Economics
The Open-Access, Open-Assessment E-Journal

Discussion Paper
No. 2013-30 | May 08, 2013 | http://www.economics-ejournal.org/economics/discussionpapers/2013-30

Environmental Impact of the 2008 Beijing Olympic Games

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Abstract
Beijing organized the 2008 Summer Olympic Games, and the main goal of the Chinese government regarding this event was to hold a "Green Olympics". A difference-in-differences approach was used to estimate the environmental impact the Olympic Games on air quality improvement in Beijing, compared to improvements in other areas in China. The results indicate that compared to other regions, air quality in Beijing improved for a short period of time. These improvements were largely due to the implementation of several temporary measures, including factory closures and traffic control. However, there is no evidence indicating that the Olympic Games reduced the concentration of sulfur dioxide in Beijing.

JEL Q51 Q53 L83 G14
Keywords Olympic Games; Beijing; air pollution; impact estimate; difference-in-differences approach

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Citation Cao Huijuan, Hidemichi Fujii, and Shunsuke Managi (2013). Environmental Impact of the 2008 Beijing Olympic Games. Economics Discussion Papers, No 2013-30, Kiel Institute for the World Economy. http://www.economics-ejournal.org/economics/discussionpapers/2013-30

Received May 2, 2013 **Accepted as Economics Discussion Paper** May 5, 2013 **Published** May 8, 2013

1. Introduction

Beijing organized the 2008 Olympic Games with the slogan, “Green Olympics, Hi-tech Olympics and People’s Olympics”. This slogan illustrates the determination of the Chinese government to offer an environmentally friendly yet impressive Olympic event. To improve air quality during the 2008 Summer Olympics (August 8–24) and the Paralympic Games (September 9–17), the Beijing government implemented various aggressive measures, both in Beijing and in the surrounding area. These temporary measures mainly focused on the industrial sector and traffic control and were considered to be effective by the Chinese government.

A specific industrial pollution control policy was enforced in 2008. Power plants were required to reduce their emissions by 30% from their levels in June. This reduction was required even for plants that had already met the Chinese emission standards. Moreover, certain heavily polluting factories were ordered to reduce their operating capacities, whereas others were completely shut down (Liu et al., 2012). To strictly control air pollutant emissions, the Beijing municipal government announced an “Air Quality Guarantee Plan for the 29th Olympic Games in Beijing”. In this plan, similar control measures were extended to surrounding areas, including Tianjin, Hebei, Shanxi, Inner Mongolia, and Shandong (all of these areas belong to Group C[1]) (Wang et al., 2010b). In Tianjin and Hebei (both of which belong to Group B), this policy was compulsorily and strictly implemented. However, for Shanxi, Inner Mongolia, and Shandong, the plan was only implemented if air conditions became extremely serious. Wang et al. (2010b) found that in June 2008, the daily emissions of sulfur dioxide (SO2), nitrogen dioxide (NOx), and particulate matter (PM10) in Beijing totaled 103.9, 428.5, and 362.7 tons, respectively. During the Olympic Games, the daily emissions of SO2, NOx, and PM10 in Beijing were reduced to 61.6, 229.1, and 164.3 tons, which were 41, 47, and 55% lower than the respective June 2008 emission levels. Additionally, factory closures reduced the SO2 emissions by 8s5% in the industrial sector (Wang et al., 2010b).

< Figure 1 about here >

To reduce the emissions of NOx, and PM10, traffic control measures were also enforced in Beijing in 2008. First, from July 1 to September 20, all on-road vehicles (including trucks and passenger cars) that failed to meet the Euro I emissions standards were banned from Beijing's roads. Second, mandatory restrictions that limited the use of government vehicles were implemented from July 20 to September 20. Additionally, the number of personal vehicles in use was reduced by 50%. Personal vehicles were allowed on roads only on alternate days based on

[1] In this study, Beijing was defined as Group A, and the “surrounding area” was divided into Group B and Group C. Beijing, Tianjin, and Hebei were defined as Group B; Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, and Shandong were defined as Group C (see Figure 1).

license plate numbers such that odd-numbered vehicles could drive on odd-numbered days and even-numbered vehicles on even-numbered days (Liu et al., 2012). According to Wang et al. (2010b) and Song et al. (2012), most manufacturers of construction materials were shut down, and all construction activities ceased temporarily. This measure was taken because most of the dust emitted was from the construction sector.

