Air pollution, environmental perceptions, and citizen satisfaction: A mediation analysis

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A B S T R A C T

Air pollution is more than an environmental or health issue. Our findings suggest that Chinese citizens exposed to more industrial sulfur dioxide (SO_2) and dust emissions are less likely to be satisfied with environmental administration. Chinese citizens living with poorer air quality also tend to be dissatisfied with law enforcement. Last, perceptions of air pollution are affected by measured industrial emissions and shape citizen satisfaction. In sum, this paper provides evidence that air pollution corrodes citizen satisfaction via environmental perceptions. This improves understanding of the political costs of environmental degradation and the underlying mechanism.

1. Introduction

In 1952, the Great Smog of London sounded an alarm about the potential health impact of air pollution (Bell et al., 2004; Anderson, 2009). At that time, however, China was on the verge of its "Great Leap Forward" and the expansion of smokestack industries was an important element. China's economic transition, initiated in 1978, led to remarkable economic growth. However, air pollution and other environmental problems have grown in recent years and increasingly affect the health of Chinese citizens (Song et al., 2017; Cohen et al., 2017; Matus et al., 2012; Zhang et al., 2010). For example, in 2005, health problems from air pollution are estimated to have cost China USD 73 billion in net wage losses and USD 122 billion in combined net wage and leisure time losses (Matus et al., 2012). Air pollution in China also contributed to 1.1 million deaths in 2015 (Cohen et al., 2017).

Air pollution is more than an environmental or health issue. Damania et al. (2003) and Cole (2007) suggest that pollution is associated with corruption and possible government failure in environmental administration and law enforcement. Mol and Carter (2006), Bina (2010), Johnson (2014), Young et al. (2015), and Jia (2017) argue that, in China, the interpretation and enforcement of environmental laws are subject to administrative discretion and that environmental authorities are fragmented and entangled, with regulatory overlaps and

governance rhetoric used strategically in departmental interests. In the Chinese context, Huang et al. (2016) show that poorer air quality is associated with perceptions of increased corruption. In an emerging area of research on the political costs of environmental degradation, Gong et al. (2017), Alkon and Wang (2018), and Shi and Guo (2019) find that pollution in China reduces political trust in government and challenges the legitimacy of economic growth.

There is also an ongoing debate over potential pathways through which pollution affects subjective well-being. Smyth et al. (2008) show that life satisfaction in China is affected by air pollution, but not by environmental awareness. Wang and Cheng (2017) find that air pollution has a direct effect on life satisfaction, but that perceived pollution is neither affected by air pollution and nor affect life satisfaction. In contrast, using data from a Chinese mining area, Li et al. (2014) reveal that risk awareness and environmental knowledge are important pathways from air pollution to reduced subjective well-being. In the Taiwan area, Liao et al. (2015) find that air quality has no direct effect on life satisfaction, despite an indirect effect through environmental perceptions. Overall, the existing evidence is therefore mixed.

