The Impact of Emission Standards on Reduction of Air Pollutants in China

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Abstract:

In the year 2000, the Chinese government first implemented a nationwide emission standard that quantitatively and qualitatively regulated the reduction of pollutants from automobile exhaust. Until now, there are all together four stages of emission standards that have been implemented, with big cities such as Beijing and Shanghai as experimental hubs. This paper first discusses the implementation process of four different stages of emission standards, and then uses a dataset covering 46 major cities in China from 2001 to 2008 to conduct an empirical analysis of the causal effect of each emission standard on air quality improvement. The finding of this paper is that the effect of emission standards on air pollution reduction is significant. On average, each stage of standard implementation will help to decrease the comprehensive air pollution index by about 20%. This result stands up to a number of robustness checks.

I. Introduction

After China's 1978 Reform and Opening Up, the number of automobiles on the road has grown quickly as a result of the increase of Chinese people's income. This result, however means that automobile exhaust pollution has become the major source of urban atmosphere pollution[1]. Until the 2000 amendment of the *Air Pollution Prevention Law*[2], Chinese government first set up the emission standards plan to control for the vehicle emissions. Starting from January 1st, 2001, the State Environmental Protection Administration implemented the first emission standard "China I" in Beijing. Now, there are altogether four emission standards which are being implemented in China, with major cities such as Beijing and Shanghai leading the way with accelerated adoption of the policies. Regulated emissions include hydrocarbon (HC), carbon monoxide (CO), oxides of nitrogen (NOx), and particulate matter (PM) and are tested using a modified version of the European NEDC test cycle.[3]

This paper aims to provide theoretical and analytical analysis of the impact of the different stages of emission standards on actual air pollution reduction. The implementation process and methodology of emission standards is explained in Section II. Section III is an empirical analysis showing the quantitative influence of emission standards on reduction of pollutants using a dataset that covers 46 major cities in China over the period from 2001 to 2008 to measure the marginal and joint effect of each standard. In the last Section IV, I will discuss my conclusion and results.

II. Emission Standards in China

Starting in the year 2000, the urban population of China has increased at the speed of 20 million people per year. Through 2010, the urban population has boomed from 458 million in 2000 to 650 million (Yearbook 2000, 2010). The process of fast urbanization in China is accompanied with a heavier burden faced by urban transportation systems. By the end of the year 2007, the number of civilian automobiles in China had reached 32.4 million, with an increase of 20.7% per year from 2000.[4] In the larger federal-level cities and the provincial capitals, the number of private cars has increased exponentially. Without a system of efficient emission control regulations, the pervasive serious hazard of car exhaust would put urban residents' health under severe danger.

In May of 1999, the State Environmental Protection Administration, in collaboration with the Ministry of Science and Technology and the State Administration of Machinery Industry, issued the *Automobile Emission Pollution Prevention Policy*[5] which specifies the objectives of pollution control and the requirements for new car model development. The objective for car exhaust control is separated into four stages (See Appendix A for Timetable of China's implementation of emission standards)[6]:

- China I: As of the year 2000, automobile emissions should be under the First European Standard (Euro I).
- China II: All light cars should be under Euro II by the year 2004, with Beijing and Shanghai serving as experimental cities.

- China III: The third stage is implemented nationwide in the year 2007, based on Euro III. Beijing, Shanghai and Guangzhou are earlier on the implementation schedule than the rest of the country.
- China IV: The fourth stage is implemented in the year 2010, with Beijing serving as the experimental city.

All four stages of emissions standards implementation are based on European standards, and with large metropolitan cities leading the implementation. The standards are quantitative in that they point out the specific emissions limits for new cars on the road. Because of the lag of China's oil production standards, prefecture-level cities and other small cities cannot meet the national standards immediately, and the effect of emission standards will be seen about one year after the emission standard was implemented.

III. Empirical Analysis

3.1 Literature Review

Most of the papers and studies on China's emission standards are qualitative analyses and case studies focusing on one or two cities. Those studies attempt to argue the merits and drawbacks of the emission standards. Only limited literature provides quantitative analysis regarding the emission standards, testing and forecasting their effects. For example, Hao, Fu, He and Wu's study on Civil Automobile Emission Pollution Control analyzes the effect of emission standards on several pollutants, including, NO, CO, O3 and so forth. It also compares China's emissions standards to other countries' practices, and studies the inspection and maintenance of emissions controls[7]. Mao, Ma, Liu and Xing's work entitled, "An Environmental Effect Analysis for the Application of European Emission Standards of Motor Vehicles in Beijing"[8] makes a pollutant emissions inventory for motor vehicles through an overall investigation of the traffic conditions based on base year findings from 2005 in the urban area of Beijing. It gives an environmental impact assessment made on the application of applying different stages of emission standards. A more recent study on China's emission standards is the "Overview of China's Vehicle Emission Control Program"[9] published by US International Council on Clean Transportation. This program was completed in conjunction with China's Vehicle Emission Control Center, a policy research group affiliated with the Ministry of Environmental Protection (MEP). This program produced a documentation of the existing MEP regulations from 2000 to 2010. All the above-mentioned studies are about single pollutant, and there are no empirical studies using statistical models to test the efficiency of the different stages of implementation of emission standards.

