Blue Beijing: Estimating the Effects of Temporary Emissions Restrictions on Air Quality

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Abstract

The paper uses a quasi-experimental regression discontinuity approach to estimate the effect of temporary emissions restrictions on air quality in China. While temporary emissions control is an effective strategy in response to high pollution events, China has been using this temporary policy instrument to improve air quality during events of international exposure. We find that post-restrictions peak levels of fine particulate matter are extremely high. This finding uncovers unintended consequences of temporary polluting restrictions.

JEL classification: Q53; Q58

Keywords: Beijing; air quality; temporary emissions restrictions; peak pollution concentrations.

1 Introduction

Temporary emissions restrictions can be an effective strategy in response to high pollution events. For example, on March 23, 2015 Paris implemented temporary measures to counter an increase in air pollution originated from absence of wind, sunshine, drop in temperature, and other meteorological conditions.[1] In China, temporary emissions restrictions have been used to improve air quality during events of international exposure like the 2008 Summer Olympic Games[2], the 2014 Asia-Pacific Economic Cooperation (APEC) meetings[3], and the 2015 Military Parade in celebration of the 70th anniversary of the end of World War II.[4]

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[1]The set of temporary restrictions affected Paris and 22 surrounding areas and involved a reduction of the speed limit and a ban of vehicles with uneven number plates. The restrictions reduced traffic jams by approximately 40%. Source: `http://www.theguardian.com/world/2015/mar/23/paris-smog-pollution-emergency-measures-traffic`. Accessed on March 31, 2016.

[2]See Chen et al. (2013b).

[3]See: `http://www.theguardian.com/world/2014/nov/04/beijing-smokescreen-hide-pollution-apec`. Accessed on March 31, 2016.

[4]See: `http://www.cnn.com/2015/09/04/asia/china-beijing-blue-sky-disappears-after-military-parade/`. Accessed on March 31, 2016.

The paper examines two sets of short-term restrictions imposed in Beijing around the days of the APEC meetings (November 10-12, 2014) and the celebratory Military Parade (September 3, 2015). While these two short-term restrictions events lasted for 10 and 15 days respectively, the air quality policies implemented before the 2008 Olympics involved both short-term restrictions and long-term regulation changes like adopting new vehicle emission standards, conversion of coal furnace into clean fuels, and plants relocation, with air quality improvement policies implemented as early as December 13, 2001 (see Chen et al. 2013b).

Papers in the natural science literature have reported a short-term pollution reduction induced by the APEC restrictions (e.g. Huang et al., 2015). We add to this debate by employing a regression discontinuity identification strategy, and by comparing the set of APEC restrictions with that of the Military Parade. Our approach allows us to compare the impact of the implementation of the restrictions with the impact of lifting them. We find that the Military Parade restrictions were more successful in inducing short-term improvements in air quality than the APEC restrictions. Most importantly, we find that post-restrictions peak levels of fine particulate matter are extremely high. This finding uncovers unintended consequences of temporary polluting restrictions.

2 Temporary Emissions Restrictions in China

Both sets of restrictions (APEC and Parade) were implemented to reduce emissions caused by industrial production and vehicles; however, there were differences both in their duration and design. Table 1 presents a summary of the restrictions. The table was constructed based on information from the Chinese and American media and the Chinese Government. In general, the restrictions around the Military Parade seem tighter than those around the APEC Meetings. For instance, the duration of the restrictions increased from 10 days for the APEC Meetings to 15 days for the Military Parade. In terms of restrictions to production, 9,298 companies in Beijing, Tianjing, and 4 provinces were affected by the first set of restrictions. For the second event, both the number of companies and the geographic region affected by the restrictions increased. The Military Parade restrictions affected 12,255 companies in Beijing, Tianjing, the 4 provinces affected in the APEC meeting, plus the companies in the province of Henan. Also, the second set of restrictions banned 80% of public vehicles, in contrast to 70% of in the APEC Meetings restrictions.[5]

[5]For both events, the Chinese Ministry of Environmental Protection sent 15 inspection teams to important locations across different municipalities and provinces. Sources: South China Morning Post (`http://www.scmp.com/news/china/article/1627530/drones-and-inspection-teams-used-monitor-pollution-ahead-apec-summit`) and Caixin Online (`http://english.caixin.com/2015-08-20/100841881.html`). Both websites accessed on March 31, 2015.