Built on these two strands of literature, this paper is intended to address three questions of policy relevance: Does air pollution cause lower citizen satisfaction with environmental administration? Does air pollution, along with corruption, cause lower citizen satisfaction with
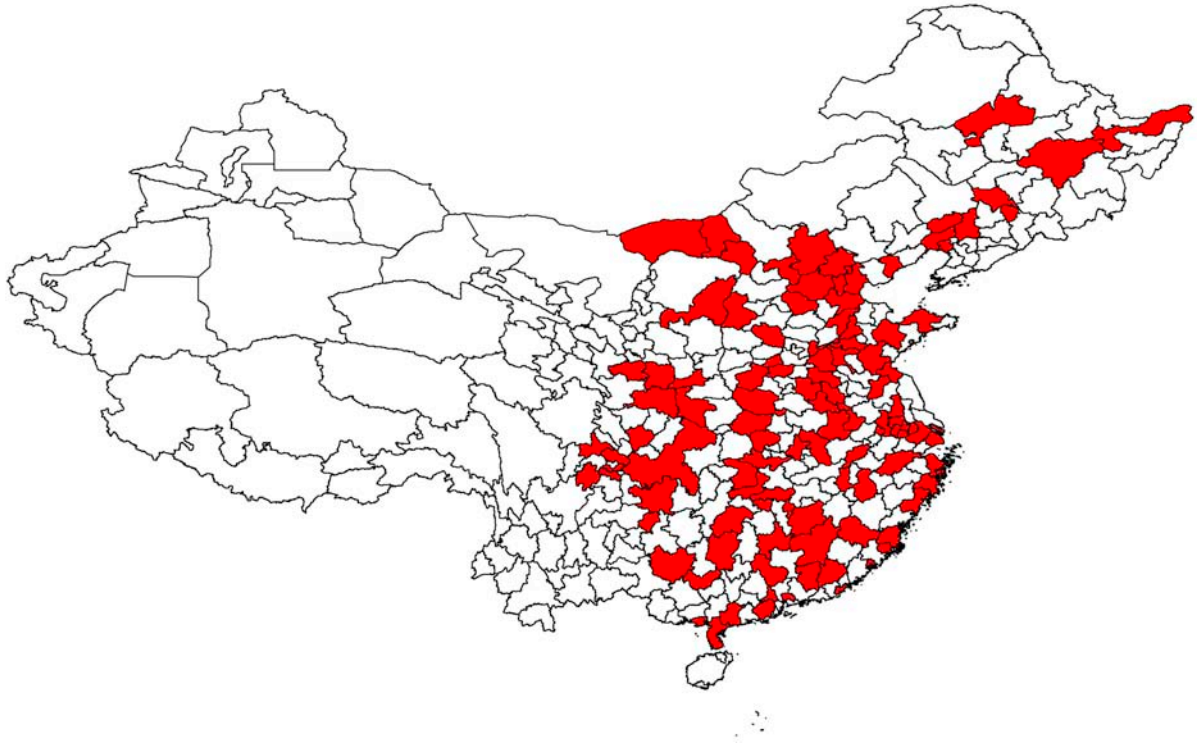
Fig. 1. The 105 sampled prefectures in mainland China.

law enforcement? Do environmental perceptions serve as a pathway through which air pollution indirectly affects citizen satisfaction? We found that Chinese citizens exposed to more industrial sulfur dioxide (SO_2) and dust emissions were less likely to be satisfied with environmental administration. Chinese citizens living with poorer air quality also tended to be dissatisfied with law enforcement. Last, perceptions of air pollution and environmental quality were affected by measured industrial emissions and shaped citizen satisfaction. In sum, this paper provides evidence that air pollution corrodes citizen satisfaction via environmental perceptions. This improves understanding of the political costs of environmental degradation and the underlying mechanism.

2. Methods and data

We specified a regression to examine air pollution (T), environmental perceptions (M), and citizen satisfaction (Y):

$$Y = + + + + + + \quad (1)$$

where i, j, and k index individuals, prefectures, and provinces, **X** and **Z** are vectors of individual characteristics and prefectural conditions, ϕ is a dummy variable to control for common effects across prefectures within a province, and ε is an error term.[1]

We specified another regression to establish whether industrial emissions play a role in forming environmental perceptions, holding other individual characteristics and prefectural conditions constant:

$$M_{ijk} = \theta_0 + \theta_1 T_{jk} + \mathbf{X}_{ijk}\lambda + \mathbf{Z}_{jk}\rho + \phi_k + \eta_{ijk}, \quad (2)$$

where captures provincial effects and η is an error term.

