Actual Air Pollution, Environmental Transparency and the Perception of Air Pollution in China

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FUNDING

This work was supported by the Humanities and Social Sciences Foundation of the Ministry of Education, China (Grant no.: 15YJCZH128) and the Humanities and Social Sciences Foundation of the Ministry of Education, China (Grant no.: 15YJC630168).

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ABSTRACT

Using data from the China Social Survey 2013 and statistics from the Ministry of Environment Protection of China and the Institute of Public and Environment Affairs, this study empirically examines the relationship between actual and perceived air pollution, and the moderating effect of environmental transparency on that relationship with a multilevel ordered logistic strategy. Estimations indicate a significant congruence of actual (both PM_{10} and SO_2) and perceived air pollution. More importantly, environmental transparency of local government is found to moderate the relationship between actual and perceived air pollution by neutralizing the halo effects and building more alert perceptions when local air quality deteriorates. Our findings not only challenge the work of identifying a mismatch of actual–perceived air pollution in some developed countries, but also suggest that, apart from abating actual air pollution, environmental transparency should be emphasized and strengthened in institutional buildings to help address pollution challenges in developing countries.

KEYWORDS

Perception of Air Pollution; Actual Air Pollution; Environmental Transparency; Multilevel Ordered Logistic Model; China.

1 INTRODUCTION

Severe air pollution is causing major health problems and consequences in China (Chen et al., 2017), with it posing a serious threat to the country's economic sustainability (Vennemo, Aunan, Lindhjem, & Seip, 2009). As a predominant subjective measure of environmental performance at local levels (Schachter, 2010; Shingler, Van Loon, Alter, & Bridger, 2008), public perception of air pollution is critical for influencing emotional and behavioral responses to air pollution (Bresnahan, Dickie,& Gerking, 1997; Qin & Zhu, 2018). Unlike professional air quality evaluations, based on a variety of scientific indicators, public perceptions of air pollution appear to be heterogeneous, complicated by various influential factors and mechanisms. Although the associations between actual air pollution and subjective evaluations of air quality and between various macro-level factors and perceived air pollution have long been focuses for researchers in developed countries, the related associations have not yet been thoroughly examined in China and other developing countries.

In this study, we empirically examine the congruence of city–level air pollution and individual–level perceived air pollution and consider how environmental transparency affects the actual–perceived air pollution relationship. To this end, we use large nationally representative data from the Chinese Social Survey 2013 (CASS, 2013) together with archival data regarding air pollutant concentration levels and an independent assessment index on the environmental transparency of 62 Chinese cities. Two–level ordered logistic models are employed to investigate the direct and moderating effects on public perceptions towards air pollution.

This study offers unique significance for the literature on the perceptions of air pollution. Firstly, most existing literature conducted in developed countries suggests a mismatch between actual and perceived air pollution (e.g. Graves, 2003; Schwartz, 2003). Their findings, however, are not necessarily applicable in the context of China, where the institutional settings, contextual features and public mentality have a significant impact on public perceptions. It remains unclear whether actual air pollution at city levels can affect the public perceptions of air pollution in China. Secondly, prior studies have predominantly focused on public pollution awareness as well as whether air pollution is a matter of concern among people from different social strata in developing countries, and have found socioeconomic characteristics at the individual level, such as poverty, livelihood and environmental knowledge to be the influential factors (Bladen & Karan, 1976; Egondi et al., 2013; Li, Folmer, & Xue, 2016; Mukherjee, 1993; Muindi et al., 2014; Saksena, 2012). However, few attempts have been made to systematically study public perceptions of air pollution under different social structural settings in developing countries. China has made progress in disclosing the actual amount of environmental information available to the general public in recent years (Li & Li, 2012). Our study will shed light on the moderating effects of environmental transparency, which has been regarded as a vital part of environmental governance (Gupta, 2010), but has not yet been paid sufficient attention in the study of environmental quality perceptions in China and other developing countries. Thirdly, existing studies have treated actual air pollution as an important independent predictor and focused on the impact of air quality indicators on public health (e.g. Chen et al., 2017), happiness (e.g. Li, Folmer, & Xue, 2014), satisfaction (e.g. Smyth, Mishra, & Qian, 2008; Yang & Yang, 2011) and behavioral responses (e.g. Qin & Zhu, 2018).Current empirical literature on public perceived air pollution in China is also mostly conducted on the basis of small survey samples targeting specific residents (e.g. Li et al., 2016; Shi, 2015), failing to provide evidence that systematically examines the relationships based on solid data and a representative sample in China. This study will adopt a robust research design to examine the effects of city–level indictors on individual–

level perceptions, and conduct a comprehensive empirical examination covering wide geographical areas and different levels of air pollution in the Chinese context.

2 LITERATURE REVIEW AND HYPOTHESES

2.1 The Relationship between Actual and Perceived Air Pollution

To date, the existing literature has focused predominantly on examining the congruence between actual and perceived air pollution. Based on the observations of developed countries, three main perspectives have been developed to analyze the public perceptions of air pollution: actual–perceived mismatch, media framing perspective, and the socially constructive perspective.

A significant correlation has been found between actual and perceived air pollution in developed countries. The visibility as well as the unpleasant odors of air pollution was found to constitute the basis of public perceptions, which was independent of the effects of individual characteristics (Malm, Leiker, & Molenar, 1980). Some studies have also found that the perceived outdoor air quality was significantly associated with the measured air quality provided by monitoring stations (Atari, Luginaah, & Fung, 2009; Oglesby et al., 2000).

Despite the aforementioned studies identifying a significant association between actual and perceived air quality, most studies in developed countries have found an actual–perceived mismatch. Graves (2003) documented an apparent "paradox" between the reality and perceptions of air quality in the United States. From 1970 to 1997, a reduction of 77 million tons of air pollutants per year had been achieved, against the six EPA criteria pollutants; this represented a 34% nation-wide reduction over the time period, however, public perceptions towards air quality worsened. Schwartz (2003) also found that, despite the dramatic progress made by the U.S. government in reducing air pollution over the last few decades, most U.S. respondents believed that air pollution had worsened or would grow worse in future and that most people would face serious risks from air pollution. Numerous studies in other countries have also documented insignificant congruence between actual and perceived air pollution. By using Seoul Citizens Health Indicator Survey and five air pollutants in the community, Kim, Yi, and Kim (2012) found that measured air quality showed an insignificant relationship with perceived air quality. Williams and Bird (2003) argued that, regardless of respondents living in urban or suburban areas, actual levels of air pollution in their area were not a reliable predictor of public perceptions towards air quality based on a survey of 200 respondents.

In order to explain such a mismatch, some scholars stressed the effect of misinformation from media framing perspective. This perspective argues the biased and pro–environmental media has consciously or unconsciously misinformed the general public by focusing on "bad news", for the sake of wider readership in the competitive media marketplace (Graves, 2003; Schwartz, 2003). Media framing effects have played a vital role in shaping the public attitudes towards environmental issues by providing different framing components, such as metaphors, news descriptions, examples, word selection, arguments, and visual images (Pan & Kosicki, 1993; Earl, Martin, McCarthy, & Soule, 2004).

