Subjective and Objective Air Quality in Urban China: The Moderating Effect of Environmental Transparency

Liang Ma[1*] and Wenxuan Yu[2]

Abstract

Due to fast industrialization and sweeping urbanization in China, environmental pollutions have been jeopardizing China's economic and biological sustainability. Environmental pollutions have ignited public outcry and social unrest, which may undermine the ruling party's regime support and legitimacy. Citizen's political actions related to environmental degradation are largely determined by their perceptions of environmental pollutions, which are subjective and socially constructed. In this study, we use data from various sources (nationwide citizen survey, government statistics, and external assessments) and employ a multilevel modeling strategy to empirically explore the antecedents of citizens' perceptions of air quality. We examine to what extent objective air quality and environmental information availability (transparency) jointly affect citizens' perceptions of air quality. After controlling for a variety of confounding variables, we find that subjective air quality is positively related to objective air quality and environmental transparency negatively moderates this relationship. The findings generate significant theoretical and practical implications for environmental policy, government performance measurement, and transparency.

Keywords: environmental pollution, air quality, China, subjective performance measurement, government transparency

Calidad del aire subjetiva y objetiva en la China urbana: el efecto moderador de la transparencia ambiental

Resumen

Debido a la rápida industrialización y urbanización radical en Chi-

[1] *School of Public Administration and Policy, Renmin University of China*

[2] *School of Public Affairs and School of Public Policy, Xiamen University, China*

[*] *Corresponding author:* liangma@ruc.edu.cn

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na, la contaminación ambiental ha estado poniendo en peligro la sostenibilidad económica y biológica de China. La contaminación ambiental ha provocado indignación pública y malestar social, lo que puede socavar el apoyo y la legitimidad del régimen del partido gobernante. Las acciones políticas de los ciudadanos relacionadas con la degradación ambiental están en gran medida determinadas por sus percepciones de las contaminaciones ambientales, que son subjetivas y socialmente construidas. En este estudio, utilizamos datos de varias fuentes (encuesta nacional de ciudadanos, estadísticas gubernamentales y evaluaciones externas) y empleamos una estrategia de modelado multinivel para explorar empíricamente los antecedentes de las percepciones de los ciudadanos sobre la calidad del aire. Examinamos hasta qué punto la calidad del aire objetivo y la disponibilidad de información ambiental (transparencia) afectan conjuntamente las percepciones de los ciudadanos sobre la calidad del aire. Después de controlar una variedad de variables de confusión, encontramos que la calidad subjetiva del aire se relaciona positivamente con la calidad objetiva del aire y la transparencia ambiental modera negativamente esta relación. Los hallazgos generan importantes implicaciones teóricas y prácticas para la política ambiental, la medición del desempeño del gobierno y la transparencia.

Palabras clave: contaminación ambiental, calidad del aire, China, medición del desempeño subjetivo, transparencia gubernamental

中国城市主客观空气质量：环境透明度的调节效应

摘要

由于中国的快速工业化和大规模城市化，环境污染已经威胁到中国的经济和生物可持续性。环境污染已经激发公众抗议，引起社会动荡，这可能会损坏执政党的政权支持力度和合法力度。公民关于环境退化所开展的政治行动在很大程度上取决于他们对环境污染的看法，而这一看法是由主观的和社会建构的。在本项研究中，笔者使用不同来源的数据(全国公民调查、政府统计和外部评估)，并采用多层建模策略对于公民对空气质量的看法成因进行了实证研究。笔者基于客观空气质量和环境信息获取(透明度)在多大程度上共同影

响公民对空气质量的看法进行了探索。在对各种混杂变量进行控制后，笔者发现主观空气质量与客观空气质量呈正相关，而环境透明度对此关系有负向调节作用。该项研究结果对环境政策、政府绩效衡量和透明度产生了重大的理论和实践意义。

关键词：环境污染，空气质量，中国，主观绩效衡量，政府透明度

Introduction

Due to fast industrialization and sweeping urbanization in China, environmental pollutions have been jeopardizing China's economic and biological sustainability. Environmental pollutions have ignited public outcry and social unrest, which may undermine the ruling party's regime support and legitimacy. Citizen's political actions related to environmental degradation are largely determined by their perceptions of environmental pollutions, which are subjective and socially constructed. Existing studies on air pollution in China in social sciences, however, are mainly conducted by ecologists and economists, considering air pollution as independent variables and using objective air quality indicators from government archives to examine its impacts on public health, happiness, life satisfaction, and political actions such as social protest and emigration (e.g., Qin and Zhu 2018; Smyth, Mishra, and Qian 2008; Wang and Cheng 2017). With few exceptions (Li and Xue 2016; Shi 2015), studies on perceived environmental pollution in China are lacking.

Citizens' perceptions of air quality are a social and psychological construct, jointly influenced by environmental pollution and information availability. The objective measurement and subjective perception of air pollution are conceptually different and empirically discernable, and it is of theoretical relevance and policy importance to examine the discrepancies between subjective and objective environmental quality. A recent study reveals that perceived government's efforts in addressing environment issues significantly influence residents' environmental perceptions in a coal-mining region in northern China. Controlling for government efforts, however, objective environmental indicators do not significantly impact subjective environmental perceptions (Shi 2015).

In this study, we focus on one of the government efforts in addressing environmental pollution, information transparency. Environment transparency is considered as an essential part of global environmental governance (Gupta 2010). It is believed that environmental transparency can protect individuals from environmental harms, enhance environmental enforcement, and facilitate social learning (Li and Li 2012). Environmental transparency is one of the most important policy tools the central government is using to monitor and evaluate the performance of local governments in environmental protection so as to enforce environment laws and regulations.

Given the importance of subjective measures of public services and government performance in public administration research (Schachter 2010; Shingler, Van Loon, and Alter 2008), we aim to examine two research questions with significant theoretical and practical implications:

(1) To what extent do people's perceptions of air quality reflect the authentic air quality measured by government hard data in China?

