



“Political blue sky” in fog and haze governance: evidence from the local major international events in China

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Abstract

The trade-off between economic development and environmental protection has always been a significant and tough issue for local governments. Studies found that some local governments took temporary measures to control air pollution and created “political blue sky” in certain periods. We collected daily air quality index (AQI) data and individual pollutant concentration data of four cities in China which have hosted major international events in 2019. The air quality of the cities taken temporary measures to control air pollution had an obvious improvement during the events. Furthermore, the improvement mainly occurred in pollution indicators, such as PM_{2.5} and PM₁₀, which are more valued and sensitive to the public. The sustainability analysis demonstrates that the air quality deteriorated again after the event, indicating that “political blue sky” comes at the cost of retaliatory pollution.

Keywords Fog and haze governance · “Political blue sky” · Regression discontinuity

JEL classification Q52 · Q53 · Q58 · R58

Abbreviations

AQI	air quality index	WIND	the magnitude of the wind
PM _{2.5}	particular matter 2.5	E, event	B3, 11–15 days before the event
PM ₁₀	particular matter 10	B2	6–10 days before the event
RD	regression discontinuity	B1	1–5 days before the event
APEC	Asia-Pacific economic cooperation	A1	1–5 days after the event
GDP	gross domestic product	A2	6–10 days after the event
TFP	total factor productivity	A3	11–15 days after the event
DID	difference in difference method	AQI_E	the data of AQI in the Ministry of Environmental Protection
SO ₂	total sulfur dioxide emissions	EA	the artificially event time
CO	total carbon monoxide emissions		
NO ₂	total nitrogen dioxide emissions		
O ₃	total ozone emissions		
TEMP_H	the maximum temperature		
TEMP_L	the minimum temperature		
RAIN	whether raining		

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Introduction

Haze pollution is a state that summarizes the generation, diffusion, and hazard processes of various suspended particles in the atmosphere. Since the “Economic Reform and open up,” China’s economy has scored enormous achievements, as well as severe environmental problem, especially the haze pollution. For the first time, green development was elevated to the height of the national strategy as one of the five major development concepts¹. Air pollution increases the unbalance

¹ The five concepts for development include innovation-driven, coordinated, green, oriented toward global progress, and beneficial to all, which were proposed at the fifth plenary session of the 18th CPC Central Committee in 2015.

development of regional economy (Qi et al. 2015), and reduces the happiness of residents (Zheng et al. 2019). Researches even attested that air pollution causes premature deaths of 33,000 people worldwide every year (Lelieveld et al. 2015). As the problem of pollution continues to emerge, it is of great practical significance to discuss the environmental governance in China. The fundamental problem of the environment is caused by the extensive economic development model in China, which lies in “the decentralization between central and local governments” (Cai et al. 2008). While the central government delegates economic powers to the local government, it still maintains the centralized political control. And the superior government promotes local officials based on their performance appraisal, namely “economic decentralization and political centralization” (Chen and Gao 2012). Under this institutional background, the central government formulates unified environmental policies, then the local governments are responsible for the implementing policies within their jurisdictions. Due to the thought of “economic construction as the center,” some local officials have sacrificed the environment for economic growth. But in politically sensitive periods, the local government is likely to take temporary measures to control air pollution, which called “political blue sky.”

Researches showed that “political blue sky” did exist in China’s environmental governance. In some specific period, the local government needed to take more care of public opinion, which led to the emergence of “APEC Blue”² and “Parade Blue”³. However, the existing literature mainly focused on China’s two sessions or international conference, and few researchers paid attention to the major international events. With the economy continuing to develop, the local governments take actions to enhance its international status and influence, while the major international event is a good way to capture the world’s attention. In general, major international events have following characteristics: short time, high media exposure, and great attention from the world. If the air quality of the city is good during the event, a perfect image will be spread through media and various channels. Therefore, the local government has a strong incentive to governance the air pollution. At the same time, there are also some drawbacks of temporary managements.

² “APEC Blue” refers to the blue sky in Beijing during the APEC meeting. During the 2014 APEC meeting in Beijing, measures such as road restrictions and shutdown of polluting enterprises were implemented to ensure good air quality.

³ “Parade Blue” originated with the “APEC Blue.” In preparation for huge military parade in Beijing, environment measures such as industrial stoppage and construction stoppage were released to ensure good air quality.

Based on the data of cities⁴ hosting major international events in 2019, we analyze the impact of the event on air quality by using multivariate linear regressions. Air quality data includes AQI and six individual pollutant concentrations (AQI, PM_{2.5}, PM₁₀, SO₂, CO, NO₂, O₃). Weather data are also adopted to control the influence of weather on air quality, including the temperature, rainfall, and wind. And the regulations of each city are defined by local government websites. We select regression discontinuity, which can observe the change of air quality more accurately and identify the influence by gradual changes with dates and seasons. So, the idea of RD will be used to study the impact of major international events on air quality. Our results show that haze governance is by no means achieved in a temporary control. Long-term institutional arrangements for haze governance are necessary. Therefore, this paper puts forward corresponding policy suggestions from industrial transformation, environmental protection law enforcement, and performance assessment, which is helpful for the practice of environmental governance in China.

The structure is organized as follows: The “Literature review” section is about literature review, which mainly elaborates the study on haze pollution, governance, and “political blue sky.” The “Methods” section provides our design and data. The “Summary statistics” section introduces summary statistics. The “Results” section reports the effects of major international events on haze governance through empirical results. The “Discussion” section presents the robustness analyses and the “Conclusion and policy implications” section concludes.

Literature review

Over the past 40 years, China has not only made great achievements in economic development, but also caused serious environmental pollution. Industrial activity has proved to be a major contributor to China’s economic output, while the massive expansion of industry results in high energy consumption, which is one of the major sources of pollution (Peng et al. 2020). With the gradual improvement of living standards and environmental awareness, Chinese public has put forward higher and higher expectations. Studies found that 45% of respondents were dissatisfied with the current air quality (Pu et al. 2019), which also required the government to strengthen environmental protection. The government has indeed put increasing emphasis on environmental protection, especially the central government, which has put forward the Ecological Civilization Construction. For example, the

⁴ Wuhan hosted 7th Military World Games from October 18 to October 27. Chengdu hosted World Police and Fire Games from August 8 to August 18. Zhengzhou held National Traditional Games of Ethnic Minorities from September 8 to September 16. Taiyuan held National Youth Games from August 13 to August 22.

Outline of the 13th Five-Year Plan (2016–2020) for National Economy and Social Development, ratified by the National People's Congress in March 2016, calls for reducing the number of days of heavy pollution in cities at or above the prefecture level by 25%, and the proportion of days with good air quality exceeding 80% by 2020. Under the requirements and expectations of the central government and the public for local governments to strengthen environmental protection, energy conservation and emission reduction have become the assessment basis for local officials' promotion, just like economic growth. If the assessment targets of environmental performance are clear and the responsibilities are in place, the effect of pollution control will be good. Nevertheless, if the public visibility too low, pollution control will be useless (Liang and Langbein 2015). Some researchers studied the air quality index and the statistics of China's prefecture-level cities, which found that air quality affects the promotion probability of officials (Li and Zheng 2016). Moreover, when the pressure of air control is high, local governments will reduce fixed asset investments and increase investments in the environment under the pressure of environmental protection.