Different from the media framing perspective, the socially constructive perspective contends that objective measures of air pollution, based on a universal set of scientific measures, cannot be automatically translated into perceived air pollution, as the public perception of air pollution is socially constructed and contextualized within, and in relation to, the individuals' characteristics and physical and social dimensions of immediate locales. The public tend to localize the information in specific contexts where goals, values and motives are embedded. Personal appraisals of air quality are the combined outcome of direct pollution–related experiences and a series of individual or localized contextual factors, such as proximity to the pollution sources, physical health conditions and sensitivity, information social networks, the neighborhood environment, and cultural and social senses of belonging (Bickerstaff and Walker, 2001, 2003). DeGroot et al. (1966) stressed the importance of neighborhood satisfaction over physical environmental–related experiences in the formation of perceptions. Moreover, some studies have demonstrated a "neighborhood halo effect" where individuals show reluctance to attributed poor air quality to their home area and consistently perceive their communities, neighborhoods or cities to be less polluted than in other areas (Groot, 1967; McBoyle, 1972; Rankin, 1969). Contrarily, the perception of air pollution may be complicated by a "stigma effect", whereby once–heavily polluted areas or individuals sensing a feeling of "breathing toxic air" can attribute harmful characteristics and identities to places where individuals are living, thereby giving rise to a negative effect on the perceptions (Bush, Moffatt, & Dunn, 2001a; Wall, 1973).

Unfortunately, there is relatively little literature that systematically studies this issue in China with a large nationally representative sample. Inspired by attention theory proposed by many economists, we theorize that public perception of air pollution is significantly associated with actual air pollution in China.

Behavioral economists believe humans are serial processors of information, and it is usually not possible for the public to attend to all social issues at the same time due to the inherent scarcity and selectivity of attention (Berlyne, 1974; Moray, 2017). Different environmental stimuli structured by social contexts and multiple dimensions of problems will help the public to evaluate the importance or urgency of information, which may shift and fix public attentiveness and shape the allocation of attention (Thorngate, 1998). In fact, contextual cues and multiple dimensions of social problems refer to what aspects of the complex environment are salient to the public at a particular time (Jones, 1994). As a result, these shifts in attentiveness will affect what issues the public focus on. In China, the allocation of public attention to air pollution has been driven by dual forces. On the one hand, the Ministry of Environment Protection (MEP) (2014) reported that, in 2014, only 16 cities included in the Air Quality Monitoring Scheme met new ambient air quality standards, while the other 145 cities included in the scheme exceeded the national standard, accounting for more than 90% of total monitored cities. In particular, only 11.2% of the monitored cities attained the national standards in terms of $PM_{2.5}$ concentration. As air pollution is highly tangible and visible, and often affects human senses, the problems associated with it, in many places of China, are so severe that the public have been "incentivized" to be sensitive to the changes in air quality in a visible way. In addition, considerable news coverage in mass and social media concerning air pollution problems has directed public attention to real–time information on air quality and relevant threats to physical health. Therefore, the context of "severe air pollution" can effectively break through the bottleneck of public attention, and direct public attention to issues of air pollution problems in various competitive public issues.

On the other hand, since the implementation of 12th Five–Year Plan, the Chinese central government has formulated at least seven binding targets to strengthen the assessment of local environmental quality, and imposed unprecedentedly stringent air pollution regulations, thereby showing a major resolution of the central government to address environmental degradation. These policies for solving environmental problems have officially been incorporated into the political agenda, which has in turn fixes public attention to a series of environmental problems, such as air pollution. Therefore, the public attention to air pollution has been driven by the above two forces and we, therefore, hypothesize that:

H1: Perceived air pollution is significantly correlated with actual air pollution levels.

2.2 Environmental Transparency and its moderating effect on the Actual–Perceived Air Pollution Relationship

To further explore the relationship between actual and perceived air pollution, we explore the possible moderating effect of environmental transparency on the actual–perceived air pollution relationship. Existing literature defines information transparency as the sharing of useful information regarding the workings of agencies, encouragement of citizen involvement and openness to public scrutiny (Oswald, 2010). Both the Rio Declaration on Environment and Development and the Aarhus Convention of the 1990s have emphasized the importance of public access to environmental information (United Nations, 1992; United Nations Economic Commission for Europe, 1998). Transparency of environmental information sets a basis for societal consensus on more desirable modes of production and consumption, which can be institutionalized as environmental standards and regulations and/or business codes of conduct (Li & Li, 2012). It is true that greater environment information disclosure does not necessarily mean greater public exposure to environmental information. It, however, will lead to more information concerning the air pollution available to the public and different social sectors. In addition, the public can be exposed to environmental information intentionally or unintentionally through different channels in their daily lives. More importantly, environmental information can potentially penetrate into different market sectors and institutions, such as local governments, news agencies, industries, and non-governmental organizations in the long term, which will enhance and reinforces the environmental awareness and consciousness of individuals when they encounters those institutions and sectors (Li &Li, 2012).

As a policy instrument to break the governance deadlock, triggered by China's fragmented and decentralized authoritarianism (Lieberthal, 1997), the enhancement of transparency in environmental information has been given great attention by China's central government. In 2007, *The Regulations on Open Government Information* were enacted by the China's State Council. According to the regulations, local governments are required to proactively release public information, while citizens are entitled to request government information as and when required (Piotrowski, Zhang, Lin, & Yu, 2009). In 2008, *The Measures on Open Environmental Information* were enforced by the National Bureau of Environmental Protection, mandating local governments and related regulatory bodies (i.e. local EPBs) to be responsible for disclosing and reporting the most up-to-date environmental information to the public. However, the execution of environmental transparency policy, at the local level, varies in the effort to fight against air pollution.

The moderating effect may result from the mechanism that environmental transparency can facilitate social learning. Perceived pollution is a socially defined concept based on the understanding of causes and consequences of environmental challenges (Hawkins, 1984). Transparency in environmental information creates an opportunity for the public to have improved access to objective information related to environmental policies, budgets, status of environmental quality, the components of pollution and the actual performance, contributing to increasing environmental awareness and shaping more accurate public environmental perceptions, when the public's interests are diverse. In addition, the perceptions of air pollution may be influenced by the difference between the visible quality of outdoor air and individuals' expectations of air quality (James, 2009). Environmental transparency can help the public to adjust expectations of air pollution by increasing public environmental awareness. With greater availability of environmental information, people from different educational and cultural backgrounds, living in different social strata and having different priorities can be better informed and educated to shape their expectations towards pollution, and enhance their capacity to reconcile and prioritize utilities, both in the present and future, thereby creating more accurate perceptions towards air pollution.