(2) What policy instruments government can take to influence people's perceptions of air pollution?

In this study, we use data from various sources (nationwide citizen survey, government statistics, and external assessments) and employ a multilevel modeling (MLM) strategy to empirically explore the antecedents of citizens' perceptions of air quality. Specifically, we examine to what extent objective air quality and environmental information availability (transparency) jointly affect citizens' perceptions of air quality. After controlling for a variety of confounding variables, we find that subjective air quality is positively related to objective air quality and environmental transparency negatively moderates this relationship. The findings generate significant theoretical and practical implications for environmental policy, government performance measurement, and transparency.

The remainder of this article is structured as follows. First, we discuss the relationship between objective air pollution and subjective perceptions of air quality. Second, we review the environmental transparency literature, discussing how environmental transparency in China would influence subjective air pollution. Third, we report our data collection and research methods. Fourth, we present and discuss our findings. Lastly, we conclude with theoretical and policy implications, limitations, and future research avenues.

Context

Air Pollution in China

Since China's "Reform and Open-up" policy in the late 1970s, China has achieved stunning economic achievement. In 2010, China overtakes Japan as World's No. 2 economy. China is also experiencing unprecedented urbanization. In 2015, more than 55.6 percent of Chinese lived in urban area (CIA World Factbook 2017). It is no doubt that economic development and urbanization have drastically improved Chinese people's economic income and quality of life. However, similar to other developing countries such as India, China is also experiencing devastating environmental pollutions (Albert and Xu 2016). China has 16 of the world's 20 most polluted cities (World Bank 2007), and environmental pollutions have already become one of the most pressing threats to China's economic sustainability and social harmony.

According to an estimate of China's Ministry of Environmental Protection (MEP) in 2010, environmental pollution costs China around 1.5 trillion RMB (227 billion U.S. dollars), or roughly 3.5 percent of its gross domestic product. Not only does environmental pollution thwart economic development, environmental pollution also produces detrimental effects on public health. Studies estimate that around 11 percent of digestive-system cancers in China may stem from unsafe drinking water (He, Fan, and Zhou 2016). A recent study shows that air pollution has caused significant health consequences, including respiratory, cardiovascular, and cerebrovascular diseases, in northern China since the 1980s (Chen et al. 2017).

Among various types of pollution, air pollution has produced most visible negative economic, social, and political impacts. Air pollution has led to social unrest and collective actions, threating political trust, and undermining legitimacy (Albert and Xu 2016). Air pollution has pushed people to migrate or emigrate (Qin and Zhu 2018). Therefore, fighting again air pollution has become one of the top priorities of the central government. Local governments have also been mobilized to fight against haze. After a lasting period of "airpocalypse" in Beijing in 2013, for instance, a senior Beijing municipal government official vowed on his own head to control the choking haze.

However, Chinese government is facing tremendous challenges in addressing air pollution issues due to various reasons. First, air pollution in China is a "wicked problem" (Rittel and Webber 1973). The components and the causes of air pollution are very complex due to China's large territory and vast differences in demographic, geographic, economic, and industrial characteristics among regions.

In the past four decades, China has experienced unprecedented fast industrialization and urbanization. However, China's economic growth heavily relies on the consumption of natural resources, energy, and cheap human labor. Due to the scarcity of other natural resources and technology deficiency, coal is still the dominant source of energy (Zhang and Crooks 2012). China is the largest coal producer in the world and produces around half of global consumption (Bawa et al. 2010). Although China's National Energy Agency claimed that coal use had been declining, international observers doubted the claim because of the increased coal power plant capacity in 2015 (Albert and Xu 2016). In the past 20 years, car ownership has skyrocketed with the fast urbanization. In 2016, China has 172 million cars (Xinhua 2016). Rapid urbanization and car ownership significantly increase energy consumption and emissions, which in turn jeopardize air pollution (Liu and Diamond 2005).

Second, air pollution is the most visible pollution, and its threat to economic sustainability and public health is equivalent to (if not higher than) other type of pollutions (e.g., water and soil). Due to its visibility, however, public complaints and outcry distract government attention from addressing other more serious environmental challenges. Also, government takes fragmented, campaign-style, and short-term superficial measures instead of holistic and fundamental strategies to address air pollution (Dasgupta and Wheeler 1997; Dong et al. 2011).

Last but not the least, curbing air pollution is a double-edged sword. Air pollution is the consequence of China's fast industrialization and economic development. On the one hand, Chinese people are the victim of air pollution; on the other hand, they are also the beneficiaries of fast economic development. Studies found that Chinese believe economic development is more important than environmental protection and such attitudes are rooted in the nation's long history of poverty, resulting in strong desire for material wealth (Harris 2006). China's environmental pollution is deeply intertwined with other problems related to industrial structure, energy consumption structure, and the model of economic development. China still has a long way to go in curbing environmental pollution.

In addition, how Chinese people perceives air pollution is further complicated by the fact that the causal mechanisms between air pollution and health consequences are ambiguous, and the negative effects of air pollution on public health are often long term and chronical (Holdaway 2013). Moreover, previous environmental studies suggest that demographic characteristics such as age, gender, education, residence, and social economic status may also influence people's environmental perceptions (Daneshvary, Daneshvary, and Schwer 1998; Ebreo, Hershey, and Vining 1999; Howell and Laska 1992; Xiao and Hong 2010). Therefore, it is more meaningful to study how Chinese people's perceptions of air pollution affect their political attitudes and actions than studying the static and "objective" air quality indicators.