Table 1: Summary of Restrictions

	APEC Meetings	Military Parade
Date of the event (duration)	November 10-12, 2014 (3 days)	September 3, 2015 (1 day)
Dates of the restrictions (duration)	Nov 3-12 (10 days)	Aug 20 - Sept 3 (15 days)
Private vehicle utilization restrictions	50% of private cars banned based on even/odd numbered license plate rotation. Vehicles used to transport dregs were banned from driving at all times.	50% of private cars banned based on even/odd numbered license plate rotation. Vehicles used to transport construction waste, tanker trucks, and other heavy trucks were banned from driving at all times.
Public vehicle utilization restrictions	70% of vehicles belonging to local governments, public institutions, social groups and state-owned enterprises were banned	80% of vehicles belonging to local governments, public institutions, social groups and state-owned enterprises were banned
Production restrictions	In Beijing, 69 firms were shut down and limited production was imposed on 72 firms. In total, 9298 companies curtailed operations in 2 municipalities (Beijing and Tianjing) and 4 provinces (Shandong, Shanxi, Inner Mongolia, Hebei)	In Beijing, 1927 firms were shut down or imposed limited production. Overall, the restrictions suspended or restricted the operations of 12,255 coal-burning boilers, factories and cement-mixing stations scattered through 2 municipalities (Beijing and Tianjing) and 5 provinces (Shandong, Shanxi, Inner Mongolia, Hebei, Henan)
Construction restrictions	All construction sites and demolition projects were suspended	All construction sites and demolition projects were suspended

The table was compiled using information from the following sources: China Daily (http://www.chinadaily.com.cn/china/2015-08/03/content_21490018.htm), Nandu Media (http://nandu.media.baidu.com/article/8545561264791106132), Baidu Baike (http://www.baike.com/wiki/APEC%E8%93%9D), China iDigest (http://m.chinaidigest.com/article/1240), Global Times (http://www.globaltimes.cn/content/939302.shtml), and the Los Angeles Times (http://www.latimes.com/world/asia/la-fg-china-air-quality-parade-20150907-story.html). Refer to the Chinese State Council website for more information about emissions restrictions (http://www.gov.cn/xinwen/2014-11/05/content_2775389.htm). All websites accessed on March 31, 2015.

3 Methods and Data

Similarly to Davis (2008), Chen et al. (2013a), and Bento et al. (2014), we evaluate the policy impact on air quality using a quasi-experimental regression discontinuity strategy. The empirical model regresses daily measures of air pollution/air quality (Y) on an indicator for the beginning of the restrictions period (R(beginning), with 0 before the restrictions, 1 at the day they start and after), an indicator for the end of the restrictions (R(end), with 0 before the restrictions end, 1 at the first day they are lifted and after), a set of weather variables (W), a set monthly indicators (M), and a highly flexible (eighth-order) polynomial time trend ($T, T^2, ..., T^8$):

$$Y_t = \alpha + \beta_B R(\text{beginning})_t + \beta_E R(\text{end})_t + \sum_j \delta_j W_{jt} + \sum_i \gamma_i M_i + \sum_{k=1}^{8} \phi_k T_t^k + \varepsilon_t,$$

where t indexes a day, j indexes weather variables, i indexes months, k indexes a time polynomial term, and ε is an error term. The coefficients of interest are β_B and β_E, which reflect the change in air quality at the beginning and end of the restrictions period, respectively. We use OLS to estimate the model. If the restrictions were effective, we expect $\beta_B < 0$ and $\beta_E > 0$.