The moderating effect may also stem from the improved political trust and reduced uncertainty generated by enhanced environmental transparency. Firstly, prior studies have found that increased information transparency of governments can help improve public perceived government performance by improving trustworthiness (Porumbescu, 2015). The willingness and capability to deliver accurate and complete government information represents an attribute of service performance and is positively related to the competence aspect of trust (Porumbescu, 2017). Greater environmental transparency demonstrates true will and commitment so as to allow the public to monitor its performance, to participate in its the policy–making process, as well as to provide a more accurate picture concerning the internal workings (Grimmelikhuijsen, 2012; Piotrowski & Van Ryzin, 2007), thereby making local governments more accountable and fair in environmental governance. Greater environmental transparency also implies that local governments are working hard to advance citizens' best interests, ultimately improving their trustworthiness (Wu, Ma, & Yu, 2017). Secondly, air pollution often involves a series of risks that are full of uncertainties (Bickerstaff, 2004). The characteristics of environmental transparency i.e., accuracy, completeness and accessibility, can affect the public's uncertainty about the services (e.g. air quality). As transparency increases, the public will face less uncertainty about air pollution because they will have more information about the working of the services, which will help them to be less uncertain about the consequences of air pollution and increase their confidence that local governments can solve air pollution problems. In contrast, the public will be less certain about the consequences of pollution due to lower environmental transparency, thereby creating more biased perceptions towards air pollution.

Therefore, the effects of actual air pollution will be contingent on the levels of environmental transparency. On the one hand, in cities with deteriorating air quality, high–level environmental transparency i.e., easy access to environmental information, timely communication with the public, and complete provision of information can promote social learning, thereby ultimately increasing public's environmental awareness and helping citizens to precisely capture the status-quo of air quality. The public perceptions of air pollution in developing countries may depend on baseline conditions where the public who are accustomed to relatively poor air quality may be less sensitive to further deterioration in air quality (Saksena, 2012). Higher environmental transparency can help neutralize the effects of baseline conditions and build more alert perceptions. The enhancement of environmental transparency may also counteract the "halo effect" that individuals show reluctance to attributed poor air quality to their home area, even though the air quality is deteriorating. On the other hand, when local air quality improves, increased environmental transparency may help to improve public perceptions and neutralize the effect of sensational coverage or the "stigma effect", where the public keep negatively biased perceptions towards local air quality through increasing the political trust and reducing uncertainty about air pollution. Given the above discussion, it is hypothesized that:

H2: Environmental transparency moderates the relationship between actual and perceived air pollution levels.

3 METHODS

3.1 Sample and Data Sources

This study intends to deepen general understanding of public perceptions towards air pollution and examines the effects of city–level variables (actual air pollution and environmental transparency of local government) on individual–level perceptions in the context of China because the outcomes of environmental quality are all manifested at the city level. To this end, we use nationally representative sample data from the Chinese Social Survey (CSS) conducted in 2013. The CSS is conducted annually or biannually, dependent on year, to gather longitudinal data on changing social structures, values, norms and quality of life that are of theoretical and practical significance to studies of China. In order to collect representative samples from these regions, the CSS adopts a multi–stage, stratified and probability-proportional-to-size sampling method. Face-to-face interviews are conducted to collect information from respondents. Furthermore, questionnaires used in the study and data obtained are freely available from the CSS website, enabling scholars to conduct comparative research. The sample size in the CSS 2013 includes more than 68 observations in each surveyed city. Several questions were added in the 2013 survey to gather information about attitudes and perceptions towards environmental quality, making it possible to systematically identify influential factors that shape public perceptions towards air pollution in China.

In our quantitative analysis, 5,805 valid respondents in 62 cities were included, if city-level pollutant PM_{10} was taken into account, and 5,801 valid respondents in 62 cities were included, if city–level pollutant SO_2 was taken into account. The sample of 62 cities is comparable in terms of administrative ranking while heterogeneous in geography and socioeconomic developments. Statistical tests were conducted, resulting in no significant correlations between missing information and major demographic characteristics being found.

3.2 Measurement of Main Variables

3.2.1 The Dependent Variable

Perception of environmental pollution is a complicated and multidimensional concept. Due to the limited availability of items provided by the CSS2013, our study uses *Perceptions of Air Pollution (PercepAirPollut)* at the individual level as the dependent variable, measured with the question "how serious do you generally think the air pollution problem is in your city?" (1= *an extremely serious problem* to 4= *not a problem at all*). We reserved the original scale of the responses so that higher values corresponded to more serious perceived air pollution. Figure 1 plots the response distribution.

-FIGURE 1 ABOUT HERE-

3.2.2 Independent Variables

Key independent variables used in this study include two city–level variables: (1) actual air pollution and (2) environmental transparency of the local government.

The variable *Actual Air Pollution* at the city level was measured using yearly–averaged pollutant concentration indicators reported by MEP and local governments. MEP enacted the new Ambient Air Quality Standard (GB3095–2012) in early 2012 and established a national environmental monitoring network that covers 988 ground–based monitoring stations in 190 China's cities. Before 2012, the Air Pollution Index (API), rather than the Air Quality Index (AQI), was reported. A major difference between the two is that the latter considers the concentration level of $PM_{2.5}$, one of the major pollutants in many cities in recent years. However, only 74 cities in the first phase were required to monitor $PM_{2.5}$ and ozone as new criteria pollutants in 2013. Therefore, the measure of daily concentration levels of $PM_{2.5}$ was not required for each city to monitor local air quality in 2013. In order to preserve sample sizes of our analysis, annual concentration levels of PM_{10} and SO_2 were used for city–level air pollutant measures. Annual concentration levels were obtained by scraping the website of the National Environmental Monitoring Center of the MEP and the database of the Institute of Public and Environment Affairs (IPE), both measured by microgram per cubic meter ($\mu g/m^3$). The distribution of yearly–averaged pollutant concentration levels (PM_{10} and SO_2) for 62 cities is illustrated in Figure 2. The dataset used in our analysis covers different levels of air pollution, ranging from the most heavily polluted cities, like Shijiazhuang City and Baoding City, to cities with excellent air quality, such as Zhanjiang City. For PM_{10}, the annual average concentration was 109.13 $\mu g/m^3$ in 2013, which is nearly five times the amount recommended by the World Health Organization (WHO, 2013).

-FIGURE 2 ABOUT HERE-

The variable *Environmental Transparency of Local Government (EnvTransp)* can be measured by either objective or subjective indicators and both may not converge due to individuals' varying predisposition and perceptual biases (de Fine Licht, 2014). IPE developed the Pollution Information Transparency Index (PITI) to evaluate the environmental transparency of environmental protection bureaus at the city level (IPE & NRDC, 2009). The data of PITI evaluates the performance of local governments' environmental information disclosure from various perspectives, including pollution–source supervisory information, information on pollution-source enforcement campaigns, information on the overall enterprise environmental performance assessment, information on verification of petitions and complaints, etc. In our study, data from the PITI was used to measure the environmental transparency of city–level governments. The distribution of environmental transparency of 62 cities in the CSS 2013 is illustrated in Figure 3. The dataset used in our analysis covers different levels of environmental transparency of local government. The mean of environmental transparency for 62 cities in the CSS 2013 was 31.91.

-FIGURE 3 ABOUT HERE-

3.2.3 Control Variables

To gain insight into the effects of direct actual air pollution and the moderating effects of environmental transparency, city–level economic development indicator was controlled and several individual–level control variables were introduced, such as gender, age, education, income status, health satisfaction, internet exposure and perceived environmental knowledge.