Environmental Transparency

The central government has considered environmental pollution as its top policy priority due to the devastating and detrimental effects of environmental pollution on environmental sustainability, public health, and political trust and legitimacy (Economy 2010). However, the implementation of environmental protection policy is largely thwarted by China's unique political system characterized by fragmented and decentralized authoritarianism (Lieberthal 1997). Local functional departments and environmental departments need to report to and under the control of both central and local governments. The fragmented and decentralized power of environment protection challenges the efforts of the central government in striking a balance between economic development and environmental protection (Tan 2014).

Given the importance of people's perceptions of air pollution and the difficulties of addressing the "wicked problem" in the short run, it is crucial to manage subjective air quality apart from actually improving air quality.

As a policy tool to break the deadlock, Chinese central government has given high hope to environmental transparency. The Regulations on Open Government Information was enacted by the State Council in 2007 and took effective in 2008. According to the Regulations, governments are required to disclose public information and citizens are entitled to request government information. Almost at the same time, The National Bureau of Environmental Protection (the predecessor of Ministry of Environmental Projection, MEP) promulgated the Measures on Open Environmental Information (OEI) in 2008 to mandate local environmental protection bureaus (EPBs) to disclose environmental information.

For individual citizens, environmental transparency can educate citizens to realize the importance of environmental sustainability and proactively take measures to protect themselves from pollution. Pollution is more than a pure objective fact. It is actually social constructed. The definition of pollution changes with people's understanding of the causes and consequences of environmental changes. With more environmental information, the public is informed and educated to understand the consequences of economic growth and development so as to make an informed decision to adjust their expectations toward pollution. Their attitudes or behaviors would change accordingly. In China's unique historical and cultural context characterized by government secrecy, disclosing environmental information to the public exhibits government's genuine wiliness and commitment in constraining corruption and abuse of power and controlling pollution (Yu 2011).

In China, due to the lack of a vibrant civil society, government monopolies environmental information provision. However, citizens themselves can also acquire information from other channels (Fung, Graham, and Weil 2007). When government information is absent, information from other sources would significantly influence their perceptions on government performance in a way government may not like. In 2009, the U.S. Embassy in Beijing began to provide air quality information to its employees and American expatriate due to the frequent appearance of choking haze. The publicity of air quality assessment went viral in social media. After accusing the Embassy for intervening China's internal affairs, the MEP was forced to release air quality information. However, the continuous inconsistence between the two data sources further jeopardized public confidence and trust in the MEP (Ma and Zhang 2015). What is even worse is that the information released by government and other sources (including citizens themselves) is inconsistent or mutual conflicting, which may result in citizens' discontent and distrust toward government.

Theoretical Hypotheses

Objective and Subjective Air Quality

In public administration literature, since 1970s, a stream of literature has examined the congruence between objective and subjective performance indicators (Miller and Miller 1991). Due to the differences in conceptualization, measurement, and model specification, the debate has continued and research findings are mixed. A stream of studies tries to empirically show that subjective government performance are influenced by individual demographic characteristics such as gender, age, education and race, and individual use experience and expectation (Brown and Coulter 1983; Stipak, 1979, 1980; Swindell and Kelly 2000; Van Ryzin and Immerwahr 2008).

Stipak (1979) argued that many public services are rarely used by citizens. The relationship between subjective indicators and objective indicators is confounded by many statistical problems. Brown and Coulter (1983) empirically explored the relationship between residents' perceived police performance (e.g., policy response time, police treatment of people, and police service quality) and corresponding objective indicators, finding that subjective indicators are not significantly related to objective indicators. However, other scholars disagreed that previous studies have various methodological problems. At least in public service areas such as park maintenance and street cleaning, if outcome-oriented objective indicators and a more scientific research design are adopted, subjective and objective indicators are significantly related, which means that citizen's perception of government performance can reflect government genuine performance (Andrews et al. 2011). Using New York public school data, Charbonneau and Van Ryzin (2011) found that parents' subjective assessment of education quality corresponds fairly well with objective school performance measures.

Proving public goods and service, and regulating market are two essential functions of government. Air is a pure public good. Without government regulation, due to air pollution's externality and spillover effects, "the tragedy of commons" takes place (Burger and Gochfeld 1998). Air quality is considered as a sign of government regulatory capacity and an essential indicator of government performance (Holzer and Yang 2004). Different from other public services such as park and library; nobody can escape from enjoying the "service." Air pollution is highly sensible and visible. However, it does not necessarily mean subjective perceptional measures are reliable in measuring air quality.

Perception of air pollution is socially constructed by individuals and societal characteristics, as well as their interactions (Li and Li 2012). Human body is an adaptive system, and long-time exposure to pollution could change the psychological and biological formula for evaluating air quality. Objective measures of air pollution are based on a universal set of scientific measures according to a set of universal scientific "truth" of public health. In contrast, regular people do not have professional equipment and knowledge to detect air quality. In addition to their personal experience, their perception of air quality is highly influenced by information provided by mass media and social media (Liu, Dong, and Wang 2011). Therefore, visible and sensible experience of residents is based on but not equivalent to the objective level of air quality.

Hadrich and Wolf (2011) studied the environmental pollution by Michigan's livestock operations and citizen complains. They found that compared with surface water pollution, odor pollution was more difficult to be verified. In China, although after the 2013 pandemic air pollution in Beijing, the municipal government had promised to clean the air, in the summer of 2016 local dwellers' complaints on the hovering haze raged the social media, blaming government's incompetence and inaction. However, according to objective scientific data, air quality in Beijing has significantly improved over years. In order to establish the significant relationship between objective and subjective air quality, we need empirical studies based on solid data, representative sample, and rigorous research design. Although there are no empirical studies specifically testing the relationship, some research on citizen environmental complaints and environmental pollution found that citizens' complaints are significantly related to air pollution (Dasgupta and Wheeler 1997; Dong et al. 2011). Therefore, we develop the first hypothesis as below.

Hypothesis 1: Subjective air quality significantly correlates with objective air quality.