The academic community has analyzed environmental pollution and governance issues from different perspectives, and the content mainly includes factors and influence of environmental pollution, the roles, status, and responsibilities of various subjects in environmental governance, international management experience, and the comparison between China and foreign countries. There are many articles about the factors affecting environmental pollution, mainly related to the theory of economic growth model (Akadiri et al. 2019), pollution governance efficiency (Zha 2015), and environmental governance system (Dianati et al. 2019). Udemba et al. (2020) took China as an example to study the relationship between pollutant emission, energy consumption, foreign direct investment, and economic growth. The results showed that there was a positive correlation between pollutant emissions with all variables except economic growth, further exposing the deterioration of environment in China with the curtailing strength from the GDP. Magazzino et al. (2020) analyzed the relationship between air pollution and COVID-19-related deaths in three French cities. They estimated the threshold of PM_{10} and $PM_{2.5}$, beyond which COVID-19-related deaths would increase. Research relevant to haze pollution started late and gradually appeared until 2013, but it has received widespread attention from all walks of life. Most researches focused on the factors of pollution, mainly about collusion (Shi et al. 2017), economy density (Zhang and Wang 2014), industrial transfer (Ma and Zhang 2014), and environmental regulation (Chen and Pan 2018; Tang et al. 2019). Studies found that the distorted industrial structure of the secondary industry, the coal-based energy structure, the rapid population concentration, and the high intensity of highway transportation are the dominating causes of frequent haze pollution in

China (Shao et al. 2016). With the development of policy analysis tools, scholars studied the impact of environmental governance policies on output, especially the impact of environmental regulations on economic growth variables, such as GDP, and analysis demonstrates that appropriate environmental regulations will increase green total factor productivity (TFP) (Shen et al. 2017) to promote high-quality economic development (Chen and Chen 2018).

Although the public government and the central government have raised higher expectations and requirements for local governments to strengthen environmental protection, local governments do not necessarily devote more resources to environmental governance and local officials even sacrifice environmental protection for economic growth. China implements a system of political centralization and economic decentralization. Moreover, according to the performance of all aspects, the governments at a higher level examine governments at lower levels and select officials. In the modern age, which takes the economic construction as the focus, GDP growth is more important than environmental protection in achievement assessment. Therefore, local government and officials have incentives to sacrifice environmental protection to promote local economic growth. The empirical results on environmental management can also be roughly divided into two categories: one is to test the relationship between fiscal decentralization and environmental pollution (Tan and Zhang 2015). The other is to test the relationship between the competition of local government, environmental pollution, and environmental governance (Liu et al. 2015). Under the “top to down” incentive competition mechanism that uses GDP as the dominating assessment index caused by decentralization, local governments use environmental governance as one of the tools in the competition for the mobility element to develop the economy (Zhu et al. 2011). They adopt the “race to the end” strategy (Li et al. 2014) to waken environmental regulations (Zhang 2016). Some studies discovered that local government investment in infrastructure and transportation could increase land prices and local GDP, leading to a lack of environmental pollution improvement under promotion incentives (Wu et al. 2013). These researches characterized the behavioral choices of local officials on environmental governance issues in China, and to a certain extent explain environmental pollution in China.

It is important to discuss whether environmental protection has become an assessment indicator for local officials, and even whether it weighs more than economic growth, but it is also worth noting that air quality and economic growth are measured in different time windows. Air quality can change from day to day and even hour to hour, but economic growth only slowly changes over long periods. Therefore, in a long period, like 1 year, even throughout their entire term, local officials may attach more importance to economic growth, even at the expense of ignoring air quality. But in certain

period, in a shorter time, the local government and officials are likely to pay more attention to air quality, because focusing on air quality in the short term will not damage the local economic growth for a long time. Studies verified that in some special periods when politics are more sensitive and need to take care about the public, the government may pay more attention to the blue sky, thereby creating temporary “APEC Blue,” “Parade Blue,” and other “political blue sky” (Liang et al. 2015). Some scholars took China’s two sessions as the object to study the haze management and found that the intensity of the haze control during the “two sessions” was especially powerful. Regardless of whether the company meets environmental protection standards, they must stop production from creating a temporary blue sky. Nevertheless, after the session, it will cause more grievous pollution (Shi et al. 2016). Some researchers analyzed the impact of emission reduction measures on air quality in Beijing by comparing air quality data from environmental monitoring stations during the APEC meetings (Yu et al. 2015). Scholars observed the characteristics of air pollution in Shijiazhuang and evaluated the effect of air quality guarantee measures during the APEC conference (Wang et al. 2016). These research results indicated that in politically sensitive periods, local governments have attached great importance to the management of haze, resulting in temporary improvement in air quality, which is our central topic—“political blue sky.”

Generally speaking, academia has formed relatively rich achievements on environmental governance, providing a solid theoretical basis for future studies. However, in the existing research, people have focused more on political events, like China’s two sessions, or economic meetings, but few studied the impact of major international events on fog and haze governance. There are still questions and challenges about the endogeneity of environmental indicators. As Wuhan hosted 7th Military World Games, it is an opportunity to select cities hosted major international events to compare and analyze by different governance policies. It has certain reference significance to the practice of environmental governance in China, and it is also helpful for the government to formulate and implement corresponding decisions and measures.

Methods

Econometric model

There are currently several methods to examine the impact of major international events on air quality. For example, the single difference method simply compares the change in air quality between different periods. And the difference in difference method (DID) examines both different period and cities. Another is the regression discontinuity (RD) designs, which studies whether the air quality changes abruptly during

the event. Simply using the single difference method is too rough. On the one hand, it cannot distinguish the result of events and other things, and on the other hand, it is not possible to strip the inherent trend of air quality changes. Using the idea of DID can more accurately control air quality changes. At the same time, RD designs can further analyze whether air quality is affected by gradual changes with dates and seasons. Therefore, the idea of DID and RD will be used to study the impact of major international events on air quality.

Because all events are held in August to October, according to the idea of RD, the time window should not be too long, so the sample (Wuhan, Chengdu, Zhengzhou, Taiyuan) includes event period and 30 days before and after the event as treatment group. At this moment, the samples of each city are slightly different and overlapped. Meanwhile, the data of 4 similar cities (Changsha, Chongqing, Jinan, Shijiazhuang) that did not hold events during the sample period and the data from last year of each city (Wuhan, Chengdu, Zhengzhou, Taiyuan) that held events are selected as control group. These similar cities were chosen because of their geographical location, city size, economic development level, and industrial structure are analogous with Wuhan, Chengdu, Zhengzhou and Taiyuan. In this way, the regression includes the idea of DID and RD design. To be more specific, it can be expressed in the form of Eq. (1).

$$Y_{cd} = \beta_0 + \beta_1 E_{cd} + \lambda x_{cd} + \delta_c + \mu_d + \varepsilon_{cd} \quad (1)$$

This paper refers to the literature of Shi to select the following variables (Shi et al. 2017; Shi et al. 2016). The subscript indicates the city corresponding to the data; and the subscript d indicates the date corresponding to the data; Y_{cd} is based on the observed air quality index (AQI, $PM_{2.5}$, PM_{10} , SO_2 , CO , NO_2 , O_3); Dummy variables E_{cd} are defined to characterize the effect of “political blue sky” during the event. In addition, other weather factors are also added as a control variable x_{cd} , mainly including the maximum and minimum temperatures, whether raining (dummy variables) and the magnitude of wind to control the impact of weather changes on haze. δ_c is a regional dummy variable, which reflects the fixed effect of the region and will not change in a short time. μ_d is a set of time fixed effects, mainly including season and holiday dummy variables to control the impact of season change and human working schedules on air pollution.