Air pollution data was collected from two sources: the US embassy in Beijing and the AQIStudy's website.[6] The US embassy reports hourly readings of particular matter 2.5 (μg/m3). These data allow us to calculate daily mean, median, and maximum levels of air pollution. The Chinese AQIStudy's website reports data from the China Air Quality Online Monitoring and Analysis Platform. This nonprofit website collects air quality data for 367 cities in China. In Beijing, readings come from 35 monitoring stations scattered throughout the city. They report daily average levels of six pollutants: particular matter 2.5 (μg/m3), particular matter 10 (μg/m3), sulfur dioxide (μg/m3), carbon monoxide (mg/m3), nitrogen dioxide (μg/m3), and ozone (μg/m3). The AQIStudy also reports a daily Air Quality Index based on the level of these six atmospheric pollutants.[7] As air pollution can be affected by weather, our regression models include daily averages of temperature (degree Celsius), humidity (%), wind speed (km/h), and precipitation (mm). These data were collected from the Weather Underground's website.[8]

Table 2 reports summary statistics of our variables, by year. As we only have data until October 31 2015, the table reports means and standard deviations for each year based on daily information from

[6]Sources: American data, U.S. Department of State (`http://www.stateair.net/web/historical/1/1.html`). Assessed on November 22, 2015. Chinese data, AQIStudy (`http://www.aqistudy.cn/historydata/daydata.php?city=%E5%8C%97%E4%BA%AC&month=201601`). Assessed on November 24, 2015.

[7]Increases in air quality are captured by *decreases* in the AQI. Source: China's Ministry of Environmental Protection (`http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201203/W020120410332725219541.pdf`). Assessed on February 1, 2016.

[8]Source: `http://www.wunderground.com/history/airport/ZBAA/2015/1/1/CustomHistory.html?dayend=18&monthend=12&yearend=2015&req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo`. Assessed on November 24, 2015.

January 1 to October 31. The 2015 statistics are calculated excluding the 15-day period from Aug 20 to Sept 3 of 2015 in which the restrictions for the Military Parade were imposed. This allows for a better comparison of the two years. The table reveals that general air quality improved from 2014 to 2015 as the average levels of all pollutants (except for ozone) decreased. This trend indicates that our estimates should account for unobservable (and potentially non-linear) time-varying determinants of air quality. This is controlled for in our empirical model by the addition of the polynomial time trend.

Table 2: Summary statistics

	2014*			2015*		
	Mean	Std. Dev.	n	Mean	Std. Dev.	n
PM 2.5 US (mean)	98.794	80.454	304	72.954	57.933	289
PM 2.5 US (median)	94.133	83.311	304	68.315	60.318	289
PM 2.5 US (max)	168.859	117.54	304	132.26	96.763	289
PM 2.5	87.108	69.398	304	71.707	56.674	289
PM 10	117.521	73.272	304	97.729	65.283	289
SO2	20.263	24.347	304	12.722	14.409	289
NO2	53.870	22.137	304	46.031	20.945	289
CO	1.208	0.811	304	1.099	0.813	289
O3	124.579	72.080	304	127.208	70.979	289
AQI	123.984	75.593	304	106.443	65.990	289
Temperature	16.064	9.729	304	15.255	9.788	289
Humidity	52.289	19.137	304	52.301	19.556	289
Wind Speed	8.503	3.828	304	9.488	4.555	289
Precipitation	1.335	6.015	304	1.012	3.814	289

* Statistics are based on daily information from January 1 to October 31. 2015 statistics exclude the 15 days (Aug 20 - Sept 3, 2015) in which restrictions were effective.

4 Results

Table 3 collects the estimates of β_B and β_E obtained through different empirical specifications. The specifications differ by left-hand side variable (9 pollutants and the air quality index) and by the data window around the restriction days (from 60 and 80 days before to 60 and 80 days after the restriction period). This varying window allows us to examine the sensitivity of our estimates to the window size.