The Moderating Effect of Environmental Transparency

In addition to the influence of objective air pollution, subjective air pollution could also be affected by their expectation, knowledge, information availability, and political attitudes, which are influenced by environmental transparency. Transparency refers to the availability and usability of government information to the public, and it is subtly different from openness and information disclosure (Wu, Ma, and Yu 2017). Openness means the disclosure of government information, which might not be equivalent to transparency. For instance, government may discretionarily and selectively disclose some information while keep others (e.g., politically sensitive data) opaque. Government may also purposely distort and manipulate the information disclosed to the public. Transparency, in contrast, means government information is not only disclosed and available to the public, but also citizens can access, understand, interpret, and use the information for private or public purposes (Fung, Graham, and Weil 2007).

Transparency is not only about the disclosure and use of government information, but also reflects the motivations and capacities of the government in addressing air pollution. Given the professionalism of air quality monitoring, the information on air quality is to some extent controlled by the government. Whether citizens can get access to and utilize this information partially depends on government interventions, and local governments who are willing to disclose and share environmental information are favorably supported by citizens. If local governments can honestly disclose environmental information and proactively adopt policies to address environmental pollution, then citizens are more likely to support their policies. Despite environmental pollution might not be substantially reduced, citizens will tolerate their sluggish improvement and perceive environmental quality in a more lenient way.

We argue that citizens' perception of air quality is positively related to objective reading of air quality, and environmental transparency moderates this relationship. Specifically, we expect that the objective–subjective air quality relationship will be attenuated when the level of environmental transparency is higher. Recent studies have consistently found that transparency moderates the relationship between people's perceptions of government performance and other social phenomena such as corruption (Park and Blenkinsopp 2011) and social equity (Wu, Ma, and Yu 2017). Given these considerations, we develop our second hypothesis as follows.

Hypothesis 2: Environment transparency negatively moderates the relationship between subjective and objective air quality, and the relationship is weaker when environmental transparency is higher.

Methods

Sample and Data

We use recent large-scale citizen survey data and external assessments in over 30 Chinese largest cities to empirically examine the interaction effects of objective air quality and environmental transparency on citizens' subjective air quality. We test the two hypotheses by using multisource data from 32 largest cities in China. The sample covers four municipalities (Beijing, Tianjin, Shanghai, and Chongqing), 22 provincial capital cities (e.g., Guangzhou and Hangzhou), five subprovincial cities (Dalian, Qingdao, Ningbo, Xiamen, and Shenzhen), and one prefecture-level city (Suzhou). The administrative structure in China consists of five layers, and cities are at the first three layers (provinces, prefectures, and counties). There are 15 prefecture-level cities granted with subprovincial authorities by the central government, and 10 of them are provincial capital cities (e.g., Harbin and Xi'an). The sample of cities is comparable in administrative ranks while heterogeneous in geography and socioeconomic development. The 32 largest cities are frequent research subject for urban management scholar in studying China (Smyth, Mishra, and Qian 2008).

Data on citizens' perceived air quality are from the 2011 Lien Chinese Cities Service-Oriented Government Survey, which telephone interviewed over 25,000 residents in 32 largest cities by Computer Assisted Telephone Interviewing (CATI) method according to a stratified sampling framework. In each city, 700 residents were interviewed, except for megacities like Beijing and Shanghai, in which 1,000 residents were surveyed. Data on the government information disclosure of air quality (environmental transparency) are from IPE's independent assessment (Lorentzen, Landry, and Yasuda 2014). As IPE did not cover Haikou, our final number of observation is 31 cities. In addition, we collect archival data from the statistics of MEP to measure air quality and other city-level variables.

Dependent Variable

One 10-point Likert scale item is used to gauge the respondents' subjective perceptions of air quality. The respondents were asked to rate their perceptions of air quality in the cities where they live. In the survey, 1 refers to the worst while 10 means the best. Although single-item measure is one of the limitations of this study, it is appropriate to capture respondents' overall assessment of air quality. Roughly 50.5 percent of the respondents scored higher than 6, which is in congruence with the 2010 MEP citizen survey.

Independent Variables

Prior studies on the effect of air quality on life satisfaction usually use annual mean concentration levels or amount of emission per capita of air pollutants (e.g., sulfur dioxide, SO_2) as the key measures of air pollution (Luechinger 2009; Smyth, Mishra, and Qian 2008). We measure urban air quality by yearly averaged pollutant concentration indicators reported by the MEP. The key air pollution indicators include SO_2, nitrogen dioxide (NO_2), and particulate matters (PM_{10}), all measured by milligram per cubic meter (mg/m^3). As of 2011, the data on $PM_{2.5}$ were unavailable in most cities and we cannot assess whether it correlates with public satisfaction with air quality.

To take all air pollutants into account, we also use an umbrella measure to gauge air quality. We use the proportion of monitored days of air quality equal to or above national secondary standard (grade II) in the whole year (percent). The MEP classifies cities into three grades according to the national air quality standards (air quality index, AQI), with higher grades (e.g., grade I) denoting better air quality. The variable is coded as a dummy, since all sampled cities are either in the status of grade II (0) or grade III (1). Air quality fluctuates seasonally and it is appropriate to concentrate on the period when we collect our survey data. We use the average air pollution measures in the first half of the year,[1] since the survey was conducted from April to August 2011.

IPE developed the Urban Air Quality Information Transparency Index (AQTI) to rate cities' performance in air quality information disclosure (IPE 2012). The initial version of AQTI released in 2010 assessed 20 Chinese cities (e.g., Beijing, Shanghai, Guangzhou) and compared their performance

1 MEP, Air quality of key environmental protection cities in the first half year of 2011, July 22, 2011, http://www.mep.gov.cn/gkml/hbb/bgg/201107/t20110730_215576.htm (accessed January 18,

with those of 10 international cities (e.g., New York, Paris). The 2012 version of AQTI ranked 113 Chinese cities monitored by the MEP as National Key Environmental Protection Cities. The MEP monitors 10 air pollutants (e.g., PM_{10}, $PM_{2.5}$, SO_2, NO_2, and so forth), and their availability, completeness, promptness, and user-friendliness on urban EPBs' websites were assessed. The air pollutants were weighted by potential health impacts and environmental management practices. The total score of AQTI ranges from 0 to 100 points, and higher scores refer to higher levels of environmental transparency.