Combining Equations (1) and (2) and assuming sequential ignorability (Imai et al., 2010), we performed a causal mediation analysis, with industrial emissions as the treatment, environmental perceptions as the mediator, and citizen satisfaction as the outcome. The impact could therefore be direct, but the treatment could also work through the mediator to affect the outcome indirectly. Given two treatment levels t_0 and t_1, the average direct effect $E\{Y_{ijk}[t_1, M_{ijk}(t)] - Y_{ijk}[t_0, M_{ijk}(t)]\}$ is captured by $_1$ and the average causal mediation effect $E\{Y_{ijk}[t, M_{ijk}(t_1)] - Y_{ijk}[t, M_{ijk}(t_0)]\}$ by $_2$ $_1$.

Data at the individual level were extracted from the Chinese Social Survey (CSS), a nationally representative survey on Chinese citizens' preferences and attitudes to a variety of contemporary issues. The 2013 CSS asked whether the respondents were satisfied with environmental administration (Question G14) and with law enforcement (Question G17).[2] The response options given in the questionnaire were "doing a very good job", "doing a good job", "doing a bad job", "doing a very bad job", and "unclear". To facilitate estimation and interpretation, we created two binary measures for citizen satisfaction as follows. We defined "doing a very good job" and "doing a good job" as "satisfied" and let it take a value of 1, while we combined "doing a bad job", "doing a very bad job", and "unclear" as "not satisfied" and let it be 0.[3] We also constructed two measures for environmental perceptions. The dummy for perceived air pollution was given a value of 1 if air pollution was perceived as "severe" or "very severe" and 0 otherwise. The dummy for perceived environmental quality was given a value of 1 if environmental quality was rated at least 70% satisfying and 0 otherwise. In addition, we included age, sex, marital status, self-reported

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[1] Prefectures are an administrative level between provinces and counties in

Table 1
Summary statistics.

Variable	Obs	Mean	SD	Min	Max
Individual level					
Satisfaction with environmental administration ($= 1$)	8621	0.512	0.500	0	1
Satisfaction with law enforcement ($= 1$)	8621	0.439	0.496	0	1
Perceived air pollution ($= 1$)	8621	0.284	0.451	0	1
Perceived environmental quality ($= 1$)	8621	0.553	0.497	0	1
Age	8621	45.919	13.494	18	72
Female ($= 1$)	8621	0.552	0.497	0	1
Married ($= 1$)	8621	0.849	0.358	0	1
Healthy (%)	8621	67.478	22.639	10	100
Urban local residency ($= 1$)	8621	0.234	0.423	0	1
High-school diploma and above ($= 1$)	8621	0.310	0.462	0	1
Middle-school diploma ($= 1$)	8621	0.330	0.470	0	1
ln(Household income per member)	8621	9.143	1.041	1.609	13.816
Medical insurance coverage ($= 1$)	8621	0.907	0.291	0	1
Prefectural level					
ln(Industrial SO_2 emissions)	105	10.892	0.793	8.793	13.245
ln(Industrial dust emissions)	105	9.915	0.781	7.692	11.774
ln(Population)	105	15.415	0.579	14.017	17.323
ln(Land area)	105	9.360	0.745	7.361	11.319
Urban area (%)	105	1.953	2.751	0.058	16.783
ln(GDP)	105	10.571	0.733	9.140	12.504
Secondary-sector GDP (%)	105	50.379	9.028	22.700	73.230

health status, residency status, educational attainment, the natural logarithm of household income per member, and medical insurance coverage to control for individual characteristics.

The China Urban Statistical Yearbook (CUSY) reports annual industrial emissions at the prefectural level. Using the 2009–2013 CUSYs, we took the natural logarithm of five-year average industrial SO_2 and dust emissions to create two measures for air pollution. Using the 2013 CUSY, we also included the natural logarithm of population size, the natural logarithm of land area, percentage urban area, the natural logarithm of gross domestic product (GDP), and the percentage of GDP associated with the secondary sector to control for geographic, demographic, and economic differences across prefectures. There were 105 prefectures across 25 provinces in our sample and their geographic distribution is visualized in Fig. 1.[4] The summary statistics for each variable are shown in Table 1.