The estimates of β_B and β_E for the Military Parade regressions are relatively robust to changing window size while estimates for the APEC regressions show more variation. In general, for the APEC meetings, we cannot reject the null of no change in air quality at the beginning of the restrictions. The one exception is the ozone (O3) model that shows a positive and statistically significant estimate of β_B. Ozone may have increased because NOx declined and there were high VOC concentrations, this phenomenon is known as "NOx Disbenefits" or NOx titration and is common in large cities. Unfortunately, due to data limitations we cannot test this hypothesis. Using both windows, we find statistical support for an increase in air pollution at the end of the restrictions in three models: the

Table 3: Regression Discontinuity Estimates of β_B and β_E

	APEC Meetings				Military Parade			
	±60 days		±80 days		±60 days		±80 days	
	Beginning	End	Beginning	End	Beginning	End	Beginning	End
PM 2.5 US (mean)	11.549	70.945*	-3.323	73.695**	-36.041***	56.521***	-32.208**	52.569***
	(42.679)	(38.981)	(40.075)	(36.564)	(11.620)	(16.114)	(12.850)	(14.069)
PM 2.5 US (median)	9.528	76.967	-4.505	80.354*	-35.761***	56.827***	-31.650**	51.146***
	(55.201)	(48.675)	(54.347)	(45.323)	(12.531)	(16.892)	(13.986)	(14.674)
PM 2.5 US (max)	-23.545	53.519	-30.548	85.738	-42.219**	82.356***	-39.629**	78.107***
	(41.261)	(64.808)	(40.030)	(55.052)	(18.635)	(23.602)	(19.702)	(21.010)
PM 2.5	13.507	51.673*	-0.628	52.945*	-37.967***	52.615***	-42.138***	52.078***
	(23.758)	(29.808)	(22.229)	(28.003)	(12.965)	(16.506)	(12.812)	(15.446)
PM 10	-0.551	39.510	-21.792	43.267	-74.589***	56.252***	-69.978***	60.432***
	(25.402)	(35.230)	(23.294)	(35.867)	(21.060)	(18.565)	(18.833)	(19.721)
SO2	-9.487	10.328	-10.862	9.629	-3.316**	2.560*	-2.363*	3.176**
	(8.796)	(6.508)	(8.805)	(6.008)	(1.507)	(1.405)	(1.329)	(1.596)
NO2	-16.317	25.333*	-19.155	25.336**	-15.054***	21.048***	-11.062***	19.807***
	(12.110)	(10.333)	(11.631)	(10.267)	(3.620)	(7.391)	(3.458)	(6.920)
CO	-0.385	0.547	-0.429	0.660**	-0.210**	0.554***	-0.139	0.361**
	(0.411)	(0.346)	(0.390)	(0.326)	(0.102)	(0.147)	(0.163)	(0.162)
O3	47.722***	1.785	42.850***	-2.466	-85.062***	55.880***	-78.444**	61.790***
	(11.539)	(13.810)	(11.372)	(13.584)	(32.636)	(19.651)	(31.774)	(17.460)
AQI	16.964	42.551	-0.743	46.459	-53.521***	66.147***	-53.556***	66.663***
	(23.719)	(35.084)	(22.282)	(33.819)	(16.093)	(19.828)	(15.211)	(19.063)

Notes: Estimates collected from Tables 4-7 (see Appendix). All regressions include a polynomial trend, weather variables, monthly dummies, and a constant. Robust standard errors are reported in parenthesis. $*p < 0.10, **p < 0.05, ***p < 0.01$.

two average fine particulate matter models (PM 2.5 US (mean) and PM 2.5) and the nitrogen dioxide model (NO2). Specifically, when using the ±60 days window, we find that once the APEC restrictions were lifted the level of these pollutants increased by 70.9 μg/m3, 51.7 μg/m3, and 25.33 μg/m3, respectively. These increases represent approximately 0.88, 0.75, and 1.14 standard deviations of their respective 2014 distribution of pollution (see table 2). The median fine particulate matter (PM 2.5, median) and carbon (CO) models show a statistically significant β_E for the ± 80 days window.