IPE also developed the Pollution Information Transparency Index (PITI) to assess environmental transparency of urban EPBs (IPE and NRDC 2009). PITI evaluated the performance of EPBs' online disclosure of pollution-intensive enterprises, clean production, environmental impact assessment, and other pollution-related information. In this article, we use AQTI and PITI to measure municipal governments' environmental transparency.

Control Variables

Individual-level variables such as gender, age, education, and income that may affect people's subjective air quality are included in the model. Gender as a dummy is coded as 1 for male and 0 female. Age is measured by an ordinal variable ranging from 2 (18–29) to 6 (above 60). Education is denoted by an ordinal variable with four categories, ranging from 1 (primary school or below) to 6 (master's degree or above). Monthly income is gauged similarly by an ordinal variable ranging from 0 (no fixed income) to 14 (above 30,000 RMB Yuan).

The demographics of the respondents are similar with the latest census data and our sample is largely representative of the population of the sampled cities. In the sample, 45.19 percent of respondents were female, and 55.89 percent had college and above degrees. The majority of the respondents (45.89 percent) aged between 18 and 29, and those older than 60 accounted for 7.59 percent. In the sample, 62.84 percent of the respondents earned monthly income below 3,000 RMB Yuan, whereas rich residents with income above 6,000 RMB Yuan only accounted for 8.30 percent.

Analytical Methods

As our data structure is nested or multilevel (individual citizens nested in cities), we adopt MLM to test our hypotheses. MLM is preferable to estimate variances at multiple levels. In the model, individuals are at Level 1 while cities are at Level 2. MLM can simultaneously estimate the variances at both Levels 1 and 2 (Raudenbush and Bryk 2002). We center Level 1 predictors within the cluster (group mean centering) and center Level 2 predictors by grand mean centering, which is appropriate to estimate the same-level and cross-level moderating effects in MLM (Enders and Tofighi 2007).

In order to test our two hypotheses, we need to estimate the moderating

2013)

effects of Level 2 variables (environment transparency) on the relationship between Level 2 independent variable (objective air pollution) and Level 1 dependent variable (subjective air quality). The first case is referred to the moderating effects at the same level (*means as outcomes* model) while the other case is cross-level (*slopes as outcomes* model). We follow standard procedures to detect moderating effects in MLMs and probe graphically, which enables us to intuitively interpret the results (Preacher, Curran, and Bauer 2006). Varying-intercept model is used to estimate the direct effects while varying-intercept, varying-coefficient model is used to estimate the moderating effects.

Results

Descriptive Statistics

Table 1 reports the descriptive statistics of our key variables. It reveals that the sampled cities vary substantially in objective air pollution indicators. Air grade in 14 sampled cities (or 43.75 percent) was rated as III, with the other 18 cities graded as II. Environmental transparency varies drastically across sampled cities with AQTI scores ranging from 9 to 76 and PITI scores between 23.2 and 83.7.

Table 1. Descriptive Statistics and Correlation Matrices

Variable	Observations	Mean	Std. Dev.	Min	Max	Correlation
Air quality satisfaction	25,139	6.328	2.075	1	10	1
SO_2	32	0.039	0.014	0.007	0.062	−0.0989*
NO_2	32	0.044	0.012	0.015	0.064	−0.0815*
PM_{10}	32	0.094	0.022	0.044	0.145	−0.182*
Air grade (III=1)	32	0.438	0.504	0	1	−0.153*
AQTI	31	32.355	19.607	9	76	−0.096*
PITI	31	50.555	17.216	23.2	83.7	−0.0051
Gender (male=1)	25,222	0.548	0.498	0	1	−0.0119
Age	24,939	3.069	1.260	2	6	0.117*
Education	24,988	3.712	1.250	1	6	−0.0438*
Income	23,595	3.348	2.780	0	14	−0.0464*

Note: The last column denotes the correlation coefficients between air quality satisfaction (the dependent variable) and all independent variables. *p<0.05.

The last column in Table 1 shows the correlations between our independent variables and the dependent variable. The results suggest all air pollutants are negatively associated with air quality satisfaction and statistically significant at the 0.05 level. The measures of environmental transparency are both negatively correlated with subjective air quality measures, albeit only the correlation coefficient of AQTI is statistically significant. In addition, we find that age, education, and income of respondents are significant antecedents of subjective correlation, while gender is not significant.

We graphically plot the relationship between subjective and objective air quality measures in Figure 1. The distribution of sampled cities in the plot implies that objective air pollution is negatively related to subjective air quality. For instance, Haikou emitted least SO_2 among 32 sampled cities (0.007 mg/m^3), and its subjective perception was also highest (8.06 out of 10). In contrast, the midyear emission of SO_2 in Taiyuan was among the highest group (0.062 mg/m^3) and its subjective air quality was relatively low (5.02). There are also some outliers, however, owing to idiosyncratic geographical and socioeconomic characteristics. Coastal Qingdao had a slightly higher concentration of SO_2 (0.059) than inland Lanzhou (0.052), but Qingdao was top in subjective air quality (7.644) while Lanzhou is at the bottom (4.103), mostly because of Qingdao' coastal advantage to quickly disperse air pollutants. Another potential explanation is that subjective air quality measures are influenced by multiple sources of air pollutants. Although Qingdao and Lanzhou were similar in the concentration of SO_2 and NO_2, Qingdao' PM_{10} emission (0.092 mg/m^3) was much lower than Lanzhou