Long-term national policies on air pollution control were also in effect, as opposed to the above policies, which were created to be temporary and specific for the Olympic Games. During the 10th five-year plan (FYP) period (2001-2005), the Chinese government established SO_2 emission targets for specific industrial sectors in heavily polluting regions. Most of sectors involved heavily polluting industries, e.g., oil refineries and steelmaking factories.

To address atmospheric SO_2 emissions and the resulting health and environmental impacts, the government established an environmental policy framework consisting of an array of environmental policies. These included policy instruments that were embedded in various types of national laws and environmental goals described in the FYPs. The plans are not law but describe economic, social, and environmental targets that are imposed through agreements, performance incentives, or existing laws (Guttman and Song, 2007; Fujii et al., 2013; Schreifels and Wilson, 2012).

Schreifels and Wilson (2012) noted that these targets were largely aspirational and not strictly enforced. As a result, China became the world's largest SO_2 emitter in 2005. According to You and Xu (2010), economic losses due to acid rain and acid deposition in China amounted to 176.42 billion Yuan in 2000, or 1.97% of China's gross domestic product (GDP).

Due to the failure of the 10th FYP, the Chinese government put greater emphasis on SO_2 reduction goals in the subsequent FYP (Schreifels and Wilson, 2012). In the 11th FYP (2006-2010), this emphasis included a novel set of political instruments, such as binding agreements with provincial governors and managers of major state-owned power companies, a modified evaluation system for government officials, political and financial incentives, performance audits, and stronger enforcement of existing laws by the Chinese government. As a result, the air quality in most Chinese cities did not continue to deteriorate despite rapid economic growth.

Arne and Maennig (2012) analysed the regional economic impact on the labor market of the 2006 FIFA World Cup in Germany using regionally and sectorally disaggregated data. They used the difference-in-differences (DD) approach and found a small but statistically significant positive employment effect on the hospitality sector. Similarly, our study also uses the DD approach to analyse the environmental impact of the 2008 Olympic Games on air quality in its host city, Beijing, and comparisons are made with other cities in China. All previous analyses applied an engineering method without particular attention to other regions, and thus, the actual effect of the Olympics on air quality is not clear. We aim to clarify whether temporary measures for air quality improvement in Beijing and the surrounding areas were more effective than the typical national polices. In this research, panel data at the city level for air pollution during the 2003-2010 period was used. This dataset covers 29 main cities.

2. Background

Wang et al. (2010b) observed that the daily emissions of SO_2, NOx, and PM10 in Beijing were significantly reduced during the 2008 Olympic Games. Schleicher et al. (2012) found that the temporary measures to reduce air pollution at the 2008 Beijing Olympic Games had a large impact over a short time frame. These measures mainly focused on factory closures and traffic control. In the study by Schleicher et al., weekly samples of fine particulate matter (PM2.5 and PM10) were collected continuously from October 2007 to February 2009. The results indicated that the PM2.5 and PM10 concentrations were comparatively lower during the 2008 Olympic Games.

Cai and Xie (2011) observed that the traffic control policy implemented was effective for air quality improvement in the short term. They conducted a modeling assessment on the effects of the odd- and even-day traffic restriction scheme (TRS) on traffic-related air pollution during the 2008 Olympic Games and noted that this temporary measure improved the air quality in the urban area of Beijing over the short term. Gao et al. (2009) and Schreifels and Wilson (2012) studied the SO_2 pollution control policies in China and found that these policies were ineffective during the 2001-2005 period, and thus, SO_2 emissions increased. However, after 2005, when air pollution control policies were implemented more strictly, SO_2 emissions were significantly reduced. Fujii et al. (2013) analysed air pollution abatement in 10 industrial sectors from 1998 to 2009 in China and concluded that air pollution was reduced significantly at the national level over those years.