We find statistical evidence that the Military Parade improved air quality during the restrictions period. In contrast with the APEC models, the Military parade estimates of β_B and β_E are statistically significant in all models (with the exception of β_B in the CO ±80 model). This suggests that the Military Parede event was more successful in promoting general air quality improvements during the restrictions days. However, our estimates show that improvements in air quality vanish once the restrictions are lifted. In general, we find that $|\beta_B| < |\beta_E|$.

The difference between the absolute value of these two estimates is particularly large in the PM 2.5 US (max) regressions. Using the ±60 days window, our results show that, on average, the implementation of the Military Parade restrictions decreased maximum levels of PM 2.5 by 42.2 g/m3, and once the restrictions were lifted maximum levels of PM 2.5 increased by 82.4 μg/m3. This indicates that Beijing's maximum intra-day concentration of PM 2.5 approximately decreased from its average of 132.3 μg/m3 to 90.1 μg/m3 at the beginning of the restrictions period, and then increased to the dangerously high level of 172.5 μg/m3 once the restrictions were lifted.[9]

5 Discussion

Fine particles pose great health risks as, due to their small size (approximately 1/30th the width of a human hair), they can lodge deeply into the lungs.[10] Our results suggest that, once the Parade restrictions were lifted, PM 2.5 peak concentrations in Beijing reached levels almost 5 times greater than the EPA 24-hour fine particle standard (35 μg/m3)[11], and almost 7 times greater than the WHO standard (25 μg/m3)[12]. At these levels, the Environmental Protection Agency (2013) classifies air quality as "very unhealthy",[13] and recommends that people with heart or lung disease should avoid all physical activity outdoors, and everyone else should avoid prolonged or heavy exertion.[14]

The medical literature is rife with studies about the short-term adverse health effects of particulate matter and other air pollutants (e.g. Katsouyanni et al., 1997; Bell et al., 2004). While the use of temporary emissions restrictions not motivated by high pollution events seems to be a harmless initiative, our results uncover unintended consequences of such short-term regulations as they show that air pollution can reach very unhealthy levels once the restrictions are lifted. These temporary restrictions can be specially harmful if there are nonlinearities in the relationship between air pollution and health such that potential health benefits from better air quality during the restrictions days are outweighed by the harm of extreme pollutant concentrations once restrictions are lifted. Further research using detailed air pollution and health data is needed to explore possible welfare losses from such type of emissions restrictions.

Disclosure statement

No potential conflict of interest was reported by the authors.

[9]Similar results are found using the ±80 days window.
[10]Source: `https://www3.epa.gov/pmdesignations/faq.htm`. Accessed on March 29, 2016.
[11]Source: `https://www.epa.gov/criteria-air-pollutants/naaqs-table`. Accessed on March 29, 2016.
[12]See World Health Organization (2006).
[13]Also available at `https://www3.epa.gov/pm/2012/decfsstandards.pdf`. Accessed on March 29, 2016.
[14]Source: `https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf`. Accessed on March 29, 2016.

Table 4: Regression Discontinuity Estimates: window of 60 days before and after the APEC Restrictions