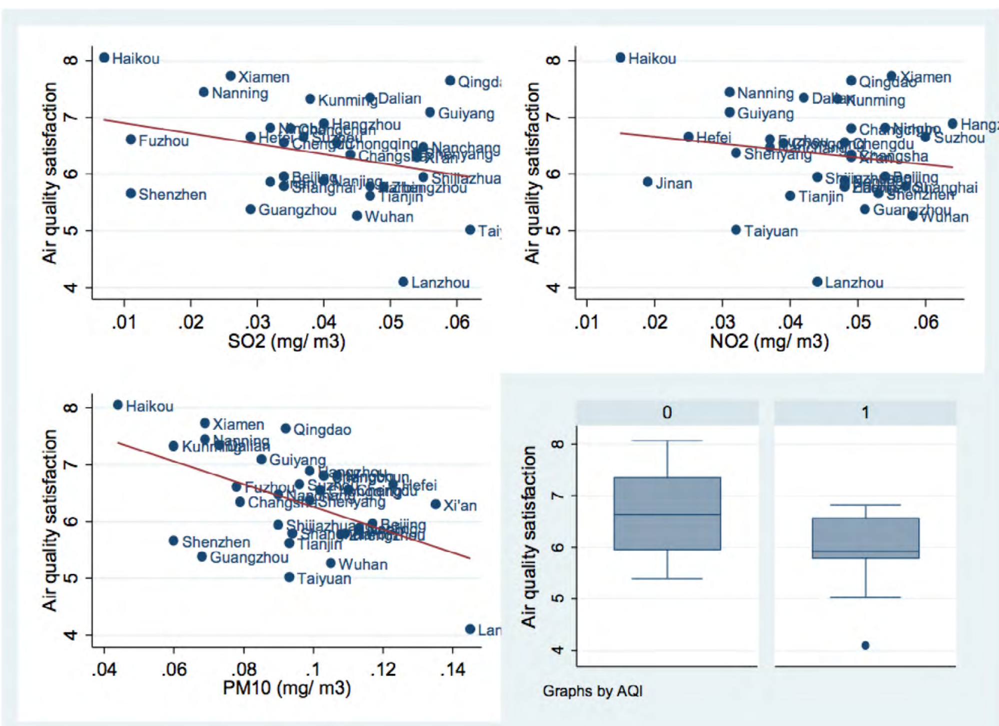

Figure 1. The relationship between objective and subjective air quality measures

(0.145 mg/m[3]). PM_{10} is one of the most visible air pollutants that often lead to citizen complaints.

Multilevel Model Estimations

We report MLM regression results for both direct and interaction effects of our independent variables (see Table 2). In the first column, the null model with no predictors suggests that 16.39 percent (interclass correlation (ICC) = 0.712/(0.712 + 3.633)) of total variances in air quality satisfaction could be attributable to Level 2 predictors. The explanatory power of Level 2 predictors is remarkably strong, particularly if we consider the small sample size (*N*=32) at Level 2 compared with large sample size at Level 1 (*N*=25,139) (Raudenbush and Bryk 2002). Actually, the impressive ICC, 0.1639, implies that residents nested in each sampled city have very similar perception on the air quality in the city. This finding implies that subjective air quality may significantly correlate with objective air quality. But, whether subjective and objective air quality are correlated need further investigated while controlling other variables. Although the variance at Level 2 (0.712) is statistically insignificant, it is substantially different from the standard error (0.179), suggesting it is essential to use MLM to estimate our models.

In the rest columns of Table 2, we sequentially enter our key independent variables and moderating variables. The results show that Level 2 air pollutants do have statistically significant effects on subjective air quality. When SO_2 is used as air pollution measure in Model 2, its regression coefficient is negative and significant ($\beta=-18.37$, $p<0.10$) and statistically significant at the 0.10 level. In Model 5, NO_2 is used to gauge air pollution, and we find that its effect is negative albeit insignificant ($\beta=-12.14$, $p>0.10$). Both PM_{10} in Model 8 and air grade in Model 11 have significantly negative effects on subjective air quality ($\beta=-19.98$, $p<0.01$; $\beta=-0.73$, $p<0.01$). In a nutshell, our results suggest that Hypothesis 1 is partially supported and objective air quality is one of the key antecedents of subjective air quality.

We report the results on the moderating effects test in Table 2. Most of our interaction terms are statistically significant and consistent with our hypotheses, and therefore, Hypothesis 2 is partially supported. In Model 3, AQTI has insignificant effect on subjective air quality and its interaction term with objective air pollution (herein SO_2) also has little effect of substance ($\beta=0.10$, $p>0.10$). The insignificant effect of AQTI can be attributable to its substantial change over the short term after MEP mandated EPBs to release air quality information, which shrank cities' disparities in transparency (IPE 2012). When we turn to Model 4 with PITI as our moderator, we find its interaction term with air pollution have significantly positive effect on subjective air quality ($\beta=1.51$, $p<0.05$).