The main explanatory variable is the hosting of major international events in various places. The reason why major international events are selected to test the effect of “political blue sky” is that major events are one of the most essential events for local governments, and haze problem is also one of the most significant issues people paid close attention to in recent years. At the same time, during the event, the media gathered extensively. If vicious events, such as haze occurs, the news will spread faster and more widely, and the public’s

voice will also get a response from media. Therefore, the government has incentives to strengthen environmental protection measures to create a short blue sky.

Data sources

Haze pollution includes sulfur dioxide, nitrogen oxides, and respirable particles (mainly referring to PM_{10} ⁵ and $PM_{2.5}$ ⁶). $PM_{2.5}$ has a small particle, strong activity, wide distribution, long residence time, and high toxicity (Wang and Feng 2019). AQI and individual pollutant concentration data are the most commonly used data for studying haze. AQI is calculated based on the index data of each pollutant concentration, which represents the daily air of each city, from 0 to 500. The larger the value, the worse the air quality.

At present, the Internet has become the primary channel for people to obtain data. So historical data are provided by the “China Air Quality Online Detection and Analysis Platform,” including AQI and six individual pollutant concentrations. In terms of analysis, the data during the events and data of 30 days before and after the events are selected. To make the difference more comparable, multiple time windows of different lengths are also adopted for robustness analysis. In the meanwhile, data from similar cities is selected for comparison and analysis. As meteorological conditions such as rainfall, temperature, and wind are significant factors affecting haze, the impact of meteorology on air quality is also controlled by data provided by “2345 Weather Network,” including the maximum temperature (TEMP_H) and the minimum temperature (TEMP_L), whether raining (RAIN) and the magnitude of the wind (WIND).

The regulations of each city are defined by local government websites. According to the policies issued by governments, except for Chengdu, all cities had documents govern air quality during the event. The details are as follows: the city government of Wuhan issued “the Decision of the Municipal People’s Government on Temporary Measures for Atmospheric Environmental Quality Management During the Seventh World Military Games,” and decided that the implementation of atmospheric environmental quality control measures would be from October 13 to October 28, the ecological environment department may require some industries or enterprises to take relevant measures in advance according to the needs of air quality guarantee. Zhengzhou Municipal Government carried out a three-month (June to September) campaign on environmental pollution treatment to effectively solve pollution problems, promote the development of environmental supervision and the continuous improvement of

environmental quality, and ensure the blue sky during the event. Shanxi Province issued “the Shanxi Province Action Plan to Win the Blue-Sky Defense in 2019” and “Notice on Environmental Quality Assurance of the Second National Youth Games,” to complete the remediation of polluting enterprises by the end of 2019, ensure the environmental quality during the Second Youth Games, and continuously improve the environmental air quality and carry out the rectification of polluting enterprises in Taiyuan.

Summary statistics

Figure 1 describes the haze change trend of the sample cities in 2018 and 2019 (the monthly data is the average of two years), we can know that the haze has distinct seasonal characteristics. For the air quality index AQI and most of the individual pollutant concentration data, they are all higher in winter than summer. Only ozone is significantly higher in summer than winter. Therefore, regression analysis must add a seasonal adjustment.

According to Table 1, the average of AQI is 83.72, but from the standard deviation, maximum, and minimum data of AQI, we can know that the average masks the huge difference of haze in different cities and periods. According to Table 2, through the comparison of air quality in different periods, some preliminary conclusions are obtained. Except for Chengdu, the main variables of each city, such as AQI, are notably lower during the event than other periods, which is in line with the policy mentioned earlier. Taking Wuhan’s AQI as an example, the average AQI is 67.3 during the event, which is remarkably lower than 80.5 (before) and 85.07 (after). The air quality of Zhengzhou and Taiyuan also improved, particularly during the event. These data indicate that some local governments did create a “political blue sky” through temporary attention in the certain sensitive period.

Results

Baseline regression results

Testing the existence of “political blue sky”

The regression results are robust heteroskedasticity-corrected standard error. The following regressions add regional and time fixed effects to control the differences between cities, seasons, and holidays, and also include weather variables (temperature, wind, and rain) to control their impact on air quality. First, we do a full sample regression on all data. According to the Fig. 2, the regression results are not significant. It’s worth noting that there are different policies for each city to treat events. In combination with the previous analysis,

⁵ PM_{10} is a pollutant particle which is less than 10 μm , also known as inhalable particles.

⁶ $PM_{2.5}$ is a pollutant particle which is less than 2.5 μm , also known as the lung particulate matter.

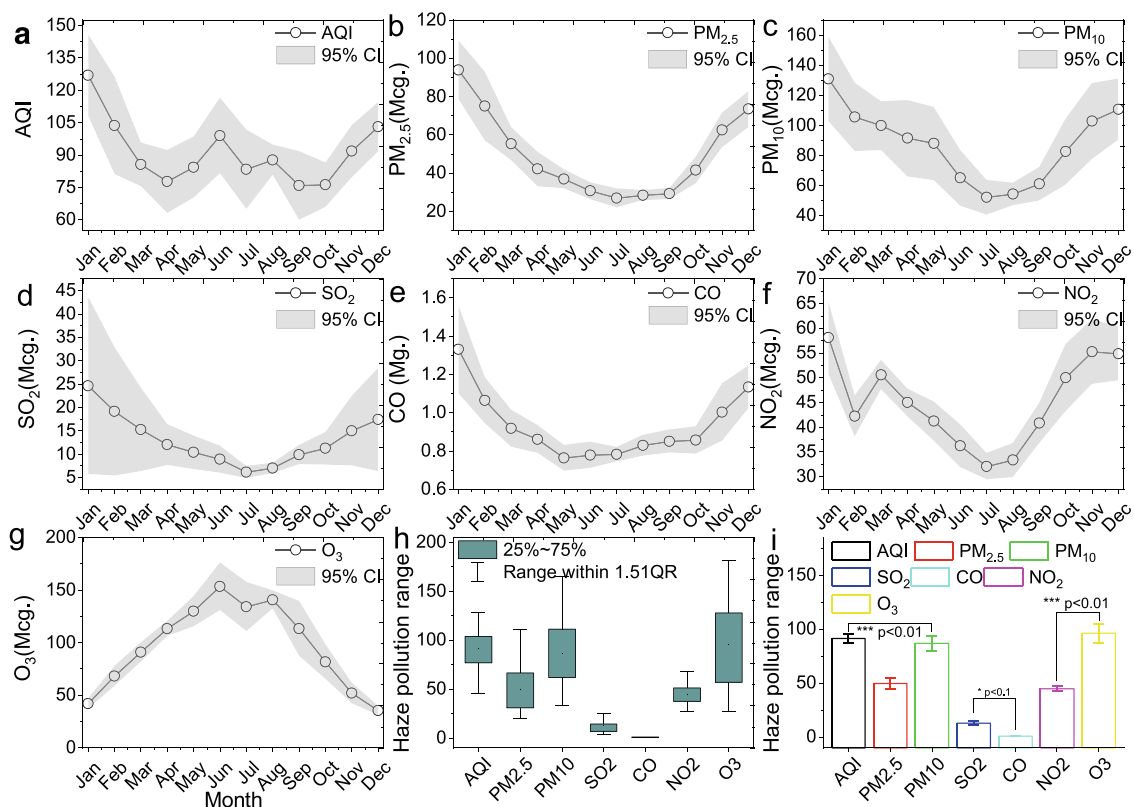


Fig. 1 Trends of haze in different months of the sample cities between 2018 and 2019. Note: **a** Two-year monthly average of AOI and its 95% confidence interval (CI); **b** two-year monthly average of PM_{2.5} and its 95% CI; **c** two-year monthly average of PM₁₀ and its 95% CI; **d** two-year monthly average of SO_{2.5} and its 95% CI; **e** two-year monthly average of