Economic Development at the city level was measured by GDP per capita in each surveyed city. GDP and population data were collected from local government archives and yearbooks. *Gender*, as a dichotomous variable, was coded as 1 for male and 0 for female. *Age* was measured as a continuous variable. *Education* was denoted by an ordinal variable ranging from 1 = *no formal education* to 9 = *postgraduate degree and above*. *Health Satisfaction* was measured by a 10-point Likert-type scale that asked respondents to rate to what extent they were satisfied with their physical well-being, with 1 = *the most unsatisfied* and 10 = *the most satisfied*. *Income Status* was measured by asking respondents to place the economic status of their families on the following scale, as compared to the average family in society, 1 = *lower class*, 2 = *lower middle class*, 3 = *middle class*, 4 = *upper middle class* and 5 = *upper class*.

It has been argued that Chinese social media users often discuss pollution and air quality as topics of interest and recognize them as major public health issues (Kay, Zhao, & Sui, 2015).

Internet media and social media, while sometimes disseminating untruthful rumors and false information, has provided greater space for citizen participation in voicing concerns and even channeling grievances towards environmental quality. Interests in air pollution, as a threat to human health, was much more widespread than as an environmental protection issue on social media and the oppositional frames were often found to be able to break through at some points during the year when environmental activists, international environmental NGOs and public intellectuals were responsible for spreading these topics and messages on social media (Cairns & Plantan, 2015). To control such influences, the variable *Internet Exposure* was included in our analysis. Internet exposure was measured by two separate questions that asked respondents how often (1 = *almost every day* to 6 = *never*) they used the internet for browsing news and for *Sina* Weibo or micro-blogging. Accordingly, the responses of these questions were recoded ranging from 0 to 5 and citizen internet exposure was measured by simply adding up the response values of these two questions. The higher value indicated that the respondent had greater exposure to information via the internet.

Environmental knowledge has been defined as the body of knowledge focused on interdependency between human society and natural environment (Berkes, Colding, & Folke, 2000). It has been argued that environmental knowledge affects the evaluation of environmental risks and perception towards environmental quality (Li et al., 2016; Omanga, Ulmer, Berhane, & Gatari, 2014; Thepaksorn et al., 2017; Zhu, Wei, & Zhao, 2016). To control this influence, the variable *Perceived Environmental Knowledge (PercepEnvKnow)* was included in our analysis, which was measured by a question that asked survey respondents to rate their level of agreement (1 = *strongly agree* to 4 = *strongly disagree*) with the following statement: "*I do not understand environmental issues, nor have the ability to comment.*" The higher value indicated that respondents had more perceived environmental knowledge. Table 1 reports the descriptive statistics of all variables used in our analysis.

-TABLE 1 ABOUT HERE-

3.3 A Two–level Analytical Framework and Method

Figure 4 displays an analytical framework that includes the central hypotheses about the direct effects of actual air pollution and the moderating effects of environmental transparency, as well as other effects of city– and individual–level control variables, based on prior discussions.

-FIGURE 4 ABOUT HERE-

Considering that our dependent variable, the perception of air pollution, is an ordinal measure, neither an OLS nor a multinomial logistic model can be deemed appropriate for analysis purposes. Hence, an ordinal regression model was applied to analyze the ordered response variable (Long, 1997). In addition, given that our dataset includes individual-level information, nested with city-level data, the use of traditional multivariate statistical tools, like single level logistic regression analysis, was not considered appropriate, as this would produce unreliable standard errors, leading to invalid inferences (Snijders & Bosker 1999). A Two-level ordered logistic model offers a viable alternative to test our hypotheses and is preferable to estimate variances at multiple levels. We centered level 1 predictors within the cluster and level 2 predictors by grand mean centering, which is appropriate for estimating same-level and cross-level moderating effects in multilevel modeling (Enders & Tofighi, 2007).

For the ordinal response variable of K categories, logistic regression was used and the model has K-1 thresholds (δ's). This model estimates logit predictions (η) for the K-1 comparative probabilities (k) of the response being at or below a given category for specific individuals (*i*) in specific groups (*j*) (O'Connell, 2010). Fixed effects in logistic regression estimate the logit of probability that an individual's perceived air pollution will be below or equal to each category. A logit of zero represents an odd ratio of 1 (no effect); a positive logit represents a higher probability of the worst perceived air pollution; a negative logit means a lower likelihood of the worst perceived air pollution. In the ordinal response models, proportional odds are most often assumed, i.e. the slope is constant at the threshold for each level 2 group, but the intercept is unique (O'Connell, 2010). To get from logit to the predicted π_{kij} , the following formula is used:

$$\pi_{kij}(\text{given level1 and level 2 predictors}) = \frac{\exp(\eta_{kij})}{1+\exp(\eta_{kij})} = \frac{odds_{(kij)}}{1+odds_{(kij)}}$$

Where η_{kij} is equal to $\ln\left(\frac{P(\mathrm{R}_{ij}\le k)}{P(\mathrm{R}_{ij}>k)}\right)$ (O'Connell, 2010).

For a *K* level ordinal outcome, the cumulative probability across the *K-1* cumulative splits is based on a model using the cumulative logit link for the response, R_{ij}, for the i^{th} person in the j^{th} group.

3.4 Multilevel Ordered Logistic Estimates

Table 2 presents the results of seven statistical models that test the validity of the advanced research hypotheses. We first report multilevel ordered logistic results for the first direct effects of our independent variables (see null model in Table 2). When the logistic model is applied, the level 1 residuals are assumed to follow the standard logistic distribution, which has a mean of 0 and a variance of $\pi^2/3=3.29$; this variance represents the within-group variance for ICC calculations for dichotomous data and the ICC can be similarly defined for ordinal outcomes (O'Connell, 2010; Snijders & Bosker, 1999). According to the results of the null model, the intra-class correlation is 17.44% (ICC=0.695/(0.695+3.29)), suggests that 17.44% of the variability in perceived air pollution at the individual level could be attributed to level 2 predictors. The explanatory power of level 2 predictors is remarkably strong, particularly if we consider the small sample size (62) of level 2, compared with the larger sample size at level 1 (5,821) in our null model. This finding suggests that perceptions towards air pollution may significantly correlate with actual air quality at the city level, but that correlations need further investigation while controlling other variables. The variance at level 2 is statistically significant, indicating that it is essential to use multilevel models to test our hypotheses.

Models 2 and 4 included city–level air pollution together with control variables, both at the individual and city level, described above. Models 3 and 5 included the interactions of environmental transparency and actual air pollution within the same level.

Two city–level variables (level 2) are found to have statistically significant effects on the perceived air pollution levels. In contrast to existing literature in some developed countries, when PM_{10} is used as the air pollution measure in Models 2 and 3, it has a positive coefficient (β=0.004, $p<0.001$ in Model 2; β=0.005, $p<0.001$ in Model 3). SO_2 in Models 4 and 5 has a similar effect on perceived air pollution (β =0.007, $p<0.05$ in Model 4; β =0.008, $p<0.05$ in Model 4). These results confirm hypothesis 1 (H1), that actual air quality is one of the key predictors to perceptions of air pollution. The positive coefficients also correspond to a higher probability of individuals' perceiving air pollution as a more serious problem when city–level air quality deteriorates.

