used can show very different results at the aggregate level. In other words, there is strong evidence to support hypothesis 1. When measuring perceptions of air quality, it is much better to use the anchoring vignettes method than to rely solely on direct self-reporting.

### *4.2. The Relationship between Actual and Perceived Air Quality*

As we have shown, perceptions of air quality should be measured using the anchoring vignettes method. We then attempted to explore the relationship between actual and perceived air quality, which is a classic research topic among scholars working in political science, public administration, and various other disciplines.

To this end, we made an aggregate index at city level, as shown in Appendix B, to combine city-level data. The actual air quality was determined using PM2.5, $SO_2$, and dust emission concentrations. In order to obtain accurate results, we employed two methods to fit the data: linear fit and lowess (Lowess stands for "locally weighted regression".) fit. The results are shown in the figures below.

Figures 6–8 show that there is a negative association between actual and perceived air quality, which means that, the higher the air pollution in a city, the less satisfied citizens will be with the air quality. In other words, there is a positive relationship between actual and perceived air quality, which provides evidence to support Hypothesis 2. However, we also find that this relationship is more apparent for PM2.5, rather than for dust emission concentrations. Citizens in China are paying more attention to PM2.5 than to other indicators such as $SO_2$ and dust emission concentrations. Even Figure 8 shows that the impact of dust emission concentrations on citizens' satisfaction with air quality is very small. Furthermore, after the actual air pollution reaches a certain level (PM2.5 = 100), citizens' level of satisfaction with air quality does not decline. Therefore, we could conclude that while the actual air quality does reduce citizens' satisfaction with air quality, this is a non-linear relationship once the pollution reaches a certain level.