CO and its 95% CI; **f** two-year monthly average of NO₂ and its 95% CI; **g** two-year monthly average of O₃ and its 95% CI; **h**, box plot of different pollutants; **i** pollutant correlation, *, **, and *** respectively indicate significance levels of 10%, 5%, and 1%

the sample will be further screened according to policy, and regression testing will be performed for each city to test the existence of “political blue sky” in haze management. The cities that have issued air governance for event indicate that AQI is significantly related to the event, and it decreases during the event, which means that the air quality improves in this

particular period. According to the regression results of each city (Fig. 2), except for Chengdu, the coefficients of dumb variables E_{cd} of each city is negative, which indicates that haze was notably lower than other periods after governance. The air quality improvement of Wuhan was most closely related to the event (Fig. 2). Among them, the AQI of Taiyuan had the

Table 1 Descriptive statistics of the main variables

Var	Units	Sample	Mean	Std.	Min	Max	Skewness	Kurtosis	IQR	Range
AQI	Index	840	83.72	34.01	25	203	0.58	2.73	48.5	178
PM _{2.5}	Mcg.	840	33.32	16.98	4	146	1.51	7.83	20.5	142
PM ₁₀	Mcg.	840	62.98	27.74	4	188	0.61	3.47	39	184
SO ₂	Mcg.	840	8.95	4.25	2	77	5.39	80.30	5	75
CO	Mg.	840	0.82	0.20	0.3	1.8	0.84	5.38	0.2	1.5
NO ₂	Mcg.	840	39.62	15.14	8	98	1.14	4.66	18	90
O ₃	Mcg.	840	122.61	51.84	14	277	0.15	2.20	82	263
RAIN	Dummy	840	0.43	0.50	0	1	0.28	1.08	1	1
WIND	Ordinal	840	1.75	0.99	0	11	1.08	11.42	1	10
HOLIDAY	Dummy	840	0.32	0.47	0	1	0.79	1.63	1	1
TEMP_H	°C	840	27.81	5.66	6	39	-0.72	3.39	8	33
TEMP_L	°C	840	18.28	5.53	1	30	-0.58	2.78	9	29

Table 2 Descriptive statistics of air quality before the events

City	Var	Before the event						During the event						After the event					
		Mean	Std.	Skewness	Kurtosis	IQR	Range	Mean	Std.	Skewness	Kurtosis	IQR	Range	Mean	Std.	Skewness	Kurtosis	IQR	Range
Wuhan	AQI	80.5	37.15	0.27	1.72	58	122	67.3	18.56	0.29	1.53	33	51	85.07	22.49	-0.93	3.12	29	88
	PM _{2.5}	30.4	11.40	-0.65	2.23	17	43	33.5	8.96	0.16	1.89	13	26	48.23	18.41	-0.15	2.36	29	72
	PM ₁₀	55.6	21.74	0.11	2.23	28	82	54.3	10.15	0.75	2.12	18	29	94.8	30.41	-0.59	2.65	38	114
	SO ₂	10.67	3.80	0.32	1.77	7	12	8.5	1.27	0.69	2.60	1	4	11.37	3.55	0.59	2.85	4	14
	CO	0.86	0.17	-0.03	1.76	0.3	0.5	0.86	0.22	-0.56	1.85	0.4	0.6	0.96	0.23	-0.31	2.35	0.3	0.8
	NO ₂	40.5	20.33	0.98	2.78	26	68	48.8	16.34	0.39	2.23	19	62	61.97	22.79	-0.04	1.83	38	78
Chengdu	O ₃	126.87	52.39	-0.01	1.73	91	187	103.2	37.71	-0.25	1.57	69	102	80.13	32.16	-0.06	1.81	48	115
	AQI	63.93	27.15	1.49	4.96	25	116	120.18	36.76	0.41	2.22	45	114	61.5	31.80	1.40	3.73	27	117
	PM _{2.5}	18.67	8.25	0.67	2.70	14	31	30.55	11.5	0.55	1.82	20	33	26	11.91	0.04	2.73	15	50
	PM ₁₀	33.77	14.54	0.58	2.59	21	56	59.73	21.48	0.43	1.58	35	57	41.77	17.94	0.36	3.33	21	81
	SO ₂	4.47	0.63	0.97	2.90	1	2	6.91	2.66	1.83	5.66	3	9	5.33	1.32	1.19	3.78	2	5
	CO	0.73	0.10	-0.28	2.59	0.1	0.4	0.8	0.09	0	1.375	0.2	0.2	0.80	0.13	-0.78	3.17	0.2	0.5
Zhengzhou	NO ₂	34.43	9.87	0.30	2.07	15	35	44	9.24	-0.11	1.92	12	29	33.6	8.51	-0.42	2.92	12	36
	O ₃	107.2	39.06	0.86	3.41	50	167	180.18	41.44	0.22	2.19	51	132	96.5	47.87	1.07	2.91	56	172
	AQI	105.97	28.38	-0.05	2.63	41	115	69.67	53.11	0.98	2.39	61	144	88.63	39.91	0.23	1.53	78	134
	PM _{2.5}	27.67	9.19	0.25	1.91	18	30	26.89	20.37	0.86	2.36	30	58	30.6	10.79	-0.36	2.04	17	38
	PM ₁₀	61.37	13.44	-0.64	3.89	19	63	50.44	32.6	0.38	1.64	58	87	67.8	26.13	-0.29	1.8	48	86
	SO ₂	6.27	2.82	0.70	3.31	4	12	6.33	2.18	0.55	1.90	3	6	7.37	2.79	1.19	4.34	3	12
Taiyuan	CO	0.80	0.22	1.96	7.13	0.2	1	0.81	0.16	1.51	5.16	0	0.6	0.90	0.22	0.87	4.51	0.3	1.1
	NO ₂	33.7	7.91	-0.08	2.39	13	32	26.33	5.29	0.03	1.52	10	13	42.57	14.63	0.52	2.58	22	57
	O ₃	163.53	35.50	-0.47	2.86	46	153	105.44	73.65	0.78	2.04	112	197	130.37	62.13	-0.09	1.5	127	201
	AQI	110.37	32.32	-0.12	2.35	48	133	86.6	29.95	1.14	2.92	36	88	74.87	27.95	0.98	3.13	36	110
	PM _{2.5}	36.37	12.72	0.34	2.95	21	57	25.8	15.75	1.25	3.42	17	48	29.43	10.98	0.03	1.96	18	40
	PM ₁₀	60.8	18.62	-0.03	2.14	27	74	54.6	19.71	0.43	1.88	29	57	62.43	21.99	-0.23	2.48	31	87
	SO ₂	8.07	2.35	-0.15	2.17	4	9	10.2	2.82	0.51	1.57	6	7	11.7	3.78	0.15	2.94	5	17
	CO	0.84	0.13	-0.43	2.99	0.2	0.6	0.73	0.24	0.37	1.62	0.5	0.6	0.83	0.19	0.53	3.02	0.2	0.8
	NO ₂	32.53	8.31	0.43	2.04	14	30	34.5	8.81	0.52	2.82	11	31	45.77	9.58	0.32	3.14	11	42
	O ₃	168.8	38.88	-0.42	2.62	54	163	136.6	39.82	0.70	2.64	46	134	114.43	46.17	0.20	2.5	57	185

biggest drop, which was 12.71 lower than other times. It was equivalent to 15% of the average sample. Wuhan and Zhengzhou also had a certain decrease, indicating that air governance during these three cities has typically intensified. Chengdu is shown that the coefficient of the dumb variable E_{cd} is large, positive and also significantly related to the event. It can be analyzed with local policies as follows:

According to the previous policies, the environmental governance issued by the Wuhan Municipal Government is more targeted and temporary. They achieved the effect of “political blue sky” through short-term control of pollutant emissions during the events. Therefore, in the regression results, Wuhan’s air quality is related to the event. It is manifested in a typically decline in AQI during the event, that is, a noteworthy improvement of air quality; Zhengzhou and Taiyuan both carried out long-term governance for 3 months or even 1 year. Therefore, the data selected of 30 days before and after the events in regression demonstrate that the correlation between the air quality and the events is weak, but the air quality index in two cities still indicates a prominent decline; on the one hand, Chengdu is not affected by environmental governance. On the other hand, the number of people and vehicles increased sharply during the event, which exacerbated the haze phenomenon. Therefore, the coefficient of the event is positive in the regression results, and it is significant, which

means that the haze is worse during the event than other times and this deterioration of air quality is closely related to the event.

AQI is a combination of multiple single pollutants. Therefore, in order to further discuss the impact of the event on every single air pollutant, the concentration of each single pollutant is used as the explanatory variable to regress. According to the Fig. 3, most of the indicators have a downward trend during the event. Several pieces of evidence exist to prove that $PM_{2.5}$, PM_{10} , SO_2 , and NO_2 have a remarkable correlation with the event. Compared to full samples, the correlation of each indicator is remarkably improved in the samples excluding Chengdu. Among them, $PM_{2.5}$ and PM_{10} have the biggest decrease, which means that these two indicators are the primary factors for air management. It can be explained from the following perspectives:

Firstly, according to the structure of AQI and the characteristics of China’s air pollution, $PM_{2.5}$ and PM_{10} are the main factors that affect its changes. Secondly, the central government takes $PM_{2.5}$ and PM_{10} as the dominating assessments for air pollution management. During some sensitive periods, local governments have incentives to strengthen governance. At the same time, $PM_{2.5}$ and PM_{10} are also one of the representatives that people are most concerned about. The source of $PM_{2.5}$ and PM_{10} is mainly composed of burned fuel and

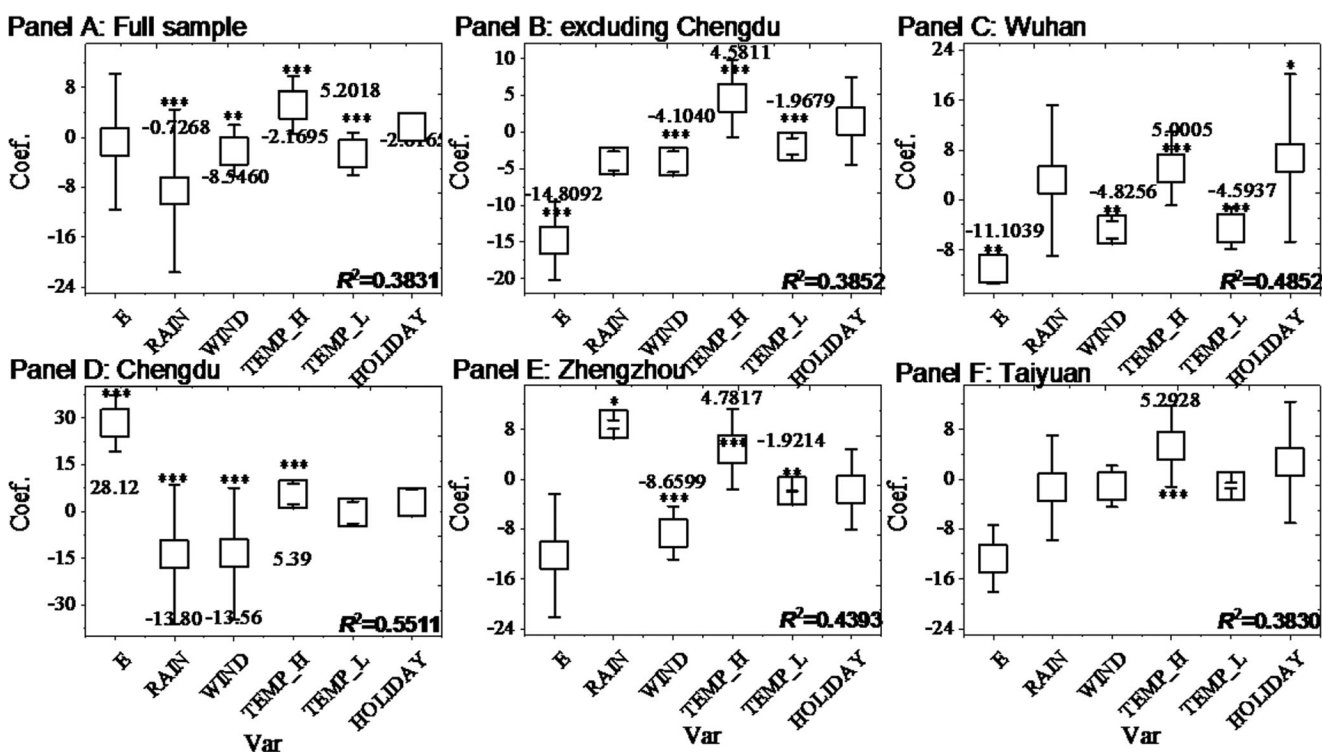


Fig. 2 Regression results. Note: **a** The regression result of the full sample and has 840 samples; **b** the regression result excluding Chengdu and has 627 samples; **c** the regression result of Wuhan and has 210 samples; **d** the regression result of Chengdu and has 213 samples; **e** the regression result of Zhengzhou and has 207 samples; **f** the regression result of Taiyuan and

has 210 samples; *, **, and *** respectively indicate significance levels of 10%, 5%, and 1%. All regressions control weather factors, regional and time effects. Coef. is the estimated coefficient value, the vertical line is 95% CI of the estimated coefficient (Coef.)