-TABLE 2 ABOUT HERE-

Table 3 lists the predictive probability of four ordered responses for the lowest and highest levels of air pollution concentration and environmental transparency. Between the cities of the lowest and highest levels of PM_{10} concentrations, the differences in the probabilities of *not a problem at all*, *not serious*, *somewhat serious* and *an extremely serious problem* were –15.3%, –15%, 8.8% and 21.5%, respectively. Between the cities of the lowest and highest levels of SO_2 concentrations, the differences in the probabilities of four responses were –6.6%, –8.4%, 3% and 12.0%, respectively. According to the results of predictions, better air quality can increase the probability of positive perception of air quality and reduce the probability of negative perception of air quality.

-TABLE 3 ABOUT HERE-

To test the moderating effects of environmental transparency on the actual–perceived air pollution relationship, the variable *EnvTransp* and the interaction terms of *Actual Air Pollution* and *EnvTransp* were included in Models 3 and 5. The coefficients of interaction terms in Models 3 and 5 are both positive and significant, suggesting that environmental transparency of local government can help moderate the actual–perceived air pollution relationship, providing important empirical evidence to hypothesis 2 (H2). However, regression coefficients cannot be directly interpreted in additive linear models, given that multiplicative interaction models aim to test conditional hypotheses (Brambor, Clark, & Golder, 2006) and the nature of two–level ordered logistic regression. In order to better visually illustrate the moderating effects of environmental transparency on the actual–perceived air pollution relationship, we compared the moderating effects of high–level environmental transparency (+1 SD), mid–level environmental transparency (mean) and low–level environmental transparency (-1SD) on the actual–perceived air pollution relationship (see Figure 5). Figure 5 (panels a and b) establishes the magnitude of effects of actual air pollution on perceived air pollution as "*an extremely serious problem*" (outcome = 4) which are heightened with the increment of environmental transparency. At the same time, Figure 5 (panels c and d) shows the magnitude of negative effects of actual air pollution on perceived air pollution as "*not a problem at all*" (outcome = 1) which are augmented when environmental transparency increases. This suggests that when air quality is deteriorating, high–level environmental transparency is required, implying that transparency helps neutralize the "halo effect" and build more accurate perceptions towards air pollution. Panel b and d (SO_2 models) also indicate that the magnitudes of actual air pollution on predicted probabilities of "*an extremely serious problem*" and "*not a problem at all*" become insignificant when the cities are at low environmental transparency levels. This suggests that the public living in the cities with low–level environmental transparency may not be able to create alert perceptions of air pollution when local air quality is deteriorating.

-FIGURE 5 ABOUT HERE-

In relation to our control variables, gender and age were seen to have an insignificant effect, while education, health satisfaction, income status, internet exposure and perceived environmental knowledge have significant effects on perceived air pollution. These results imply that healthier citizens are more tolerant of air pollution. Also, better–educated, higher–income individuals, and those with greater internet exposure and more environmental knowledge, have relatively lower perceptions of air pollution and tend to be more discontent with air quality.

4 CONCLUSIONS AND POLICY IMPLICATIONS

Using a two–level ordered logistic regression model and a large scale dataset that covers 62 cities in China, this study empirically examines to what extent actual air pollution affects the public perceptions towards air pollution. This study also investigates the moderating effects of environmental transparency on the actual–perceived air pollution relationship. While acknowledging that perceptions of air pollution are greatly influenced by a series of individual characteristics, our findings emphasize the perception of air pollution that is greatly embedded in and influenced by city–level economic, social and political settings.

Firstly, our work empirically confirms a significant congruence of actual and perceived air pollution (both PM_{10} and SO_2), when other influential factors are controlled. This finding contrasts the work in most developed countries that identifies an actual–perceived mismatch concerning air pollution. Our findings suggest that the air quality of different localities in China still play an important role in the formation of individual perceptions of air pollution. Between the cities of the lowest and highest levels of PM_{10} concentrations, the differences in the probabilities of "*not a problem at all*", "*not serious*", "*somewhat serious*" and "*an extremely serious problem*" were –15.3%, –15%, 8.8% and 21.5%, respectively. Between the cities of the lowest and highest levels of SO_2 concentrations, the differences in the probabilities of four responses were –6.6%, –8.4%, 3% and 12.0%, respectively. Our work argues that these results are attributable to the allocation of public attention driven by dual forces. On the one hand, public attention has been directed by the severity of air pollution. As air pollution is highly tangible and visible and often affects human senses, air pollution problems in many Chinese cities are much more severe, compared with the air quality in many developed countries, thereby giving rise to the scenario that the public have been "incentivized" to be sensitive to changes in air quality, in a visible way. In addition, with the widespread use of the internet as well as a wide–ranging discussion on air pollution problems by the Chinese mass and social media, the public is becoming increasingly aware of the pollution issues, which compelled public attention to focus on real–time air quality readings and relevant threats associated with physical health. On the other hand, the allocation of public attention is directed and fixed to a series of environmental issues as a result of the central government's political agenda for solving environmental problems. Therefore, the context of "severe air pollution" can effectively break through the bottleneck of public attention, thereby directing public attention to the issues of air pollution problem among a large number of highly competitive public issues.

Secondly, and more importantly, our study adds further dynamics to discussions on how environmental transparency helps citizens perceive air pollution closer to actual levels of air pollution and generates accurate perceptions by exploring the moderating effects of environmental transparency. The significant interaction terms of environmental transparency and actual air pollution suggest that the effects of actual air pollution on perceived air pollution vary dependent on the levels of environmental transparency. By visualizing the moderating effects of high–, mid–, and low–level environmental transparency on the actual–perceived air pollution relationship, we find that the magnitudes of effects of actual air pollution (both in PM_{10} and SO_2) on perceived air pollution as "*an extremely serious problem*" (outcome = 4) and "*not a problem at all*" (outcome = 1) are heightened with the increase in environmental transparency. It is also important to note that for the models of SO_2, the magnitudes of actual air pollution on predicted probabilities of "*an extremely serious problem*" and "*not a problem at all*" becomes insignificant when the cities are at low environmental transparency levels.

These findings stem from the mechanism that environmental transparency can facilitate social learning, which help to neutralize the "halo effect" and the effect of baseline conditions prevalently observed in developing countries, even though the air quality is deteriorating. In addition, enhanced environmental transparency may improve public perceptions towards air pollution by increasing political trust. Environmental transparency implies willingness and commitment to allow the public to monitor its performance, and provide a more accurate picture of the internal workings, which helps to increase the perception of accountability of local government with respect to environmental pollution. Greater environmental transparency also demonstrates that local governments are working to advance citizens' best interests, ultimately improving the trustworthiness of local governments. Furthermore, the characteristics of environmental transparency i.e., accuracy, completeness, and accessibility, can affect the public's uncertainty about air pollution. Greater environmental transparency offers the public less uncertainty related to air pollution and fine–tunes their judgments that local government can solve air pollution problems. These will help to neutralize the effects of sensational coverage or the "stigma effect" when local air quality improves.