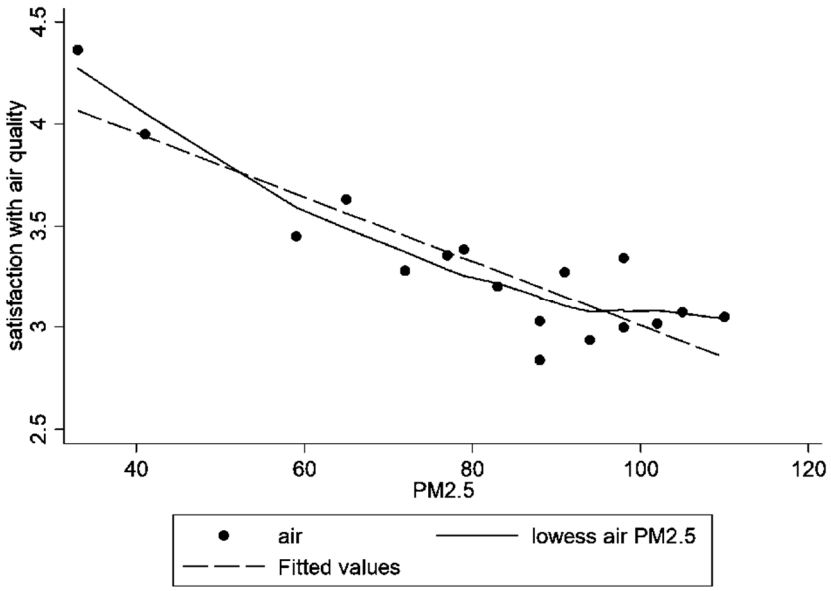


**Figure 6.** PM2.5 and air quality satisfaction

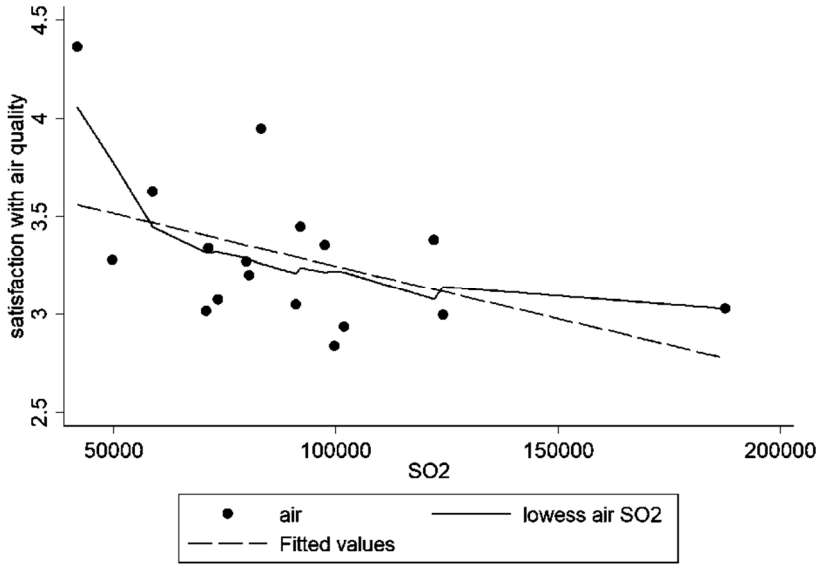


**Figure 7.** $SO_2$ and air quality satisfaction.

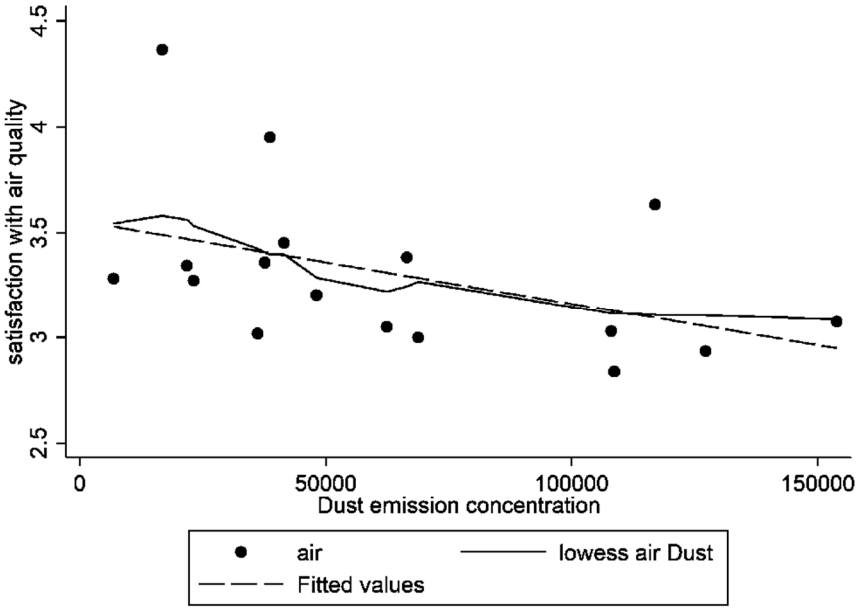


**Figure 8.** Dust emission concentration and air quality satisfaction.

### *4.3. Underlying Factors Influencing Satisfaction with Air Quality*

To estimate the effects of expectation and information sources on levels of satisfaction with air quality, we designed two anchoring vignettes to correct the measurement error of dependent variables. In order to combine these two vignettes for regression, the Compound Hierarchical Ordered Probit (CHOPIT) model was preferred. As can be seen above, our dependent variable was a 5-point ordinal measure (likewise for the two vignettes), which is suitable for use with the CHOPIT model [34]. Because the data was collected from different cities in Shandong province, we ran two regression models to control for fixed effects related to a given city.

Two parts were included in the CHOPIT model: the self-assessment component and the vignettes component. The actual level for respondent $i$ is $\mu_i$, a continuous unidimensional variable (with the

direction defined by the order of the response categories—values indicating more satisfaction were coded as higher). Respondent $i$ perceives $\mu_i$ with random normal error so that

$$Y_i^* \sim N\left(\mu_i, \sigma^2\right) \tag{2}$$

is respondent $i$'s unobserved perceived level. The actual level is a linear function of observed covariates $X_i$, such as information sources, expectation, and all other control variables. The first column of covariates can be a constant term (if it is not needed for identification) and an independent normal random effect $\eta_i$:

$$\mu_i = X_i\beta + \eta_i \tag{3}$$

with parameter $\beta$ and

$$\eta_i \sim N\left(0, \omega^2\right) \tag{4}$$

The reported survey response category is $y_i$ and is generated by the model via this observation mechanism:

$$y_i = \kappa \text{ if } \Gamma_i^{k-1} \leq Y_i^* < \Gamma_i^k \tag{5}$$

with a vector of thresholds $\Gamma_i$ (where $\Gamma_i^0 = -\infty$, $\Gamma_i^k = \infty$, and $\Gamma_i^{k-1} < \Gamma_i^k$, with indices for categories $k = 1, \ldots, K$) that vary over the observations as a function of a vector of covariates, $V_i$ (the first column of which can be a constant term), and unknown parameter vectors $\gamma$ (with elements the vector $\gamma^k \geq 0$). The vignette component should also be specified in this research. The actual level for vignette $j$ is $\theta_j$ ($j = 1, \ldots, J$), measured on the same scale as $\mu_i$ and the $\tau$'s. Respondent $i$ perceives $\theta_j$ with random normal error so that

$$Z_{ij}^* \sim N\left(\theta_j, \sigma_j^2\right) \tag{6}$$

represents respondent $i$'s unobserved assessment of the level of vignette $j$.

The perception of respondent $i$ regarding the level of vignette $j$ is elicited via a survey question with the same $K$ ordinal categories as the corresponding self-assessment question. Thus, the respondent turns the continuous $Z_{ij}^*$ into a categorical answer to the survey question $Z_{ij}$ via this observation mechanism:

$$Z_{ij} = k \text{ if } \Gamma_i^{k-1} \leq Z_{ij}^* < \Gamma_i^k \tag{7}$$

with the thresholds determined by the same $\gamma$ coefficients and the same explanatory variables, but with values measured for units $i$, $V_i$:

$$\Gamma_{i1}^1 = \gamma^1 V_i \tag{8}$$

$$\Gamma_{i1}^k = \Gamma_{is}^{k-1} + \gamma^k V_i (k = 2, \ldots, K_1 - 1) \tag{9}$$

The regression results can be seen in Table 4, in which the regressions have been abbreviated in order to save space.

As shown in Table 4, model 2 controls the fixed effects at city level to obtain robust estimation results for this parameter. As we can see, doing so does have some effect on the model results.

Holding other things constant, expectations of public services has a negative significant impact on levels of satisfaction with air quality, which is significant at 0.001 level. In other words, the higher the expectation citizens have for urban public services, the lower their satisfaction with the ambient air quality. This finding is very strong and robust, regardless of whether city-level fixed effects are controlled for. As such, we have found evidence for research hypothesis 3, namely that the higher citizens' expectations are of their urban public services, the lower their level of satisfaction with air quality.

Information sources are very important for citizens' perceptions; however, our survey yielded mixed evidence in this regard. Neither social media, such as Wechat, nor official websites influenced citizens' levels of satisfaction with air quality. However, when city-level fixed effects were controlled for, the experience of public service had a negative and significant impact on air quality satisfaction levels

(holding other variables as fixed). The significance level was 0.001. Therefore, we find that among many information sources, the experience of public service matters a lot for air quality satisfaction levels, which means that citizens' direct experiences are much more influential than hearing information from others.

**Table 4.** CHOPIT model for air quality satisfaction.

| | **Model 1** | **Model 2** |
|---|---|---|
| | **Satisfaction with Air Quality** | **Satisfaction with Air Quality** |
| Expectation | −0.1895 *** | −0.198 *** |
| | (0.0165) | (0.017) |
| Wechat | 0.0065 | 0.0425 |
| | (0.038) | (0.0387) |
| Official website | 0.077 | 0.0693 |
| | (0.0521) | (0.053) |
| Experience | −0.0188 | −0.1028 *** |
| | (0.0355) | (0.0365) |
| Male | −0.0038 | 0.0212 |
| | (0.0378) | (0.0391) |
| Citizenship | −0.0263 | 0.0261 |
| | (0.0394) | (0.0409) |
| Semi-CPC member | 0.043 | 0.0466 |
| | (0.1776) | (0.1839) |
| Democratic party member | −0.1178 | −0.1432 * |
| | (0.0722) | (0.0748) |
| League member | −0.1036 | −0.0377 |
| | (0.4797) | (0.4949) |
| Independents | −0.0455 | 0.0844 |
| | (0.3482) | (0.3586) |
| The Unaffiliated | −0.1549 ** | −0.1512 *** |
| | (0.0546) | (0.0565) |
| Age | 0.1336 *** | 0.1318 *** |
| | (0.0327) | (0.0339) |
| Education | 0.0077 | 0.0104 |
| | (0.0177) | (0.0186) |
| City fixed effects controlled? | No | Yes |
| Self-reported N | 4522 | 4522 |
| Vignettes N | 4522 | 4522 |