	PM25 US (mean)	PM25 US (median)	PM25 US (max)	PM25	PM10	SO2	NO2	CO	O3	AQI
APEC Beginning	11.549	9.528	-23.545	13.507	-0.551	-9.487	-16.317	-0.385	47.722***	16.964
	(42.679)	(55.201)	(41.261)	(23.758)	(25.402)	(8.796)	(12.110)	(0.411)	(11.539)	(23.719)
APEC End	70.945*	76.967	53.519	51.673*	39.510	10.328	25.333**	0.547	1.785	42.551
	(38.981)	(48.675)	(64.808)	(29.808)	(35.230)	(6.508)	(10.333)	(0.346)	(13.810)	(35.084)
Temperature	5.531*	4.432	18.591***	9.627***	6.186**	-0.249	1.017	0.052*	8.734***	10.268***
	(3.114)	(3.296)	(5.194)	(2.619)	(3.119)	(0.443)	(0.997)	(0.028)	(1.882)	(2.925)
Humidity	4.325***	4.416***	3.861***	3.409***	3.431***	0.175**	0.707***	0.037***	-0.335*	3.878***
	(0.502)	(0.516)	(0.866)	(0.400)	(0.494)	(0.083)	(0.138)	(0.005)	(0.185)	(0.452)
Wind Speed	-0.543	-0.770	-3.117*	0.127	-0.484	-1.189***	-2.191***	-0.040***	0.789**	0.899
	(0.975)	(1.063)	(1.812)	(0.772)	(1.095)	(0.218)	(0.360)	(0.012)	(0.357)	(0.956)
Precipitation	-8.498***	-8.815***	-10.037***	-7.870***	-7.721***	-0.509**	-1.341**	-0.061***	-3.873	-9.169***
	(2.307)	(2.299)	(2.656)	(2.124)	(2.701)	(0.254)	(0.672)	(0.018)	(2.479)	(2.522)
Constant	-5987.824***	-5491.526***	-8853.609***	-5165.543***	-8122.682***	-368.597	-1212.978*	-41.928**	-325.640	-6759.583***
	(1836.570)	(1899.981)	(2895.941)	(1474.596)	(2017.257)	(323.270)	(730.608)	(18.235)	(1406.331)	(1776.032)
N	130	130	130	130	130	130	130	130	130	130
r2	0.717	0.697	0.626	0.735	0.676	0.733	0.751	0.743	0.742	0.714

Notes: All regressions include monthly dummies and an eighth-order polynomial trend. Robust standard errors are reported in parenthesis.
$*p < 0.10, **p < 0.05, ***p < 0.01$.

Table 5: Regression Discontinuity Estimates: window of 80 days before and after the APEC Restrictions

	PM25 US (mean)	PM25 US (median)	PM25 US (max)	PM25	PM10	SO2	NO2	CO	O3	AQI
APEC Beginning	-3.323	-4.505	-30.548	-0.628	-21.792	-10.862	-19.155	-0.429	42.850***	-0.743
	(40.075)	(54.347)	(40.030)	(22.229)	(23.294)	(8.805)	(11.631)	(0.390)	(11.372)	(22.282)
APEC End	73.695**	80.354*	85.738	52.945*	43.267	9.629	25.336**	0.660**	-2.466	46.459
	(36.564)	(45.323)	(55.052)	(28.003)	(35.867)	(6.008)	(10.267)	(0.326)	(13.584)	(33.819)
Temperature	8.560***	7.796**	18.917***	11.391***	9.848***	0.067	1.642*	0.069***	11.117***	12.999***
	(3.190)	(3.389)	(4.643)	(2.690)	(3.270)	(0.371)	(0.928)	(0.026)	(1.951)	(3.099)
Humidity	3.729***	3.798***	3.949***	3.089***	2.838***	0.089	0.508***	0.033***	-0.506***	3.438***
	(0.440)	(0.492)	(0.683)	(0.364)	(0.472)	(0.063)	(0.116)	(0.004)	(0.194)	(0.412)
Wind Speed	-1.542	-2.045*	-2.038	-0.499	-1.554	-1.391***	-2.593***	-0.046***	0.546	0.024
	(0.961)	(1.182)	(1.737)	(0.753)	(1.132)	(0.227)	(0.392)	(0.012)	(0.395)	(0.956)
Precipitation	-0.959	-1.101	-0.123	-0.835	-1.653**	-0.172***	-0.289**	-0.005	-0.696*	-1.077
	(0.670)	(0.704)	(0.781)	(0.585)	(0.710)	(0.060)	(0.141)	(0.005)	(0.400)	(0.714)
Constant	-319.745***	-266.954**	-561.574***	-355.587***	-331.140***	28.031*	-25.247	-1.918**	103.438	-399.652***
	(97.620)	(107.258)	(167.236)	(78.150)	(106.330)	(14.415)	(29.644)	(0.868)	(67.960)	(95.531)
N	170	170	170	170	170	170	170	170	170	170
r2	0.682	0.652	0.590	0.695	0.606	0.739	0.726	0.734	0.794	0.666