Our results imply that, in addition to strengthening air pollution regulation and strictly reducing air pollutants emission, other institutional and policy reforms, the channels and availability of environmental information disclosure in particular, are of great importance to public health prevention and intervention in China and other developing countries. If the perception of air pollution is greatly complicated by the halo effect or low–level environmental information disclosure, the public is more likely to neglect the hazardous consequences of air pollution, thereby failing to mitigate the negative health effects experienced through pollution-averting activities, such as deliberately reducing pollution exposure and wearing masks.

Our findings may contribute to the existing literature on the public perceptions of air pollution. Firstly, few empirical attempts that use large–scale survey data and concrete city–level data to systematically assess the determinants of public perceptions towards air pollution in China. This void in literature is peculiar, when it is considered that much research in other countries, especially developed countries, has emphasized that individuals' perceptions of air pollution are not correlated with actual air pollution. This study is possibly the first on systematically investigating the effects of macro–level factors on the public perceptions of air pollution in China. Secondly, prior studies in developing countries have predominantly focused on the impacts of individual characteristics, such as poverty, livelihood as well as environmental knowledge on the public awareness/concern of air pollution in China and other developing countries. By moving beyond such individual–level perspectives, our work analyzes the effects of environmental and political structural settings on the public perception of air pollution. Thirdly, high–level air pollution in developing countries may yield a "saturation" effects or baseline–condition effects that there is little variation in perceptions across social and demographic groups. Our findings suggest that increases in environmental transparency would be one solution to neutralizing such effects, and to build-up more accurate air pollution perceptions, thereby ultimately guiding the public to adopt pollution-averting activities and preventive actions for those residents living in heavily polluted cities of many developing countries. Fourthly, our work advances the socially constructive perspective established in developed countries by exploring the moderating effects of environmental transparency and discussing how environmental transparency helps citizens perceive air pollution closer to actual levels of air pollution and eventually generates accurate perceptions. Although the socially constructive perspective on explaining the public perceptions of air pollution in developed countries involves macro–level or a contextual factor i.e., embedded local knowledge, it fails to recognize the effects of political structural factors. For China, how to solve the contradiction between the localized environmental administration and the implementation of local environmental policy has becomes a major challenge faced by environmental management. Our work could not only be a starting point for further theoretical and empirical research on various contextual/structural factors on the perception of air pollution but also for other kinds of pollution in developing countries.

Besides, our study provides solid evidence supporting the reduction of air pollutants via a variety of scientific methods and the reforms of environmental information disclosure are equally important to air pollution governance in China and other developing countries. Since 2003, environmental protection has been ranked high on the agenda of Chinese governments. The GDP-based assessment criteria have been reformed. However, the execution of environmental information disclosure and institutionalization of the principles in related laws and regulations are still far from satisfaction, partly due to the fact that China is a country with a top–down government decision-making and a culture of state secrecy (Tan, 2014). A number of environmental experts and practitioners in China have attached importance to the functions that environmental transparency brings about to the whole society and regulation systems, i.e. co-production of environmental enforcement, monitoring the enterprises of pollution behaviors, legitimizing the environmental decision-makings, broadening political space to influence environmental policies, and realizing the environmental accountability of local governments (Johnson, 2014; Wang, 2016). While acknowledging the benefits aforementioned, the results of our study emphasize another desirable function that environmental transparency can be one of the most urgent solutions to make more accurate perceptions of air pollution.

The burgeoning influx of government information may not be automatically accessed and comprehended by the public because ordinary citizens may not be interested in reviewing and/or be professionally proficient in processing large amounts of government data, including budgets and policy files. It is, therefore, important to note that future transparency policy in developing countries, more than just providing more information to the public (Welch , Hinnant, &Moon, 2005) and the information released by the government, should be improved to be relevant or proactively customized to citizens' capacity, interests and preferences, be more responsive to the citizens' needs for information to improve their perceptions of environmental outcomes and be helpful in modifying citizens' life–styles and developing necessary pollution-averting activities.

Limitations do exist. Firstly, this study does not consider the variables of our interest to be culturally dependent, even within the same country. As Bush, Moffatt, and Dunn (2001b) argued, the public tend to be active in negotiation and critically evaluate such information, based on a wide range of cultural resources, including experiential and local knowledge. Future studies should explore the effects of cultural factors and conduct cross-cultural comparisons with qualitative approaches. Secondly, our research only studies the same-level interaction (level 2); however, some cross–level interactive effects (either moderating or mediating effects, or both) may exist based on multilevel regression models. Thirdly, this study only includes a limited number of individual characteristics and future studies may explore the differences in perceptions between rural and urban residents and compare regional differences in different localities in China and other developing countries. In fact, most of the population still resides in rural areas and these citizens may be more vulnerable to air pollution due to the lack of necessary knowledge, and environmental-related resource deprivation in developing countries. Future research should focus more on the perceptions of rural residents and compare these with those living in urban areas.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Notes

1. Due to the recent CSS2015 not including the questions about the public perceptions of air pollution, we use the CSS2013 in our analysis to systematically analyze the determinants of public perceptions towards air pollution. The dataset of CSS2013 covers 115 cities in China, including all four municipalities (Beijing, Tianjin, Shanghai and Chongqing), thirteen capital cities of provinces and autonomous regions (e.g. Hangzhou and Wuhan) and two sub–provincial cities in China (Xiamen and Ningbo). The remaining are prefectural–level cities. For further information, please refer to the website http://www.cssn.cn/sjxz/dcpt/dcxm/201312/t20131210_ 899020.shtml
2. The Institute of Public & Environmental Affairs (IPE) is a non-profit environmental research organization registered and based in Beijing, China. Since its establishment in June 2006, IPE has dedicated itself to collecting, collating and analyzing government and corporate environmental information to build a database of environmental information. For further information, please refer to the website http://wwwen.ipe.org.cn/about/DataServices.aspx for more information.