We used the algorithm proposed by Imai et al. (2010) to estimate Equations (1) and (2) and identify the effect of air pollution on citizen satisfaction through environmental perceptions.[5] Imai et al. (2010) allow for logit and probit models in their algorithm, but we chose to estimate Equations (1) and (2) as two linear probability models to facilitate the computation and interpretation of coefficient estimates.[6]

3. Results

Table 2 summarizes the results on citizen satisfaction with environmental administration as the outcome variable. The treatment

variable is industrial SO_2 emissions in Columns 1–4 and industrial dust emissions in Columns 5–8. The mediator variable is perceived air pollution in Columns 1–4 and perceived environmental quality in Columns 5–8. Table 2 shows that, first, industrial emissions significantly reduced the likelihood of environmental administration being considered satisfactory. Second, measured air pollution played an important role in forming environmental perceptions. Third, environmental perceptions had a strong effect on satisfaction with environmental administration. These results were robust to different indicators of measured and perceived air pollution.

The fact that the estimates of β_1 and β_2 were both statistically significant at the 1% level established the mediation effect of environmental perceptions. Following Imai et al. (2010), we produced the bootstrap estimates of average direct, mediation (indirect), and total effects and their 95% confidence intervals (CIs) (Table 2). The bottom line of Table 2 shows that the causal mediation effect of environmental perceptions accounted for approximately 20% of the total effect of industrial emissions on citizen satisfaction with environmental administration.

We followed the same procedure to gauge the direct and indirect effects on citizen satisfaction with law enforcement. The results in Table 3 show that measured air pollution remained critical to environmental perceptions. Furthermore, higher measured and perceived air pollution were associated with lower trust in law enforcement. The total effect mediated was estimated to range between 5.6% and 27.6%. These results provide additional evidence on the political costs of air pollution and the underlying mechanism of action.

4. Conclusion

This paper has examined how air pollution corrodes citizen satisfaction with both environmental administration and law enforcement. It suggests that environmental deterioration can be politically costly and result in reduced trust in government administration, both environmentally and in other areas such as law enforcement. We found that Chinese citizens were concerned about protecting the environment, but also about collusion between supervisory officials and polluting firms, for example. Citizens' perceptions about the environment also had an important effect on their opinions on both environmental administration and law enforcement.

Our findings suggest that improving environmental protection may be a means to enhance the legitimacy of the regime. Instead of viewing pollution reduction as a technical problem, policy-makers in China should improve environmental governance based on the rule of the law. This would be expected to translate into higher perceptions of environmental quality and ultimately greater citizen satisfaction with government performance.

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[4] The four municipalities under the direct administration of the Chinese central government, i.e., Beijing, Tianjin, Shanghai, and Chongqing, were pooled with the 101 prefectures. Dropping these four municipalities (555 observations) does not affect our findings.

[5] A two-level null model was used to examine the data on satisfaction with environmental administration, satisfaction with law enforcement, perceived air pollution, and perceived environmental quality. The corresponding intraclass correlation coefficients were 0.040, 0.039, 0.084, and 0.046, respectively. The mediation analysis based on a two-level, varying-intercept, and varying-coefficient model produced essentially the same results.

[6] We obtained essentially the same results from logit and probit models.