Notes: All regressions include monthly dummies and an eighth-order polynomial trend. Robust standard errors are reported in parenthesis.
$*p < 0.10, **p < 0.05, ***p < 0.01$.

Table 6: Regression Discontinuity Estimates: window of 60 days before and after the Military Parade Restrictions

	PM25 US (mean)	PM25 US (median)	PM25 US (max)	PM25	PM10	SO2	NO2	CO	O3	AQI
Parade Beginning	-36.041***	-35.761***	-42.219**	-37.967***	-74.589***	-3.316**	-15.054***	-0.210**	-85.062**	-53.521***
	(11.620)	(12.531)	(18.635)	(12.965)	(21.060)	(1.507)	(3.620)	(0.102)	(32.636)	(16.093)
Parade End	56.521***	56.827***	82.356***	52.615***	56.252***	2.560*	21.048***	0.554***	55.880***	66.147***
	(16.114)	(16.892)	(23.602)	(16.506)	(18.565)	(1.405)	(7.391)	(0.147)	(19.651)	(19.828)
Temperature	10.944***	10.626***	16.065***	12.638***	10.420***	0.371**	1.848***	0.075***	13.167***	15.429***
	(1.774)	(2.039)	(2.575)	(2.074)	(1.865)	(0.159)	(0.491)	(0.014)	(2.351)	(2.305)
Humidity	2.010***	2.030***	2.600***	2.213***	0.831**	0.009	0.159	0.018***	-0.370	2.217***
	(0.385)	(0.418)	(0.518)	(0.432)	(0.351)	(0.030)	(0.108)	(0.003)	(0.405)	(0.487)
Wind Speed	-1.278	-1.421	-1.934	-0.777	-2.665**	-0.246**	-2.244***	-0.013	-5.344***	-1.577
	(1.290)	(1.342)	(1.878)	(1.445)	(1.162)	(0.105)	(0.366)	(0.010)	(1.355)	(1.619)
Precipitation	-0.508	-0.530	-0.802	-0.383	-0.035	-0.047	-0.099	0.004	-0.591	-0.422
	(0.331)	(0.353)	(0.484)	(0.365)	(0.473)	(0.031)	(0.172)	(0.004)	(0.757)	(0.405)
Constant	879.030	730.077	628.541	-409.871	1281.529	117.503	655.971	8.684	1888.276	344.530
	(1402.983)	(1340.143)	(2076.581)	(1597.337)	(1699.404)	(201.410)	(404.425)	(13.718)	(1907.935)	(1800.507)
N	133	133	133	135	135	135	135	135	135	135
r2	0.603	0.564	0.633	0.607	0.553	0.413	0.744	0.639	0.717	0.626

Notes: All regressions include monthly dummies and an eighth-order polynomial trend. Robust standard errors are reported in parenthesis.
$*p < 0.10, **p < 0.05, ***p < 0.01$.