All of the previous studies on air pollution control during the Olympic Games focused on the local level in Beijing and demonstrated that the temporary measures used were effective in the short term. The studies on air pollution at the national level indicated that air pollution control policies were effective in the long term, as air pollution was significantly reduced over longer time frames. However, no previous study has indicated whether air quality was relatively improved in Beijing compared to improvements in other areas of China.

Considering these previous studies, our hypothesis is that during the 2008 Olympic Games, due to some temporary measures, such as factory closures and traffic control, air quality improved in Beijing compared to other areas in China.

3. Methodology and data

3-1. Difference-in-differences approach

The DD approach was established to identify treatment effects that occur at a particular location after a specific period. The DD approach is used to compare the differences in outcome between a treatment and control group (the affected and unaffected group) and also to compare the differences before, during, and after a specific period. This approach can be used to evaluate the impact of a mega-sports event. According to Hotchkiss et al. (2003) and Jasmand and Maennig (2008), the DD approach can be used to isolate the impact of an event from pure macroeconomic shocks, and the use of additional geographic units as a control group is suggested.

In this study, temporary measures are defined as those measures that started during the preparation for the Olympic Games and ended shortly after the Olympic Games ended. Air quality improvement due to a change in environmental policy was the studied outcome. The study used the host city, Beijing, and its surrounding areas as its treatment group; other parts of China constituted the control group. The specific environmental impact of the Olympic Games is the difference in air quality between the treatment and control groups outlined above.

The DD approach is consistent with our research objective (see, e.g., Dachis et al. (2011)) and can be used to clarify the environmental impact of the 2008 Olympic Games on air quality in its host city, Beijing. Let t denote time, with t = 2008 as the intervention point, t < 2008 denotes the period before the 2008 Beijing Olympic Games, and t > 2008 denotes that after it. Let i denote the location. The two indicators, based on the time dimension t and spatial dimension i, can be defined as:

$$X^P = \begin{cases} 1 & if \quad t \geq 2008 \\ 0 & else \end{cases} \tag{1}$$

$$X^V = \begin{cases} 1 & if \quad i \in v \\ 0 & else \end{cases} \tag{2}$$

In Equation (1), X^P denotes the period during or after the 2008 Beijing Olympic Games[2]. In Equation (2), X^V denotes the areas belong to the treatment group (Beijing and the surrounding area) or the control group (the other areas in China).

According to Dachis et al. (2011), this function (see Equation 3) can be broken down into five parts: (1) the function l (i, t), which has a latent effect on air quality improvement that is continuous in time i and location t; (2) the air quality improvement that occurs after the 2008 Beijing Olympic Games, as γX^P; (3) a jump in the air quality improvement that occurs in the host city, Beijing, and the surrounding area, as βX^V; (4) an interaction effect on time and location, as $\lambda X^P X^V$; and (5) a mean-zero error term.

$$e\,(i, t) = \gamma X^P + \beta X^V + \lambda X^P X^V + \epsilon\,(i,t) \tag{3}$$

3-2. Data

Several types of air pollutants are established as dependent variables, whereas "time term",

[2] Due to some temporary measures start from 2007, this study also discussed the change after 2007 in the result as an alternative specification.

"location term", and "interaction term of time and location" are defined as independent variables. In this study, city-level data were used for air pollution levels for the 2003-2010 period. This dataset consisted of 29 cities, all of which were provincial capital cities for 29 different provinces in China[3].

Datasets used included: (1) the concentration of SO2, PM10, and NOx, indicating the annual average level of each type of air pollutant; (2) the amount of SO2, dust, and soot emitted from the industrial sector; (3) GDP at the provincial level, and the consumer price index (CPI) to deflate the data series to 2005 price levels; and (4) the emitted SO2, dust, and soot per GDP. This final variable reflects technological progress related to pollution reduction and the general industrial structure of the city. With regard to SO2, PM10, and NOx, because these pollutants are mainly emitted from the industrial sector, we used the overall emission amount of the industrial sector in the model calculations. Dust and soot were compared to the concentration of PM10.