Note: Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In addition, we could not find any evidence for a significant variation in air quality satisfaction levels between males and females, or between citizens and non-citizens. Interestingly, when control the fixed effects on city level show in model 2, we did find evidence showing that, compared to CPC members, members of democratic parties on average had a lower level of satisfaction with air quality (holding other variables constant), which is significant at a 0.05 level. Both model 1 and model 2 shows that the masses also on average had a lower level of satisfaction with air quality than CPC members

(holding other factors constant), which is significant at a 0.001 level. We found that age has a positive and significant impact on air quality satisfaction levels, regardless of whether city-level fixed effects were controlled for. The significance levels were 0.001 for both model 1 and model 2. Finally, there was no evidence to suggest a significant variation in satisfaction levels between people of different educational levels.

## 5. Discussion and Conclusions

Using the anchoring vignettes method and a large-scale data set that covers 17 cities in Shandong province, this study empirically examines the underlying factors which influence air quality satisfaction at both the individual and city level in China. Estimating the air quality satisfaction by combining the two vignettes instead of directly asking is preferred since citizens' view of air quality satisfaction can be varied a lot. Therefore, when respondents are put into the same air quality context where each one can have same understanding to what is clean air, it is reasonable that the satisfaction level can be compared. This study found that anchoring vignettes should be used to measure satisfaction with air quality, especially in order to compare the satisfaction index at city level, from which the relationship between actual and perceived air quality can then be investigated. Our findings confirm the relationship between the two variables. However, citizens are influenced to a larger extent by PM2.5 as opposed to $SO_2$ and dust emission concentrations. More importantly, this study also investigated the impact of expectations of public services on levels of satisfaction with air quality, a subject which has hitherto received little attention. Our findings support the research hypothesis that the higher citizens' expectations are of public services, the lower their levels of satisfaction with air quality.

At the city level, our findings empirically confirm a significant congruence of actual and perceived air pollution (PM2.5, rather than $SO_2$ and dust emission concentrations). In recent years, PM2.5, as a salient indicator of air quality, has been reported both by official and social media so that it is getting more and more attention by the public. Compared to $SO_2$ and dust emission concentrations, PM2.5 has an impact on citizen's air quality perception to a larger extent, which makes it clear that sustainable citizenship is becoming increasingly important in China. In other words, citizens are paying more attention to the effects of air quality, especially measured by PM2.5, on public health. Therefore, the air quality can be perceived by citizens accurately. However, Figure 6 shows that citizens' satisfaction with air quality won't decrease when the value of PM2.5 arrives at 100 and above. Because air quality is one of the key indicators for public environment, in line with the relevant Public Administration literature highlighted above, our findings likewise might suggest that the relationship between objective and subjective measures of satisfaction with public services delivered by local governments is non-linear.

Secondly, our study contributes to discussions on how to measure satisfaction with air quality by applying a new statistical method—the anchoring vignettes. Without this approach, each respondent may hold a quite different idea as to what "very satisfied" means, a problem which previous studies have been unable to resolve and which causes measurement errors. To the best of our knowledge, the present study is the first to design two vignettes in order to anchor citizens' responses to obtain an accurate measurement of their levels of satisfaction with air quality. We then used a non-parametric estimation method to gain a corrected satisfaction index, from which a comparison of satisfaction levels can be developed.

We found that, although measurement errors were corrected via the anchoring vignettes method, citizens' expectations of public services were still varied. In congruence with what has been argued regarding EDM, satisfaction with public services will be influenced by citizens' expectations. However, prior research has produced rather mixed evidence for this argument. After the anchoring vignettes method was applied, we found that citizens' expectations have a significant impact on their satisfaction with air quality (i.e., with a part of the public environment service which is understood to be the responsibility of the government to deliver). Our research thereby contributes strong and robust evidence to discussions regarding the effect of expectations on levels of satisfaction with the public

environment. Nevertheless, the causes which underlie the variation in expectations may be important and should therefore be the subject of further study.

Our findings have significant policy implications which can be divided into three parts. First, citizens accurately perceive the quality of the air quality, which is something that government at all levels of China should pay close attention to, in other words, citizens have the capability to participate in the governance of public affairs, especially for air pollution control. Second, information on the public environment, especially regarding air quality, should be released in a timely manner, as this is something which citizens are getting more and more influenced by. Third, and most importantly, the government should pay direct attention to citizens' requests and expectations for clean air and a healthy environment instead of only economic development.