Table 2
Air pollution, environmental perceptions, and citizen satisfaction with environmental administration.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Satisfaction with environmental administration	Perceived air pollution	Satisfaction with environmental administration	Perceived air pollution	Satisfaction with environmental administration	Perceived environmental quality	Satisfaction with environmental administration	Perceived environmental quality
ln(Industrial SO_2 emissions)	−0.029** (0.011)	0.028*** (0.010)			−0.028** (0.011)	−0.031*** (0.011)		
ln(Industrial dust emissions)			−0.053*** (0.013)	0.056*** (0.012)			−0.053*** (0.013)	−0.057*** (0.013)
Perceived air pollution	−0.254*** (0.012)		−0.253*** (0.012)					
Perceived environmental quality					0.249*** (0.011)		0.248*** (0.011)	
Individual covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefectural covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8621	8621	8621	8621	8621	8621	8621	8621
R^2	0.091	0.082	0.092	0.084	0.101	0.060	0.102	0.061
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**
Direct effect	−0.029	[−0.051, −0.007]	−0.053	[−0.079, −0.029]	−0.028	[−0.050, −0.007]	−0.053	[−0.078, −0.029]
Mediation effect	−0.007	[−0.012, −0.002]	−0.014	[−0.020, −0.008]	−0.008	[−0.013, −0.002]	−0.014	[−0.021, −0.008]
Total effect	−0.036	[−0.060, −0.013]	−0.068	[−0.095, −0.042]	−0.036	[−0.059, −0.014]	−0.067	[−0.094, −0.042]
Total effect mediated	0.197	[0.118, 0.521]	0.211	[0.150, 0.338]	0.214	[0.129, 0.553]	0.210	[0.151, 0.333]

Individual covariates include age, sex, marital status, self-reported health status, residency status, educational attainment, ln(household income per member), and medical insurance coverage.
Prefectural covariates include ln(population), ln(land area), urban area (%), ln(GDP), and secondary-sector GDP (%).
Robust standard errors are given in parentheses.
*, **, and *** correspond to statistical significance at 10%, 5%, and 1% levels, respectively.

Table 3
Air pollution, environmental perceptions, and citizen satisfaction with law enforcement.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Satisfaction with law enforcement	Perceived air pollution	Satisfaction with law enforcement	Perceived air pollution	Satisfaction with law enforcement	Perceived environmental quality	Satisfaction with law enforcement	Perceived environmental quality
ln(Industrial SO_2 emissions)	−0.044*** (0.012)	0.028*** (0.010)			−0.042*** (0.012)	−0.031*** (0.011)		
ln(Industrial dust emissions)			−0.025* (0.013)	0.056*** (0.012)			−0.022* (0.013)	−0.057*** (0.013)
Perceived air pollution	−0.095*** (0.012)		−0.095*** (0.012)					
Perceived environmental quality					0.141*** (0.011)		0.141*** (0.011)	
Individual covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefectural covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8621	8621	8621	8621	8621	8621	8621	8621
R^2	0.041	0.082	0.040	0.084	0.053	0.060	0.052	0.061

Table 3 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Satisfaction with law enforcement	Perceived air pollution	Satisfaction with law enforcement	Perceived air pollution	Satisfaction with law enforcement	Perceived environmental quality	Satisfaction with law enforcement	Perceived environmental quality
	Mean	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**	**Mean**	**95% CI**
Direct effect	− 0.044	[−0.067, − 0.021]	− 0.025	[−0.051, 0.000]	− 0.042	[−0.065, − 0.020]	− 0.022	[−0.048, 0.003]
Mediation effect	− 0.003	[−0.005, − 0.001]	− 0.005	[−0.008, − 0.003]	− 0.004	[−0.008, − 0.001]	− 0.008	[−0.012, − 0.005]
Total effect	− 0.046	[−0.070, − 0.023]	− 0.030	[−0.057, − 0.004]	− 0.046	[−0.070, − 0.024]	− 0.030	[−0.056, − 0.005]
Total effect mediated	0.057	[0.038, 0.114]	0.176	[0.092, 0.988]	0.094	[0.062, 0.180]	0.266	[0.135, 1.334]

Individual covariates include age, sex, marital status, self-reported health status, residency status, educational attainment, ln(household income per member), and medical insurance coverage.

Prefectural covariates include ln(population), ln(land area), urban area (%), ln(GDP), and secondary-sector GDP (%).

Robust standard errors are given in parentheses.

*, **, and *** correspond to statistical significance at 10%, 5%, and 1% levels, respectively.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2020.109287.

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