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TABLE CAPTIONS

TABLES

Variable	Obs	Mean	Std. Dev	Min	Max	Correlation	Level
PercepAirPollut	5,821	2.865	0.941	1	4	1	Individual
Gender (male = 1)	5,821	0.449	0.497	0	1	0.028*	Individual
Age	5,821	45.991	13.851	18	72	-0.139***	Individual
Education	5,812	3.536	2.024	1	9	0.254***	Individual
Health Satisfaction	5,806	6.777	2.251	1	10	0.032***	Individual
Income Status	5,806	3.696	0.905	1	5	0.023**	Individual
Internet Exposure	5,805	2.032	3.226	0	10	0.219***	Individual
PercepEnvKnow	5,805	2.645	0.802	1	4	0.126**	Individual
EnvTransp	62	31.911	12.695	8.3	65.9	-0.183***	City
Actual Air Pollution PM_{10} ($\mu g/m^3$)	62	109.134	40.221	45	305	0.117***	City
Actual Air Pollution SO_2 ($\mu g/m^3$)	62	41.491	21.222	11	105	0.063***	City
GDP per cap. (100 thousand per person)	62	6.604	4.762	1.009	29.063	0.127***	City

Note: The column "Correlation" denotes the correlation matrices between the perceived level of air pollution and other variables, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 1

Variable	Model 1 Null β (s.e.)	Model 2 PM_{10} β (s.e.)	Model 3 PM_{10} β (s.e.)	Model 4 SO_2 β (s.e.)	Model 5 SO_2 β (s.e.)
Fixed effects					
Gender (male = 1)		-0.025 (0.051)	-0.001 (0.053)	-0.001 (0.054)	-0.002 (0.053)
Age		-0.003 (0.002)	-0.002 (0.002)	-0.002 (0.002)	-0.002 (0.002)
Education		0.151 (0.017)***	0.132 (0.017)***	0.130 (0.017)***	0.131 (0.018)***
Health Satisfaction		-0.034 (0.012)***	-0.044 (0.013)***	-0.042 (0.013)***	-0.041 (0.013)***
Income Status (ref = 1)					
2		0.775 (0.476)	0.789 (0.484)	0.672 (0.500)	0.669 (0.499)
3		0.831 (0.467)*	0.849 (0.475)*	0.731 (0.491)	0.728 (0.491)
4		1.051 (0.468)**	1.067 (0.476)**	0.946 (0.492)*	0.942 (0.493)*
5		1.079 (0.469)**	1.085 (0.477)**	0.983 (0.494)**	0.978 (0.494)*
Internet Exposure		0.042 (0.011)***	0.040 (0.011)***	0.040 (0.011)***	0.040 (0.011)***
PercepEnvKnow (ref = 1)					
2		-0.064 (0.108)	-0.065 (0.108)	-0.061 (0.110)	-0.061 (0.109)
3		0.165 (0.107)	0.164 (0.107)	0.174 (0.108)	0.173 (0.107)
4		0.330 (0.126)***	0.330 (0.125)***	0.318 (0.127)**	0.319 (0.126)**
Actual Air Pollution		0.005 (0.001)***	0.005 (0.002)***	0.007 (0.003)**	0.007 (0.003)**
EnvTransp			-0.013 (0.006)**		-0.012 (0.007)*
Actual Air Pollution × EnvTransp			0.001 (0.000)*		0.003 (0.001) *
GDP per cap.(log)		0.159 (0.115)	0.160 (0.115)	0.142 (0.120)	0.163 (0.119)
Random effects					
Variance (constant)	0.695 (0.135)***	0.561 (0.093)***	0.562 (0.092)***	0.555 (0.132)***	0.555 (0.133)***
Cut point 1	-1.078 (0.095)***	0.302 (0.439)	0. 345 (0.558)	0.182 (0.576)	0.196 (0.575)
Cut point 2	0. 862	2.312	2.394	2.245	2.259

	(0.094)***	(0.440)***	(0.559)***	(0.577)***	(0.576)***
Cut point 3	2.328 (0.100)***	3.786 (0.441)***	3.889 (0.560)***	3.752 (0.578)***	3.766 (0.577)***
Log-likelihood	-7084.817	-6610.900	-6268.756	-6137.510	-6136.731
Observations	5,821	5,805	5,805	5,801	5,801
Number of groups	62	62	62	62	62

Note: (1) The Brant test indicates that the proportional odds assumption has not been violated ($\chi2$ = 9.53 and p = 0.069) for all predictors; (2) Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2

Ordered Responses	The Lowest Level of PM_{10}	The Highest Level of PM_{10}	The Lowest Level of SO_2	The Highest Level of SO_2
Outcome=1 *Not a problem at all.*	6.6%	21.9%	7.6%	14.2%
Outcome=2 *Not serious*	16.7%	31.7%	18.5%	26.9%
Outcome=3 *Somewhat serious*	44.3%	35.5%	44.8%	41.8%
Outcome=4 *An extremely serious problem*	32.4%	10.9%	29.1%	17.1%

Note: The other variables were set at the means.

Table 3

FIGURE CAPTIONS

Figure 1. Frequency Distribution of Perceptions towards Air Pollution

Figure 2. Concentration Distributions of Air Pollutants in 62 Cities

Figure 3. The Distributions of Environmental Transparency Index in 62 Cities

Figure 4. A Two–level Analytical Framework of Perceptions towards Air Pollution

Figure 5. The Moderating Effects of Environmental Transparency on the Actual–Perceived Air Pollution Relationship

FIGURES

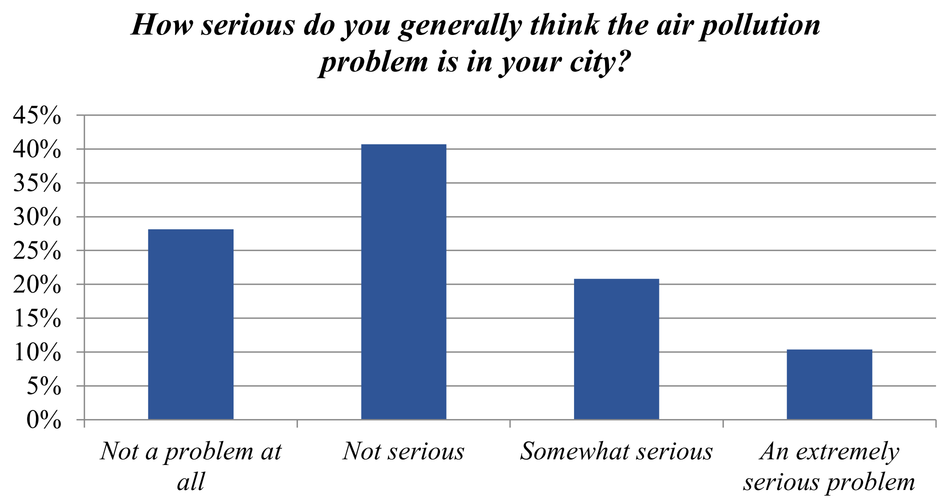
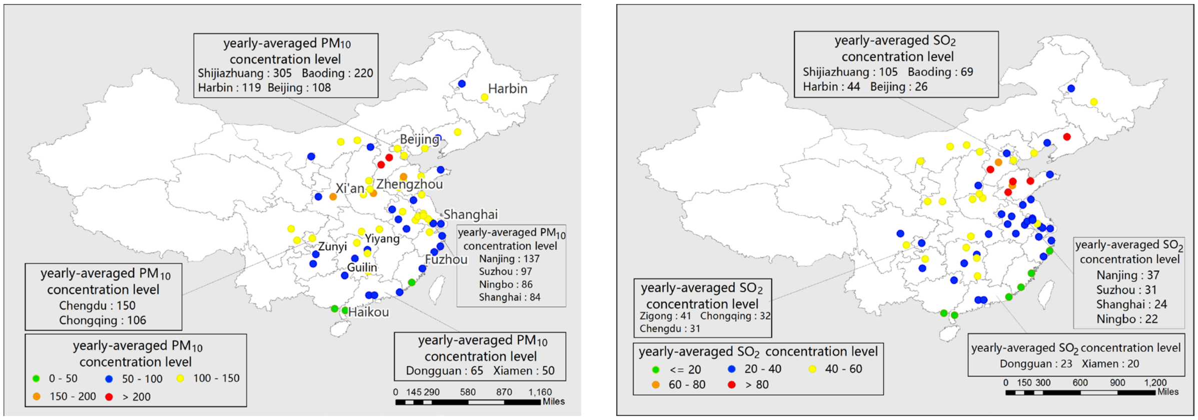
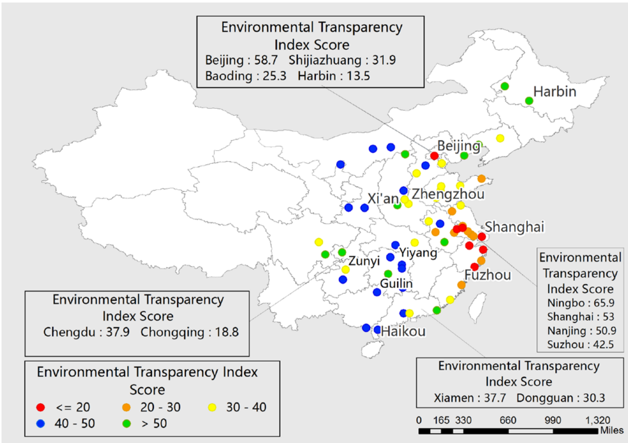