4. Results and Discussion

The results of the DD approach, expressing the change in pollution concentration, are shown in Table 1. Group C exhibits a statistically significant expected sign of interaction effect for time and location. Group C's data were further analysed by date. In the case of Group C-2007, the concentration of PM10 and NOx exhibited a statistically significant interaction effect for time and location. In the case of Group C-2008, only the concentration of PM10 exhibited an interaction effect for time and location, with statistical significance. The interaction effect for the NOx concentration was not statistically significant.

< Table 1 about here >

Group B also exhibited a statistically significant result for the interaction effect for time and location. For Group B-2007, the SO_2 concentration exhibited an interaction effect for time and location. Group B-2007 also exhibited an interaction effect for the NOx concentration that was statistically insignificant. In the case of Group B-2008, the interaction effect for SO_2 and NOx were both statistically insignificant.

The coefficients for all interaction terms in Groups B and C were negative, indicating that the interaction effect between time and location has a negative effect on pollution levels. It can be inferred that in Beijing and the surrounding areas, the level of air pollution was lower than in other areas of China, especially during the 2007-2008 period. This improved air quality may be related to the 2008 Beijing Olympic Games, as this event led the local government of Beijing

[3] Xinjiang, Tibet, Hong Kong, Macau, and Taiwan are not included due to missing data.

implemented temporary measures for air quality improvement, which mainly focused on the industrial sector and traffic control.

A specific industrial pollution control policy was enforced in 2008 (see Appendix 1) through the "Air Quality Guarantee Plan for the 29th Olympic Games in Beijing". This plan was also extended to surrounding areas, including Tianjin, Hebei, Shanxi, Shandong, and Inner Mongolia (Wang et al., 2010b). In Tianjin and Hebei, both of which are in Group B, this policy was implemented compulsorily and strictly. However, in Shanxi, Inner Mongolia, and Shandong, all of which were in Group C, this policy was implemented only if air quality became extremely serious. The plan was implemented as a temporary measure, only starting shortly before and lasting throughout the 2008 Beijing Olympic Games. The results from the DD approach indicate that those temporary measures had an effect on air pollution control. As a result, the concentration level for each of these air pollutants, SO_2, PM10, and NOx, was significantly decreased in Beijing and the surrounding areas compared with other areas.

However, as discussed, a traffic control measure was also enforced in Beijing in 2008. This measure mainly focused on reducing the number of vehicles on the road, especially emphasizing heavily polluting vehicles. According to Wang et al. (2010b), emission control measures for mobile sources, including high-emitting vehicle restrictions, government vehicle limitations, and alternate day driving rules for Beijing's 3.3 million private cars, reduced NOx by 46% from the traffic sector. According to the above results, it is clear that the impact of the interaction effect on the three types of pollutants was different, even within the same year. This difference is mainly due to the difference in air pollutants originating from various emitters. According to Wang et al. (2010b), the industrial sector emitted most of the SO_2, whereas vehicles emitted only PM10 and NOx.

Given the above results, the temporary air quality control measures in the host city, including factory closures and traffic control, had a significant effect in the short term. However, there was no significant effect in the long term compared with that in other areas, possibly because temporary measures did not have sufficient time to generate lasting effects. Motivated by these results, it is suggested that other measures, such as pollution abatement investment and scrap and build in the industrial sector, should be implemented continuously.

A discussion of the post-evaluation term is provided below. In each case, every post-evaluation term of SO_2 and PM10 exhibited statistical significance. Additionally, the coefficient of each "post-evaluation" is negative. However, every post-evaluation term of NOx exhibited an insignificant result, indicating that the concentration of SO_2 and PM10 decreased during the 2003-2010 period, whereas NOx did not decrease significantly at the national level.

The result of the post-evaluation term for the concentrations of SO_2 and PM10 is consistent with the implementation of environmental measures during the 10^{th} and 11^{th} FYPs. These post-evaluation after terms indicate that the SO_2, soot, and dust from the industrial sector were reduced significantly during the implementation of the pollution reduction policies. Some specific measures for SO_2 reduction were mentioned in the 10^{th} FYP that mainly focused on the industrial sector. In the 11^{th} FYP, some specific measures for soot, dust, and NOx reduction in urban areas were also mentioned, although the focus was still mainly on SO_2. The concentration of NOx did not change significantly, possibly due to the rapid increase in vehicles throughout the country. It is suggested that specific measurements for NOx be implemented more strictly at the national level.