The moderating effect of environmental transparency on the relationship between NO_2 and subjective air quality was not supported by using

Table 2. Multilevel Model Estimates

Model	1	2	3	4	5	6	7	8	9	10	11	12	13
Pollution variable		SO_2			NO_2			PM_{10}			Grade		
Moderating variable			AQTI	PITI		AQTI	PITI		AQTI	PITI		AQTI	PITI
Fixed effects													
Pollution		−18.37*	−21.40*	−19.73*	−12.14	2.06	−3.73	−19.98***	−19.87***	−15.22**	−0.73***	−0.64***	−0.64**
		(10.28)	(12.12)	(11.35)	(12.80)	(16.59)	(14.06)	(5.85)	(5.44)	(6.03)	(0.27)	(0.24)	(0.26)
Transparency			−0.01	0.00		−0.00	0.01		−0.01	−0.00		−0.02**	−0.01
			(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)		(0.01)	(0.01)
Interaction			0.10	1.51**		−0.97	−1.31		0.80***	0.83**		0.03**	0.02
term			(0.57)	(0.60)		(1.13)	(0.96)		(0.25)	(0.33)		(0.01)	(0.02)
Gender		−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03	−0.03
(male=1)		(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Age		0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Education		−0.02**	−0.03***	−0.03***	−0.02**	−0.03***	−0.03***	−0.02**	−0.03***	−0.03***	−0.02**	−0.03***	−0.03***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Income		−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***	−0.03***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Constant	6.37***	6.37***	6.35***	6.47***	6.37***	6.41***	6.39***	6.37***	6.38***	6.40***	6.69***	6.59***	6.64***
	(0.15)	(0.14)	(0.15)	(0.14)	(0.15)	(0.18)	(0.15)	(0.13)	(0.11)	(0.12)	(0.18)	(0.16)	(0.17)
Random effects													
Variance	0.71	0.64*	0.55**	0.51***	0.69	0.59**	0.60**	0.52***	0.36***	0.43***	0.58**	0.45***	0.50***
(L2)	(0.18)	(0.16)	(0.14)	(0.13)	(0.17)	(0.15)	(0.15)	(0.13)	(0.09)	(0.11)	(0.15)	(0.12)	(0.13)
Variance	3.63***	3.55***	3.56***	3.56***	3.55***	3.56***	3.56***	3.55***	3.56***	3.56***	3.55***	3.56***	3.56***
(L1)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
AIC	103,938	95,487	92,775	92,773	95,489	92,777	92,778	95,480	92,762	92,767	95,484	92,769	92,772
BIC	103,962	95,552	92,855	92,853	95,554	92,858	92,858	95,545	92,843	92,847	95,548	92,849	92,853
N	25,139	23,221	22,543	22,543	23,221	22,543	22,543	23,221	22,543	22,543	23,221	22,543	22,543

Note: Standard errors in parentheses. ***$p<0.01$, **$p<0.05$, *$p<0.1$.

either AQTI or PITI as the moderator (see Models 6 and7). In terms of PM_{10}, the moderating effects of both AQTI ($\beta=0.80$, $p<0.01$) and PITI ($\beta=0.83$, $p<0.05$) are supported (see Models 9 and 10). In the case of AQI, only the moderating effect of AQTI is significant and positive ($\beta=0.03$, $p<0.05$) (see Models 12 and 13). In sum, the substantially similar results among the four air pollutants corroborate Hypothesis 2.

To visually illustrate the moderating effect of environmental transparency on the relationship between objective and subjective air quality measures, we draw the marginal changes of simple slopes of air pollution as the function of the two moderators in Figure 2. In Panel A of Figure 2, we reveal that air pollution (measured by SO_2) is negatively associated with subjective air quality when PITI is at the −1 standard deviation (SD) condition, but its sign turns to be slightly positive at the +1 SD condition. The result suggests the negative effect of air pollution (herein SO_2) on subjective air quality is attenuated with the increment of environmental transparency (PITI). When the value of centered PITI (ranging from −27.355 to 33.145) is larger than the lower confidence bound of region at the 0.05 level (−2.2323), the slopes of air pollution turn to be statistically insignificant. Pan-

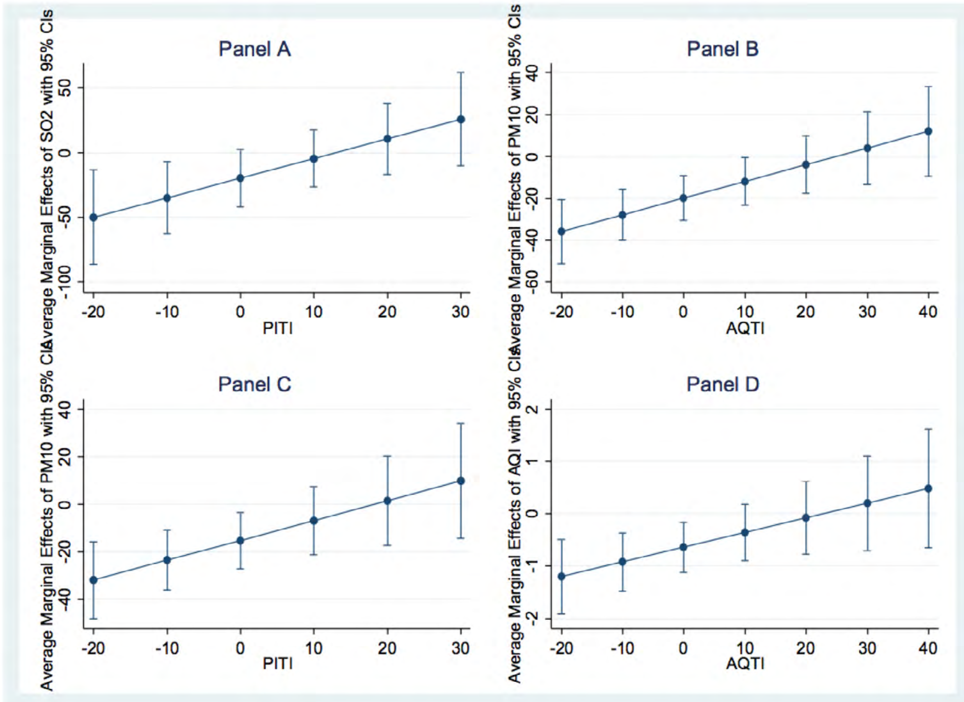

Figure 2. The moderating effects of transparency on the objective–subjective air quality relationship

el B–D in Figure 2 reveals similar patterns by using different measures of air pollution and transparency.