Table 7: Regression Discontinuity Estimates: window of 80 days before and after the Military Parade Restrictions

	PM25 US (mean)	PM25 US (median)	PM25 US (max)	PM25	PM10	SO2	NO2	CO	O3	AQI
Parade Beginning	-32.208**	-31.650**	-39.629**	-42.138***	-69.978***	-2.363*	-11.062***	-0.139	-78.444**	-53.556***
	(12.850)	(13.986)	(19.702)	(12.812)	(18.833)	(1.329)	(3.458)	(0.163)	(31.774)	(15.211)
Parade End	52.569***	51.146***	78.107***	52.078***	60.432***	3.176**	19.807***	0.361**	61.790***	66.663***
	(14.069)	(14.674)	(21.010)	(15.446)	(19.721)	(1.596)	(6.920)	(0.162)	(17.460)	(19.063)
Temperature	10.526***	10.278***	15.114***	12.286***	10.422***	0.534***	2.122***	0.077***	10.636***	15.228***
	(1.654)	(1.884)	(2.318)	(1.905)	(1.603)	(0.147)	(0.476)	(0.027)	(1.988)	(2.110)
Humidity	1.870***	1.915***	2.423***	1.895***	0.485*	0.002	0.119	0.021***	-0.319	1.943***
	(0.335)	(0.365)	(0.453)	(0.366)	(0.282)	(0.025)	(0.094)	(0.004)	(0.381)	(0.408)
Wind Speed	-1.662	-1.726	-2.531	-1.870*	-3.659***	-0.295***	-2.315***	-0.031*	-3.753**	-2.578**
	(1.106)	(1.167)	(1.592)	(1.047)	(0.872)	(0.082)	(0.275)	(0.018)	(1.444)	(1.171)
Precipitation	-0.603	-0.638*	-1.007*	-0.540	0.051	-0.033	-0.050	-0.005	-0.606	-0.585
	(0.367)	(0.374)	(0.565)	(0.422)	(0.414)	(0.034)	(0.138)	(0.006)	(0.657)	(0.459)
Constant	-175.296***	-174.951***	-250.157***	-214.205***	-37.937	5.005	57.757***	1.777	-47.696	-208.367**
	(61.463)	(65.059)	(92.582)	(79.446)	(71.995)	(6.809)	(20.863)	(1.757)	(87.328)	(90.868)
N	152	152	152	175	175	175	175	175	175	175
r2	0.598	0.561	0.627	0.638	0.548	0.415	0.759	0.501	0.719	0.649

Notes: All regressions include monthly dummies and an eighth-order polynomial trend. Robust standard errors are reported in parenthesis.
$*p < 0.10, **p < 0.05, ***p < 0.01$.

References

Bell, M. L., A. McDermott, S. L. Zeger, J. M. Samet, and F. Dominici (2004). Ozone and short-term mortality in 95 US urban communities, 1987-2000. *Journal of the American Medical Association 292*(19), 2372–2378.

Bento, A., D. Kaffine, K. Roth, and M. Zaragoza-Watkins (2014). The effects of regulation in the presence of multiple unpriced externalities: Evidence from the transportation sector. *American Economic Journal: Economic Policy 6*(3), 1–29.

Chen, Y., A. Ebenstein, M. Greenstone, and H. Li (2013a). Evidence on the impact of sustained exposure to air pollution on life expectancy from chinas huai river policy. *Proceedings of the National Academy of Sciences 110*(32), 12936–12941.

Chen, Y., G. Z. Jin, N. Kumar, and G. Shi (2013b). The promise of Beijing: evaluating the impact of the 2008 olympic games on air quality. *Journal of Environmental Economics and Management 66*(3), 424–443.

Davis, L. W. (2008). The effect of driving restrictions on air quality in mexico city. *Journal of Political Economy 116*(1), 38–81.

Environmental Protection Agency (2013). National ambient air quality standards for particulate matter. *Federal Register 78*(10), 3085–3287.

Huang, K., X. Zhang, and Y. Lin (2015). The apec blue phenomenon: Regional emission control effects observed from space. *Atmospheric Research 164*, 65–75.

Katsouyanni, K., G. Touloumi, C. Spix, J. Schwartz, F. Balducci, S. Medina, G. Rossi, B. Wojtyniak, J. Sunyer, L. Bacharova, et al. (1997). Short term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. *British Medical Journal 314*(7095), 1658.

World Health Organization (2006). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: global update 2005: summary of risk assessment.