In Group B, every treatment term for each of the pollution concentrations exhibited statistical significance. Additionally, the coefficient of each treatment term is positive, indicating that air quality in this area (Beijing, Tianjin, and Hebei) was much worse than in other areas of China during the 2003-2010 period. Xu et al. (2013) noted that this area suffers from severe air pollution, which is consistent with the results of this study. Wind-blown dust, coal combustion, vehicular emissions, and industry activities all contribute to the poor air quality. The air quality is particularly poor for several reasons. First, the tertiary industries in Beijing, Tianjin, and Hebei contribute 75.5, 45.3, and 35.2% of the local GDP, respectively. Moreover, the industrial sectors in Tianjin and Hebei contribute approximately 53.0% and 52.0% of the local GDP, respectively in 2009. Second, the stock of vehicles in the two mega-cities, Beijing and Tianjin, increased exponentially in the past 10 years, reaching 5 million in Beijing and 1.8 million in Tianjin in 2011. Third, in 2009, the coal consumption in this area amounted to 333 million tons, accounting for 10.3% of the total national consumption.

We estimate the change in pollution emissions from the industrial sector and also the pollution emissions adjusted by economic scale. Both of these measures exhibited a statistically insignificant result for the interaction term (see Appendix 3 and Appendix 4). This result would indicate that in the industrial sector, there was no environmental impact due to pollution from the Olympic Games.

Pollution emissions in Beijing and the surrounding areas from the industrial sector were reduced due to technological progress leading to pollution reduction and the shutting down of factories nationwide. However, after the 2008 Olympic Games, pollution reduction did not exhibit any significant effects in Beijing and the surrounding area compared to the national level. It can be inferred that the reduction in air pollution in Beijing may have resulted mainly from traffic control during the Olympic Games. Considering that the industrial sector is one of the main air pollution emitters, progressive new technologies for pollution reduction should be introduced in the industrial sector to reduce air pollution in the long term.

5. Conclusion

To the best of our knowledge, this is the first paper that quantified the environmental impact of the Olympic Games on air quality in Beijing compared to air quality improvements in other areas in China. This study used air pollution panel data at the city level for the 2003-2010 period.

The results indicate that air quality improved in Beijing, but that these improvements were only short term, after the 2008 Olympic Games. This temporary reduction was due to several temporary measures, mainly factory closures and traffic control. However, there is no evidence to support the notion that air pollution measures related to the Olympics reduced the concentration of SO_2. One issue that deserves further attention is that we used only city-level data, which only covered 29 cities over a short term. Future research should cover additional areas over a longer term.