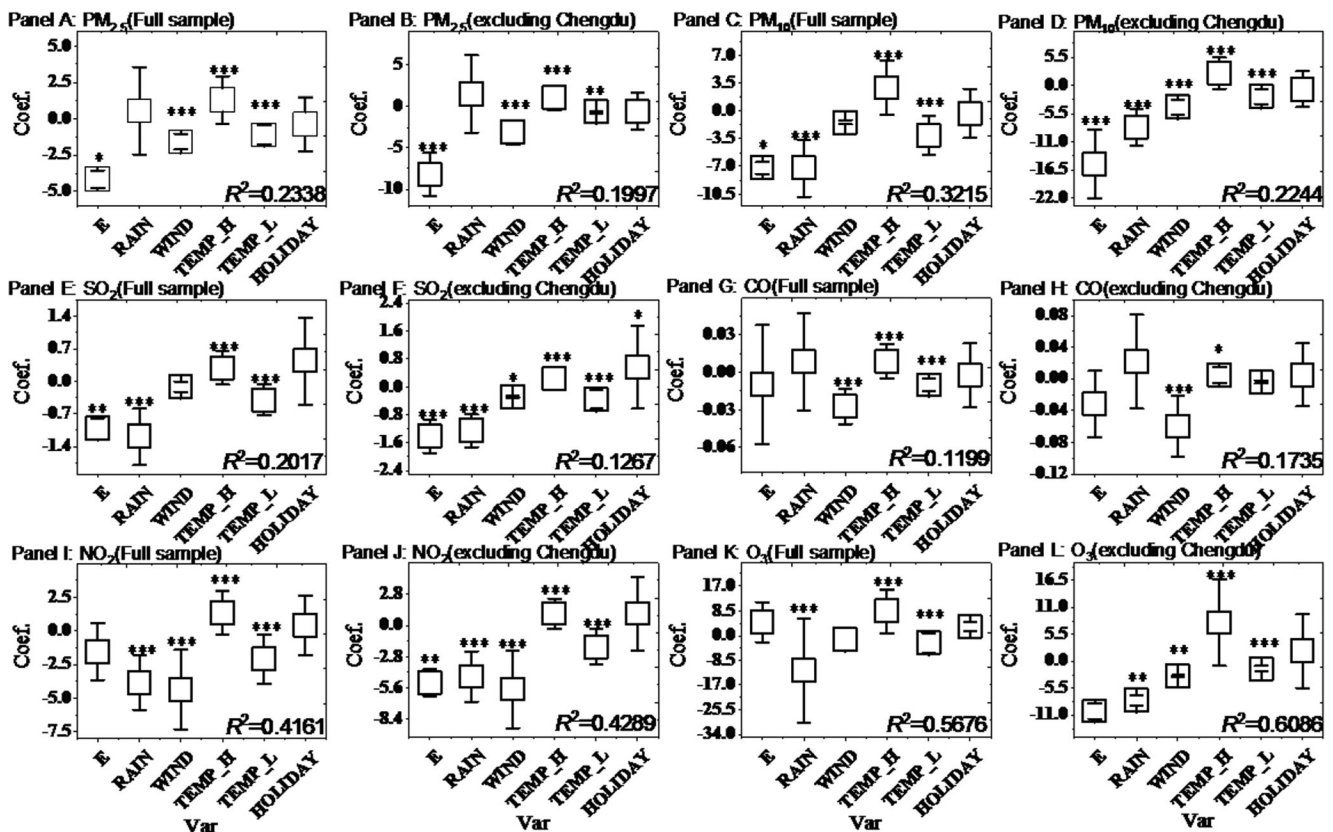


Fig. 3 Regression results of individual pollutant. Note: a b respectively are the estimated results of full sample and excluding Chengdu sample with $PM_{2.5}$ as explained variable; c d respectively are the estimated results of full sample and excluding Chengdu sample with PM_{10} as explained variable; e f respectively are the estimated results of full sample and excluding sample Chengdu sample with SO_2 as explained variable; g h respectively are the estimated results of full sample and

excluding Chengdu sample with CO as explained variable; i j respectively are the estimated results of full example and excluding Chengdu sample with NO_2 as explained vairable; k l respectively are the estimated results of full sample and excluding Chnegdu sample with O_3 as explained variable. The vertical line is 95% CI of the estimated coefficient (Coef.); *, **, and *** respectively indicate significance levels of 10%, 5%, 1%

industrial and construction dust. They are easier to be mitigated by temporary attention than other indicators. SO_2 mainly comes from factory emissions. In addition to car exhaust, a large proportion of NO_2 also comes from factory combustion, so their improvements are also prominent. CO is mainly from motor vehicle exhaust, and O_3 is manifested as the photochemical reaction of air pollution under the influence of sunlight. Therefore, they are not relevant to the events (see Fig. 3G, H, K, L).

Testing the sustainability of “political blue sky”

Overall, according to the regression results above, this evidence suggests that the air quality has been prominently improved during the event in the cities where the government temporarily managed the air quality. But, is this “political blue sky” sustainable? In order to examine this issue, some dummy variables (before and after the event) are added to the equation. We set 5 days as a unit and add several variables into regression, including “11–15 days before the event (B3),” “6–10 days before the event

(B2),” “1–5 days before the event (B1),” and “1–5 days after the event (A1),” “6–10 days after the event (A2),” and “11–15 days after the event (A3).”

According to the results (Fig. 4), the air quality began to improve around 10 days before the event, and it improved typically during the event. Nevertheless, the air quality began to deteriorate after the event. Companies reduced or even stopped production after the air governance, which effectively controlled pollution, and created a short blue sky. But when the event ended, the company restarted production and even strengthened the work intensity to make up for the losses during the event, which led to a deterioration of the air quality. Specifically, the indicator AQI first decreased due to the event and then increased again when the events ended. The change trends of $PM_{2.5}$ and PM_{10} are the same as AQI. In the meanwhile, SO_2 and NO_2 also declined, but after the event, both of them proved a slight downward trend or not a significant change, which further illustrates the impact of the event mainly occurs on $PM_{2.5}$ and PM_{10} .

To further explore the sustainability of air quality improvement during events, the data of each city is regressed again