With regard to individual-level control variables, we find that gender has insignificant effect, albeit females have slightly better air quality perception than males. Age has significantly positive effect on subjective air quality, suggesting that elder residents are more tolerant of air pollution. Education and income are both significantly and positively associated with subjective air quality, which implies that high-educated and high-earned residents have relatively higher expectations toward air quality and they are consequently more discontent.

Discussions

How to strike a balance between economic development and environmental sustainability has been one of the top policy priorities in contemporary urban governance, particularly for developing countries such as China (Economy 2010). In China, economic slowdown and pandemic environmental pollution have led to social protest and unrest (Albert and Xu 2016). It is imperative for government to respond in a more transparent manner. In China, failures in managing environmental pollution and citizen's perceptions are threatening the ruling party's political trust and legitimacy.

In this study, we use the data from a recent national citizen survey and a third-party assessment in over 30 Chinese major cities to empirically examine the congruence of subjective air quality and objective air quality measured by government archive data and the moderating effects of environmental transparency on the relationship. Independent and interaction effects of air pollution and environmental transparency on public satisfaction with air quality are quantitatively analyzed by MLM technique. We find that given the same level of environmental pollution, citizens actually would perceive a better level of air quality with a higher level of environmental transparency. Our quantitative analysis reveals the independent and interaction effects of air pollution and environmental transparency on subjective air quality.

Contributing to the literature on transparency, which has been debating whether transparency is good for public administration, this study suggests that environmental transparency is of crucial importance in addressing environment challenges. Other than other benefits such as better decision making for government, private businesses, and individual citizens, one of the most important benefits for democracy is environmental information provided by environmental transparency regime can of help in constructing citizens' perceived reality, air quality in this case. So far, most transparency studies were conducted in the western democratic context (Cucciniello, Porumbescu, and Grimmelikhuijsen 2017). This study focuses on transparency in the context of authoritarian China and examine its effects in a specific policy area, environmental protection. Our findings imply that government and nonprofit organizations can leverage various information-based policy instruments such as information disclosure, openness, and policy campaign to inform, educate, and empower the public to curb air pollution collectively (Li 2012).

In the literature of public performance measurement, the debate on whether and to what extent subjective performance measures echoes objective ones centers on the conceptualization issues of subjective and objective measurements and methodological complications (Kelly 2003). In this study, we explore the relationship in a new policy area, environmental protection, which has not been examined by public administration scholars. We compare subjective and objective air pollution measures to avoid the notorious inputs versus outcome comparison problems (Parks 1984). We also adopt a more sophisticated and advanced research design and data analytic technique to address potential statistical complications such as common method biases. Our findings suggest that public administrators should realize that citizens do have sufficient capacity to detect government performance and their perception of government performance is not only normatively important but also technically essential (Swindell and Kelly 2000; Van Ryzin, Immerwahr, and Altman 2008). Furthermore, our study emphasizes the role government can play in influencing citizen's perceptions, highlighting the potential of environmental transparency for global environmental governance (Li 2012; Tan 2014).

Given the escalating air pollution in urban China, central and local governments have been endeavoring in spending more resources in environmental regulations. Despite the government proclaims that air quality has been steadily improving, citizens do not resonate and buy, generating an enlarging gap between government rhetoric and citizen perceptions. Given the lingering air pollution, citizens may be hopeless of and habituate themselves to air pollution (Menz 2011), because it has been an essential part of their lives (Johnson et al. 2017). How to mitigate citizens' discontent with air pollution? Our findings suggest that government should be more transparent in disclosing information and engaging the public, which helps to retain social legitimacy and support.

Information-based policy instrument is among lots of policy instruments available to policy-makers, and incentive-based and mandatory instruments are equivalently and even more powerful in improving environmental performance. Despite information-based instrument is not the most powerful policy instrument, it is a promising and cost-efficient one. Lots of recent developments in environmental governance use information disclosure and transparency to nudge residents and industrial enterprises to reduce environmental pollution. It is thus important to highlight the value of information-based policy instruments in improving air quality, both objectively and subjectively.

Environmental transparency may be undermined by giant industrial enterprises due to interest entrenchment (Lorentzen, Landry, and Yasuda 2014), and government should leverage the power of social accountability and citizen participation. The ubiquitous data manipulation must be addressed by introducing third-party engagement, since it is common to find interrupted points or discontinuities of air quality monitoring, especially when air pollution is heavy. It is also relevant to expand the comprehensiveness of coverage and the density of monitoring stations, particularly in rural areas, which help citizens more precisely perceive and respond to air pollution.

The limitations of the study are threefold, and we hope future studies can replicate and extend our findings. First, the measurements of our key variables could be improved in future research. The measurement of subjective air quality is based on a single item from a national citizen survey, and we will address the issue in our future study. Although air quality is highly sensible and easier to be detected and felt, a subjective AQI consisting of multiple questions would be better. Citizens' perceptions and satisfaction are conceptually different, and we cannot distinguish their fine-grained differences due to data limitations. Our measurement of objective air quality could also be improved by using more recent data, since the Chinese government revised the national Ambient Air Quality Standards and included the concentration level of $PM_{2.5}$ in 2013. It should be noted that information disclosure is different from information availability or access, and we use the former as a proxy of the latter. In the survey, we asked the respondents about their access to government information, but it is not specifically about environmental information. We encourage future studies to collect more fine-tuned data to measure environmental transparency.

Second, our data are cross-sectional and we cannot infer causal mechanisms through which objective air quality measures affect subjective perceptions. It would be promising to use experimental design (e.g., natural and quasi-experiments) to examine the interaction effects of air pollution and transparency on citizens' perceptions. Third, we only surveyed residents in large cities in China, and our findings reported here should not be overgeneralized to small and medium-sized cities. Given China's large geographical disparity in economic development, energy structure, and environmental pollution, we call for future research to replicate and extend our investigation in other contexts (e.g., small and medium-size cities) and employ more solid measures and data analysis technique to answer the research questions.

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