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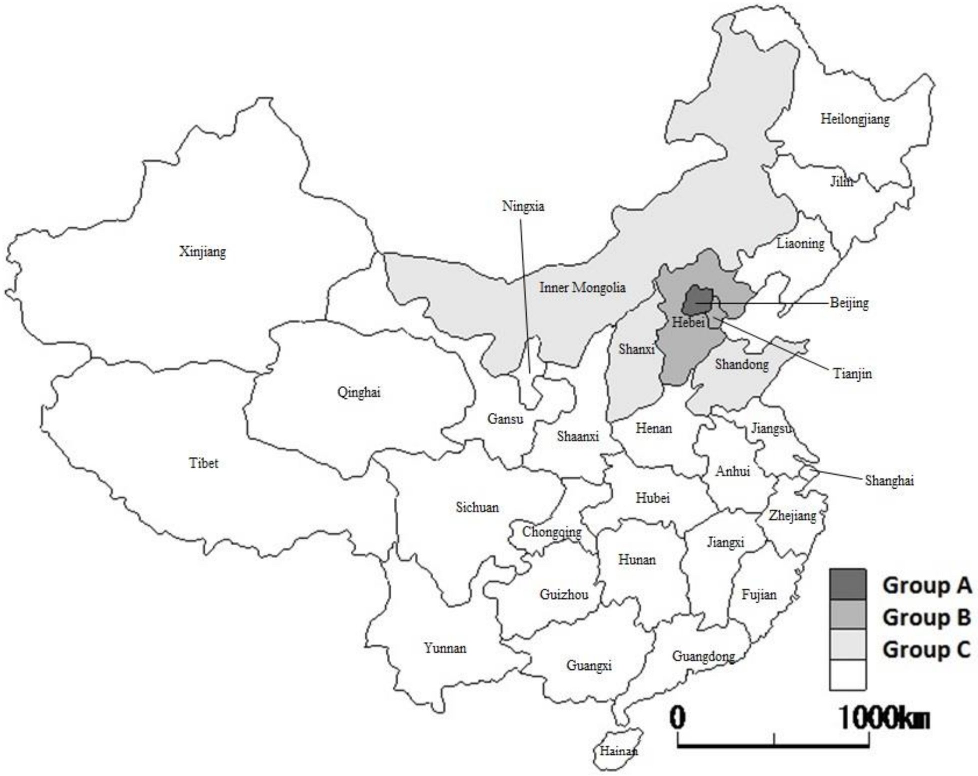
Figure 1. Map of China



Note 1:Group A: Beijing

Group B: Beijing, Tianjin and Hebei

Group C: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia and Shandong

2: In this study, Xinjiang, Tibet, Hong Kong, Macau and Taiwan are not included due to missing data.

Table 1 Change of pollution concentration (unit of concentration: ug/m^3)

Group B-2007						
	SO_2		PM10		NOx	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-6.327	0.02	-13.683	0.00	0.404	0.82
Treat	18.455	0.00	26.404	0.00	13.478	0.00
Interaction	-16.590	0.05	-10.567	0.35	-9.071	0.014
Obs.	232		232		232	
R^2	0.08		0.13		0.05	
Group B-2008						
	SO_2		PM10		NOx	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-8.641	0.00	-12.808	0.00	-0.318	0.86
Treat	14.428	0.01	25.959	0.00	12.090	0.00
Interaction	-11.381	0.19	-12.903	0.27	-8.393	0.15
Obs.	232		232		232	
R^2	0.09		0.12		0.05	

Group C-2007						
	SO_2		PM10		NOx	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-6.772	0.02	-11.446	0.00	0.957	0.62
Treat	15.346	0.00	26.380	0.00	2.627	0.39
Interaction	-6.145	0.33	-16.096	0.05	-7.207	0.09
Obs.	232		232.		232	
R^2	0.10		0.16		0.01	
Group C-2008						
	SO_2		PM10		NOx	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-8.959	0.00	-10.617	0.01	0.261	0.90
Treat	13.830	0.00	24.722	0.00	1.646	0.54
Interaction	-4.152	0.52	-17.038	0.05	-6.994	0.114
Obs.	232		232.		232	
R^2	0.12		0.15		0.01	

Appendix 1 Air pollution control policy in China during 2001-2008.

National level		Local level	
Year	**Environmental regulations**	**Period**	**Measures on air quality improvement**
2001	Emissions standard of air pollutants for coal-burning, oil-burning and gas-fired boiler		
2002	State council approves plotting programs for acid rain control region and SO_2 control region		
2002	Technology policies on SO_2 emissions control from coal combustion		
2003	Cleaner production promotion Law		
2003	State council issues the regulations on pollution levy		
2003	Vehicle emission standards Euro II for light-duty vehicles and heavy-duty diesel engines		
2004	Emissions standard of air pollutants for cement industry		
2005	Air quality reporting system in 113 cities		
2007	Comprehensive working plan of energy conservation and emission reduction		
2008, March	Vehicle emission standards Euro IV for light-duty vehicles	2008, Feb.27	Air quality guarantee plan for the 29th Olympics in Beijing
2008, July	Vehicle emission standards Euro IV for heavy-duty diesel engines	2008, Jul.7	Vehicle restriction based on license plate number
		2008, Jul.28	Emergency measure for extreme air condition