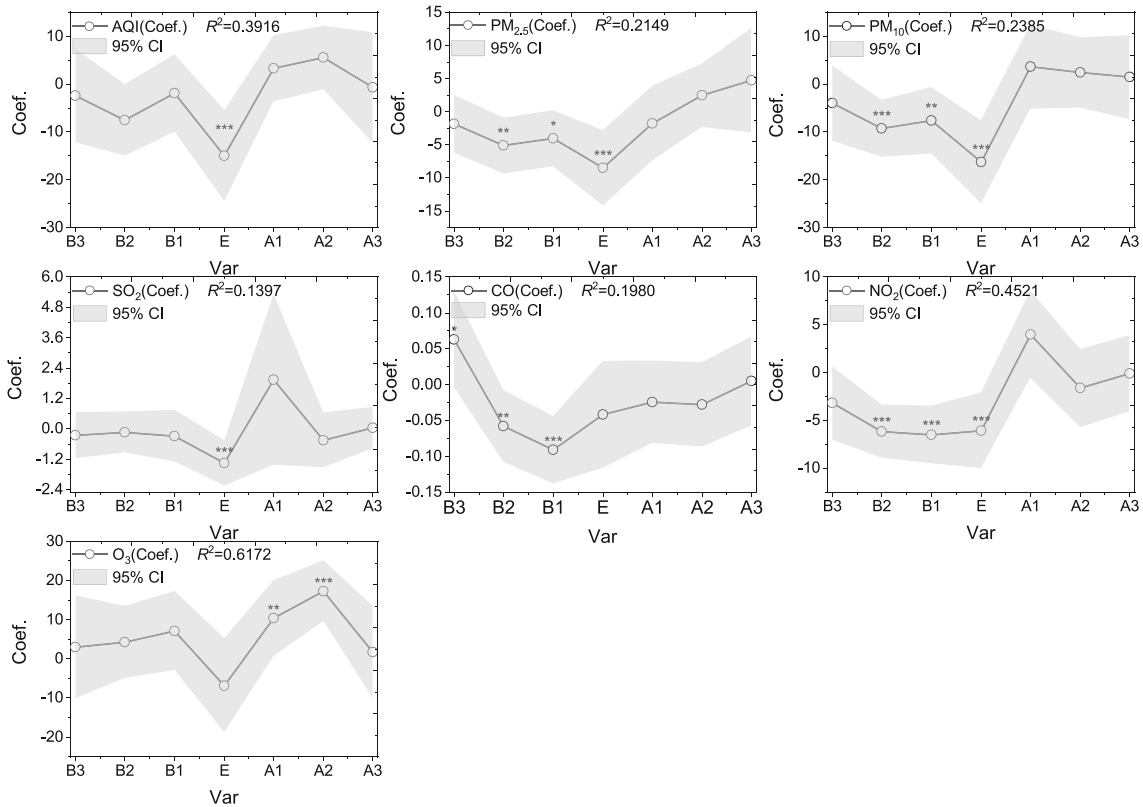
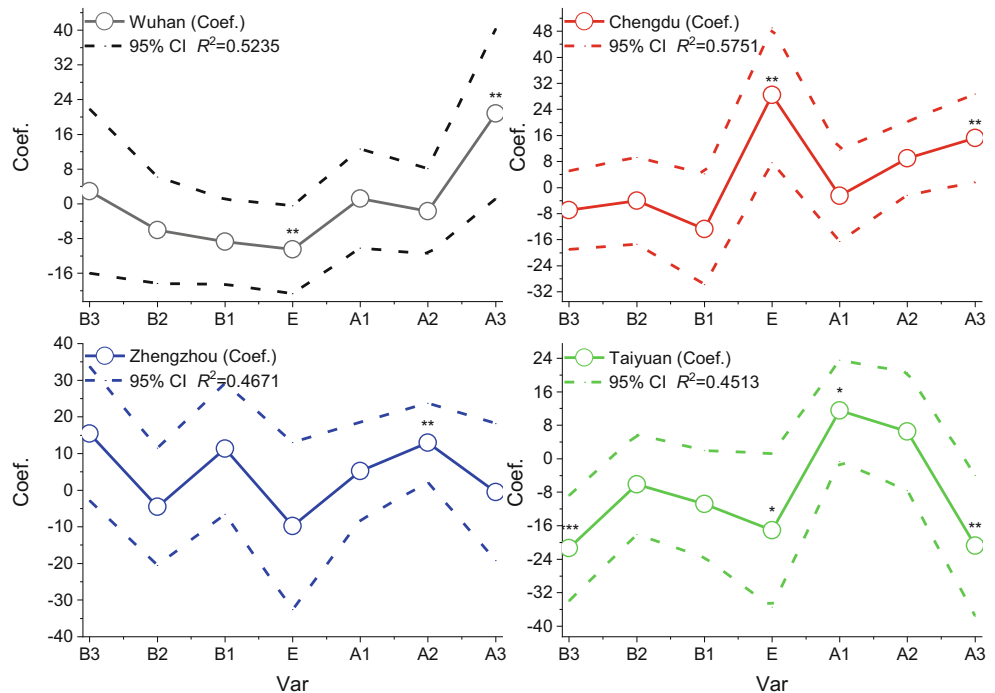


Fig. 4 Changes in air quality indicators before and after the event. Note: *, **, and *** respectively indicate significance levels of 10%, 5%, 1%; the shaded part is the 95% CI of the estimated coefficient (Coef.). The data of Chengdu is deleted here

after adding the aforementioned dummy variables. Analysis testifies that the more provisionally the policy release, the shorter the governance time range, the more obvious the improvement effect is, and even the more severe the retaliatory

rebound is after the event. To be specific, the Wuhan Municipal Government issued a temporary control for nearly 10 days. Figure 5 shows that the air quality started to improve notably about 5 days before the event. And AQI decreased by

Fig. 5 Changes in indicators before and after the events. Note: *, **, and *** respectively indicate significance levels of 10%, 5%, 1%



10.52 during the event. However, the air quality deteriorated rapidly nearly 10 days after the event, and the deterioration was greater than the improvement, which increased by 20.83. Zhengzhou and Taiyuan also had the same trend, which is more moderate, consistent with their long-term policies. Zhengzhou dropped by 9.78 during the event but increased by 12.97 within 10 days after the event. Taiyuan decreased by 17.08 during the event and increased by 11.50 again within 5 days after the event.

RD design

Using the idea of RD design is capable to better solve the problem of event identification. If we can observe a sudden change in air quality during the event, it is reasonable to believe that this sudden change in air quality is caused by the event, that is, the event has a significant impact on air quality; if we cannot, the event is not considered to effect on air quality. Therefore, based on the idea of RD design, trends of time series are added into regression to control the season changes. The starting period is July 9, which is the earliest date of all samples. According to the results, air quality improved conspicuously during the event. Specifically, the regression results show that the air quality is better during the event. AQI decreased by 13.06 in Table 3, which is equivalent to about 15.6% of the average. The coefficients of all single pollutants are negative, and the improvement mainly occurred on PM_{2.5} and PM₁₀, which is the same as the result above.

Robustness analysis⁷

Robustness of AQI

The data of AQI comes from an unofficial website, China Air Quality Online Detection and Analysis Platform, which is the results of the average calculation of hourly data of the General Environmental Protection Station. Therefore, in order to verify the empirical results, the data of AQI published in the National Urban Air Quality Daily of the Ministry of Environmental Protection are used for robustness analysis.

Through simple calculations, we can find that the correlation coefficient between the AQI_E and AQI is as high as

99%, indicating that the trends shown between them are completely consistent, so it is used as a substitute indicator of AQI for robustness. The analysis and regression result scarify that the data of the Ministry of Environmental Protection are consistent with the result above in Table 4. Therefore, the data of AQI used is reliable.

Different time windows

Lee and Lemieux believed that in the design of RD, considering different time windows is also an essential test for the robustness of the results (Lee and Lemieux 2010). If the window period is too long, there will be no contrast due to seasonal changes, and if the window period is too short, it is impossible to obtain accurate estimates of the impact. The window periods of 40 days, 20 days, 15 days, 10 days, and 5 days before and after the event are used as robustness analysis.

The corresponding results demonstrate that, except for Chengdu, in most of the window periods, the air during the event improved obviously in Table 5. At the same time, for each pollutant, it can also be seen that during the event, the decline also mainly reflects on the primary pollutants, such as PM_{2.5} and PM₁₀, which are consistent with former conclusions.

Counterfactual test of events

According to the logic of the analysis above, during the event, local officials pay more attention to environmental protection, and related companies have incentives to reduce emissions, resulting in temporary improvement in air quality. It is also possible to artificially set the event time to make a counterfactual inference. If this artificial time also has a temporary improvement in air quality, the regression results above may be caused by other unobserved factors. The same date of the previous year is set as the event time, and 30 days before and after the period are also included in the regression. The results indicate that the changes are not as obvious as previous results in air quality and most individual pollutants during the artificial event (Table 6), and the correlation is not strong. The counterfactual inference also confirms the reliability of previous conclusion.