Figure 1



Note: Due to data availability of surveyed cities, 62 cities of yearly–average PM_{10} and SO_2 concentration levels are displayed in the figure



Note: Due to data availability of surveyed cities, 62 cities of environmental transparency index scores are displayed in the figure.

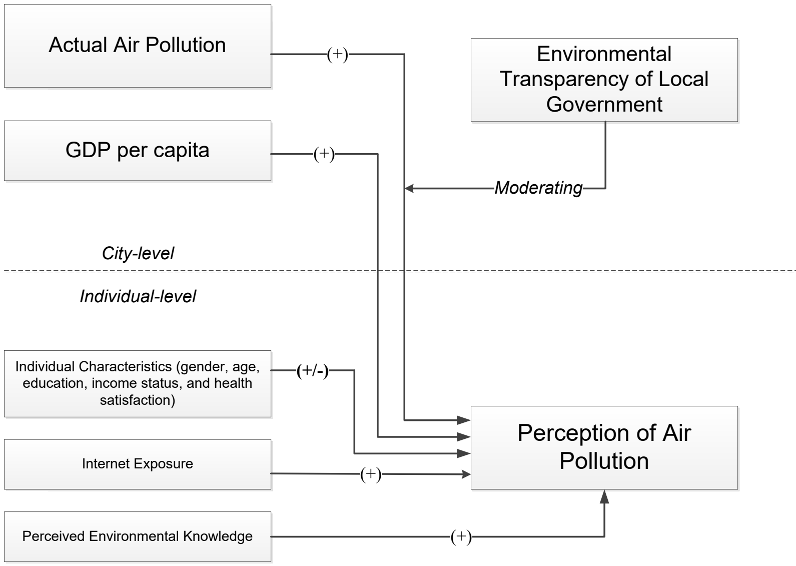
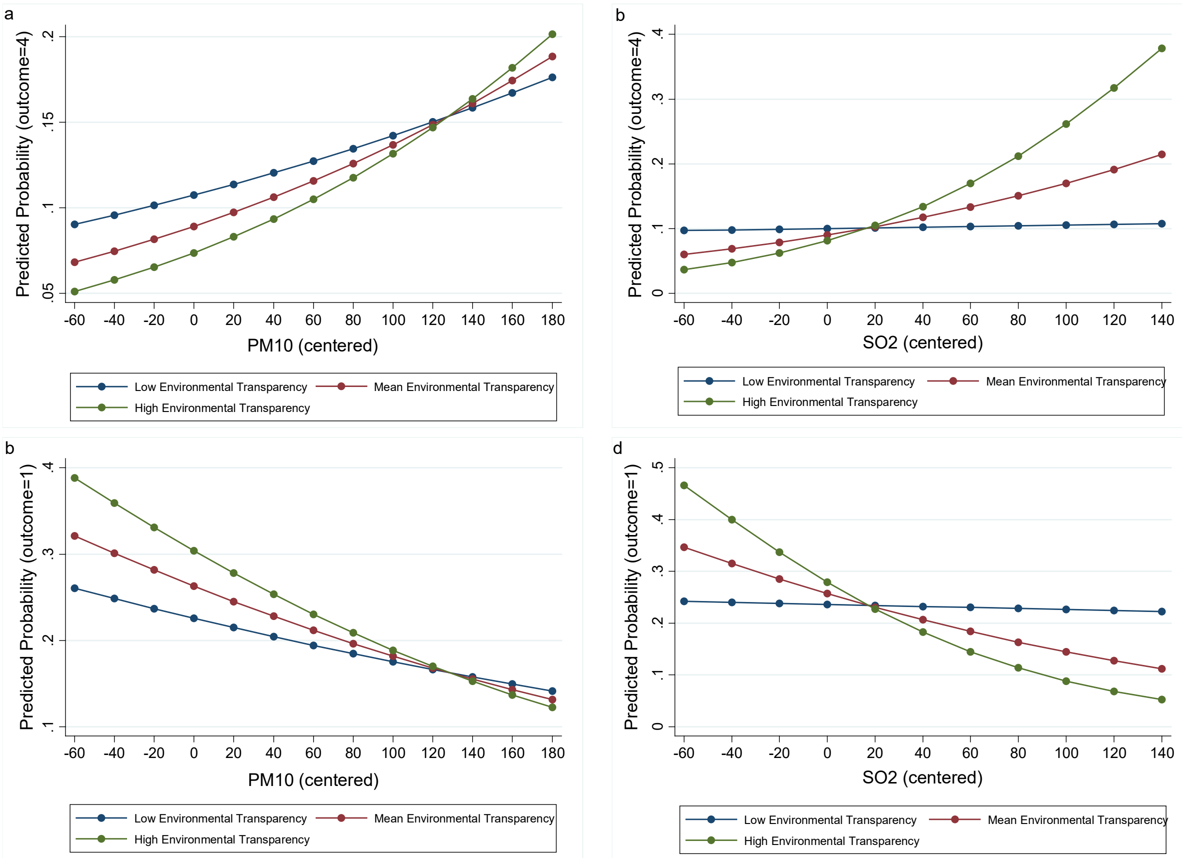

Actual Air Pollution
(+)
Environmental Transparency of Local Government
GDP per capita
(+)
Moderating
City-level
Individual-level
Individual Characteristics (gender, age, education, income status, and health satisfaction)
(+/-)
Perception of Air Pollution
Internet Exposure
(+)
Perceived Environmental Knowledge
(+)

Figure 4



Note: The other variables were set at the mean

Figure 5