Appendix 2 Summary of data at provincial level, among 29 main cities in China.

variable	data	unit
concentration		
SO_2	SO_2 concentration [a]	ug/m^3
PM_{10}	PM_{10} concentration [a]	ug/m^3
NOx	NOx concentration [a]	ug/m^3
emission		
SO_2	the amount of SO_2 emitted from industrial sector [b]	10 thousand ton
dust	the amount of dust emitted from industrial sector [b]	10 thousand ton
soot	the amount of soot emitted from industrial sector [b]	10 thousand ton
GDP	GDP [a] at provincial level (deflated to 2005 price level)	100 million Yuan
emission adjusted by economic scale		
SO_2	the amount of SO_2 emitted from industrial sector per GDP	100 ton per Yuan
dust	the amount of dust emitted from industrial sector per GDP	100 ton per Yuan
soot	the amount of soot emitted from industrial sector per GDP	100 ton per Yuan

Note 1: [a] data source: China Statistical Year Book
[b] data source: China Environmental Statistical Year Book

2: In this study, Xinjiang, Tibet, Hong Kong, Macau and Taiwan are not included due to missing data. Also, soot emitted in 2005 was not included due to missing data.

3: All of these 29 main cities are provincial capital cities of 29 provinces in China.

Appendix 3 Change of pollution emission (unit of emission: 10 thousand ton)

Group B-2007

	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-2.062	0.71	-11.671	0.00	-95.786	0.00
Treat	-17.357	0.16	-6.342	0.26	-31.727	0.44
Interaction	-4.480	0.80	2.904	0.72	24.097	0.66
Obs.	232		232		232	
R^2	0.02		0.09		0.14	

Group C-2007

	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-1.492	0.80	-10.627	0.00	-83.863	0.00
Treat	30.193	0.00	8.434	0.05	54.280	0.08
Interaction	-4.991	0.70	-3.594	0.55	-45.578	0.26
Obs.	232		232		232	
R^2	0.08		0.11		0.15	

Group B-2008

	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-4.866	0.40	-11.919	0.00	-74.107	0.00
Treat	-18.070	0.10	-6.141	0.22	-25.916	0.48
Interaction	-4.074	0.82	3.337	0.69	18.571	0.74
Obs.	232		232		232	
R^2	0.03		0.09		0.08	

Group C-2008

	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-4.328	0.47	-10.931	0.00	-64.739	0.00
Treat	29.437	0.00	7.802	0.04	43.661	0.11
Interaction	-4.636	0.72	-3.105	0.61	-35.992	0.39
Obs.	232		232		232	
R^2	0.08		0.11		0.09	

Appendix 4 Change of pollution emission adjusted by economic scale (unit: 100 ton per Yuan)

Group B-2007						
	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-0.007	0.00	-0.005	0.00	-0.031	0.00
Treat	-0.009	0.00	-0.005	0.00	-0.020	0.13
Interaction	0.004	0.40	0.003	0.12	0.018	0.31
Obs.	232		232		232	
R^2	0.15		0.23		0.14	

Group C-2007						
	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-0.007	0.00	-0.005	0.00	-0.027	0.00
Treat	0.002	0.47	0.000	0.79	0.011	0.29
Interaction	-0.002	0.48	0.000	0.97	-0.010	0.43
Obs.	232		232		232	
R^2	0.11		0.19		0.14	

Group B-2008						
	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-0.008	0.00	-0.005	0.00	-0.024	0.00
Treat	-0.009	0.00	-0.004	0.00	-0.015	0.19
Interaction	0.004	0.38	0.003	0.16	0.014	0.44
Obs.	232		232		232	
R^2	0.15		0.20		0.09	

Group C-2008						
	SO_2		dust		soot	
	coef.	P-value	coef.	P-value	coef.	P-value
After	-0.007	0.00	-0.004	0.00	-0.021	0.00
Treat	0.001	0.58	0.000	0.74	0.008	0.36
Interaction	-0.002	0.63	0.000	0.98	-0.008	0.55
Obs.	232		232		232	
R^2	0.11		0.16		0.08	