Table 3 Regression results of the individual pollutant of the RD design

	AQI	PM _{2.5}	PM ₁₀	SO ₂	CO	NO ₂	O ₃
<i>E</i>	- 13.0645*** (4.6807)	- 6.4310** (2.5974)	- 11.6415*** (3.7881)	- 0.9533** (0.4526)	- 0.0156 (0.0351)	- 3.0033 (1.9149)	- 10.3751* (6.0390)
<i>N</i>	627	627	627	627	627	627	627
<i>R</i> ²	0.4009	0.2547	0.3273	0.1823	0.2044	0.5201	0.6087

Note: *, **, and *** respectively indicate significance levels of 10%, 5%, 1%. The data of Chengdu is deleted here

Table 4 Robustness of AQI

	AQI_E		Wuhan	Chengdu	Zhengzhou	Taiyuan
	(1)	(2)				
<i>E</i>	− 0.5287 (5.1106)	− 14.6474*** (4.7828)	− 11.2752** (4.4422)	26.9558*** (9.5880)	− 12.1640 (11.0530)	− 11.1972 (9.1531)
<i>N</i>	840	627	210	213	207	210
<i>R</i> ²	0.3753	0.3801	0.4748	0.5524	0.4436	0.4067

Note: (1) is the full sample regression result and (2) deletes the data of Chengdu. *, **, and *** respectively indicate significance levels of 10%, 5%, 1%

Discussion

Based on the empirical study of AQI and individual pollutant data from four Chinese cities that had hosted major international events in 2019, results suggest that “political blue sky” is a common phenomenon for pollution governance in various regions. Firstly, three cities of them distinctly improved the air quality during the event, which were closely related to the government’s temporary treatment. The regression results of the individual pollutant also indicate that the improvement of air quality during the event mainly occurred on PM_{2.5} and PM₁₀, because these indicators are the main sources of haze, which attract widely attention from the public and the government. Then, the test of the sustainability of blue sky fully demonstrates that the temporary governance which had obvious short-term effect was inapplicable for long-term planning. It turns out that some environmental policies caused more severe retaliatory pollution after the event, and the degree was even greater than improvement. Air quality deteriorated

again as companies restarted production and even strengthened the work intensity to make up for the losses. In other words, “political blue sky” created by the short-term emphasis on environmental protection is at the cost of more vengeful pollution. And a series of robustness analyses verify the reliability of previous results.

As in previous studies, the results reconfirm that in some sensitive periods, local governments have attached great importance to haze management, resulting in temporary improvement in air quality. Nevertheless, as existing researches focus more on political activities, such as China’s two sessions or economic conferences, few articles pay attention to the impact of major international events on haze governance. This paper takes Wuhan Military World Games as an opportunity to explore the impact of international events on environmental governance under the influence of “political blue sky,” which is helpful for the government to formulate and implement corresponding decisions and measures.

Table 5 Robustness with different time windows

	40 days	20 days	15 days	10 days	5 days
AQI	− 15.4615*** (4.9904)	− 14.3614*** (4.7725)	− 14.2988*** (4.9492)	− 13.3812** (5.2049)	− 13.8809*** (5.2240)
PM _{2.5}	− 8.7017*** (3.008)	− 7.9388*** (2.8343)	− 8.8087*** (2.9042)	− 7.6451** (3.0088)	− 7.3297** (2.9573)
PM ₁₀	− 14.6715*** (4.4582)	− 15.7398*** (4.2637)	− 18.0572*** (4.2383)	− 17.3999*** (4.4486)	− 19.5900*** (5.0325)
SO ₂	− 1.1731** (0.4440)	− 1.3917** (0.5658)	− 1.1360** (0.4553)	− 1.3910*** (0.4923)	− 1.4901** (0.6209)
CO	− 0.0347 (0.0378)	− 0.0394 (0.0381)	− 0.0634 (0.0393)	− 0.0447 (0.0409)	− 0.0514 (0.0467)
NO ₂	− 4.1509 (1.9096)	− 5.7463*** (2.0615)	− 6.1853*** (2.1363)	− 6.4972*** (2.2504)	− 6.9538*** (2.5833)
O ₃	− 9.8474(5.9884)	− 11.5953* (6.1217)	− 11.9761* (6.2305)	− 10.7539 (6.5352)	− 9.7130 (7.0134)

Note: *, **, and *** respectively indicate significance levels of 10%, 5%, 1%. The table shows the regression coefficient of the event when each variable in the first column issued as the explained variable. This table combines multiple tables and omit other variables to save space. The data of Chengdu is deleted here

Table 6 Artificially event time

	AQI	PM _{2.5}	PM ₁₀	SO ₂	CO	NO ₂	O ₃
E_a	- 7.8147 (5.3715)	- 5.6017** (2.4622)	- 4.6862 (4.6436)	0.3989 (0.9467)	- 0.0980** (0.0402)	1.8711 (2.8919)	- 8.1971 (7.8519)
N	627	627	627	627	627	627	627
R^2	0.3787	0.1945	0.2120	0.1229	0.1809	0.4253	0.6080

Note: *, **, and *** respectively indicate significance levels of 10%, 5%, 1%. The data of Chengdu is deleted here

Conclusions and policy implications

Conclusions

During some certain sensitive times, the local government will adopt temporary measures to control pollution and create a harmonious scene of blue sky. This “political blue sky” appeared in the 2008 Beijing Olympic Games and the 2014 APEC conference, which seems to have become a “magic weapon” for air pollution management at all levels of government. However, the sustainability of this “political blue sky” is questionable. Many scholars have already conducted related studies about it. Based on an in-depth analysis of their theoretical basis, this paper selected the data of AQI and individual pollutant from four Chinese cities that have hosted major international events in 2019 to make an empirical study. There are still several things to be improved. Because of limited ability and effort, only city variables are selected to analyze regional effects, lacking more detailed study of heterogeneity, such as terrain and development of each city, which needs further analysis and discussion. At present, our results show that “political blue sky” is a regular measure for pollution governance in some cities. Then, the improvement of air quality during the events mainly occurred on PM_{2.5} and PM₁₀. At the same time, sustainability analysis shows that “political blue sky” comes at the cost of more serious pollution after political events. In order to achieve a real sense of blue sky, the “political blue sky” created by temporary measures is not advisable.

Policy implications

Due to the typical external characteristics that environment has, the pollution management must rely on the power of government to control, especially the role of local governments. In certain special periods, it is easy to create a temporary “political blue sky” through some political orders, but the research conclusions demonstrate that it is not sustainable and usually accompanied by retaliatory pollution. Therefore, it must be recognized that fog and haze management is not a short-term work, but long-term institutional arrangements.

The priority is to change temporary measures to normal supervision. Fog and haze management should focus on

motivating and guiding the government to the source of pollution. In terms of industrial transformation, it is necessary to steadily eliminate backward production capacity and link with the performance assessment of local governments, rather than leaving it as usual and suspending production in sensitive periods to meet the inspections.

Technological innovation is the key to promote industrial green transformation and development. Meanwhile, increasing investment in research plays a policy-oriented role. In environmental protection law enforcement, the authority of environmental protection departments should be increased, so that environmental protection will get on the track of normalization, instead of the current situation.

In the performance assessment, innovative indicators must be put more emphasis on and reform evaluation system of government so that officials will more rely on technological innovation to promote environmental governance. The air quality monitoring system and assessment indicators must be improved, and we should establish warning mechanism to deal with severe air pollution, such as haze.

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