Despite these robust findings, our study nevertheless has certain shortcomings. First, only 17 cities were studied, which is too small a sample size from which to establish a robust relationship between actual air quality and public perceptions of it. Future studies should expand this survey to cover more cities and thereby obtain much more evidence. Second, the factors that influence citizens' expectations deserve further research which goes beyond what we could achieve in this article. Third, this study includes only a limited number of individual characteristics, and future studies might explore the effects of income on levels of satisfaction with air quality.

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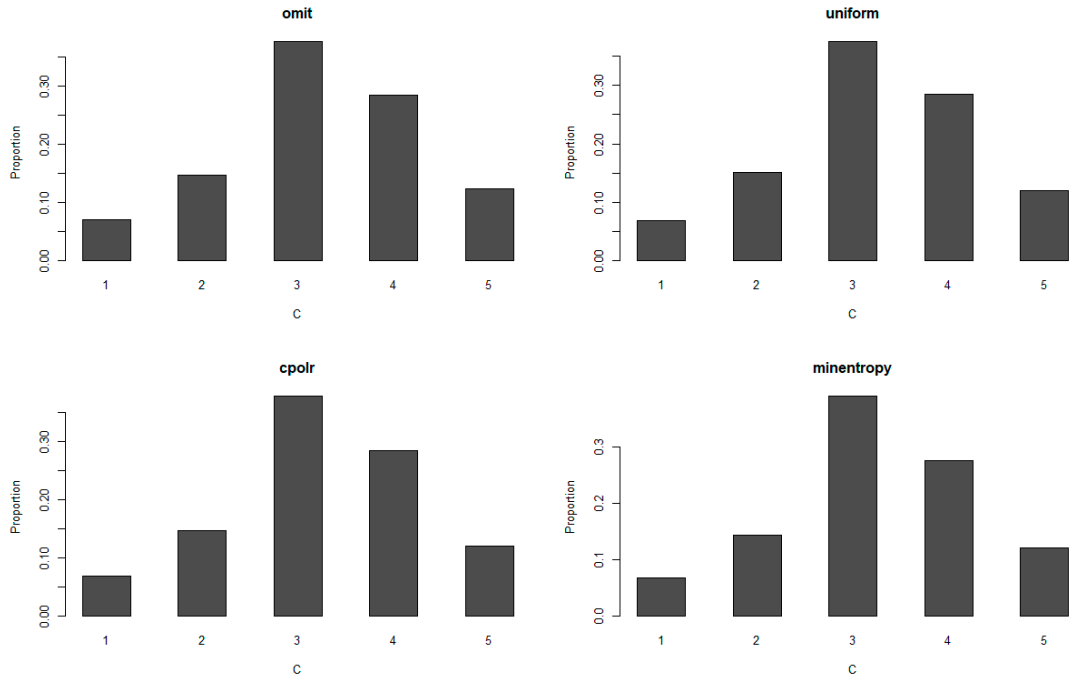
## Appendix A



## Appendix B

| City | Satisfaction after Anchoring | Satisfaction before Anchoring | Difference |
|---|---|---|---|
| Binzhou | 3.357 | 3.627 | −0.270 |
| Dezhou | 3.204 | 3.367 | −0.163 |
| Dongying | 3.281 | 3.428 | −0.147 |
| Heze | 3.05 | 3.150 | −0.100 |
| Jinan | 2.838 | 2.948 | −0.110 |
| Jining | 2.999 | 3.249 | −0.250 |
| Laiwu | 3.075 | 3.212 | −0.137 |
| Liaocheng | 3.342 | 3.543 | −0.201 |
| Linyi | 2.936 | 3.194 | −0.258 |
| Qingdao | 3.449 | 3.746 | −0.297 |
| Rizhao | 3.63 | 3.931 | −0.301 |
| Taian | 3.272 | 3.567 | −0.295 |
| Weihai | 4.363 | 4.711 | −0.348 |
| Weifang | 3.383 | 3.747 | −0.364 |
| Yantai | 3.948 | 4.232 | −0.284 |
| Zaozhuang | 3.018 | 3.179 | −0.161 |
| Zibo | 3.029 | 3.227 | −0.198 |

Note: the difference equals to satisfaction after anchoring minus satisfaction before anchoring.

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