3.2 Data

I collected city-level data for 46 cities, covering northern and southern China, including metropolises such as Beijing and Shanghai, provincial capitals such as Changchun and Guangzhou, and other smaller prefecture-level cities. I chose a comprehensive air pollution index as my dependent variable. This index reflects the overall air quality of a city, including several major air pollutants such as NO_X, CO_X, SO_2

and PM[1]. Major independent variables include a categorical dummy of standards from 0 to 3, increasing with the intensity of the standards. And three other variables named China2, China3 and China4, which are set equal to 1 if these standards have been implemented. Although the timetable shows that other than experimental cities, the standards were implemented nationwide, due to the different quality of gasoline, however, in China, small cities would see a lagged effect of the standards. Therefore, I separate my selected cities into three categories: experimental cities, provincial capitals and small cities. Each of these categories has a different time of entry for the implementation of standards[2]. Other control variables include the number of civil motor automobiles and the added value of industry. This database is collected from Chinese Environmental Yearbooks (2001-2009) and Chinese Provincial Yearbooks (2001-2009). Due to the different statistical methodology, some data points are missing. Please see Appendix B for a description of each variable.

3.3 Econometric Models

I chose to use a two-way fixed effects model as my baseline model because with fixed effects, I can knock out the unobserved characteristics that do not change over time. The fixed effects estimator allows for arbitrary correlation between a_i (the time-invariant characteristics that may bias by point estimator) and the explanatory variables in any time period. Any explanatory variable that is constant over time for all units get swept away

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[1] Comprehensive Air Pollution Index is the sum of each pollutants factor. The bigger the index, the worse the air quality. The pollutant factors are weighted by their contributions to the air pollutant index.

[2] "According to the regulations of State Environmental Protection Administration, the nationwide implementation of China III has started. But in view of the adaptation of China's fuel standard, especially in small cities, there will be a one-year transition period for China II emission standard." Lihong, Xu, "国三上岗，节能仍需努力", China Financial and Economic News, July 23th, 2008

by the fixed effects model. It is also necessary to consider the random effects model whose outcome is more efficient than fixed effects. To apply the random effects, my data should satisfy an assumption that there is no autocorrelation between the independent variables and other unobserved a_i. A Hausman test was conducted to determine if random effects or fixed effects should be used. If the p-value is large, then I can choose random effect as my model. The P-value of Hausman test is 0 which means that I cannot use a random effects model. Fixed effects is the best choice.[3]

First, I used fixed effects on the city level to estimate the impact of emission standards. The model is[4]:

$$P_{it} = \beta_0 + \beta_1 standard_{it} + \delta \sum_{2001}^{t} year_t + a_i + u_{it}$$

In this equation, "i" stands for city level variation, and "t" is the variation in time. The dependent variable *P* is the comprehensive air pollution index. The variable *standard* stands for the categorical dummy for each of the standards, increasing with the change of intensity. The variable *year* is a time dummy, except the first year.

However, seeing from the results table, the coefficient on the major independent variable *standard* is positive, which should be improbable. And the p-value is sufficiently low so that there is no significance in this model. The second model includes two control variables in an attempt to remove some omitted variable bias.[5]

$$P_{it} = \beta_0 + \beta_1 standard_{it} + \delta \sum_{2001}^{t} year_t + \beta_2 lauto_{it} + \beta_3 lindustry_{it} + a_i + u_{it}$$

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[3] See Appendix H

[4] See Appendix C for Model 1

[5] See Appendix C for Model 2

The variable *lauto* stands for the logged number of civilian automobiles in each city, and *lindustry* is the logged added value of industry at the city level. Unfortunately, although the coefficient on *standard* becomes negative, the results are still not significant. Therefore, I decide to visually examine the change of the air pollution index during the past 8 years[6]. From the three graphs of changes of air pollution index from 2001 to 2008, I can see that my dependent variable may have a time trend that each city's air pollution index decreased during the 8 years from 2001 to 2008, thus there is a unit-specific trend for every city. The next model includes a dummy for each id*year, or a unit-specific trend. The equation for this new model is:[7]

$$P_{it} = \beta_0 + \beta_1 standard_{it} + \beta_2 \sum_{2001}^{t} id_i * year_t + \beta_3 lauto_{it} + \beta_4 lindustry_{it} + a_i + u_{it}$$

The results from this model are significant at 90% level. The coefficient of the treatment variable *standard* is -0.163, which can be interpreted that for each step of the emission standards, from China I to China II and so on, there is a reduction in the comprehensive air pollution index by 16.3%. However, one of my control variables is not significant, which means that the model may suffer from multicollinearity. The correlation between *lauto* and *lindustry* is 0.7947[8], indicating that the "*lauto*" variable should be dropped. The final model is[9]:

$$P_{it} = \beta_0 + \beta_1 standard_{it} + \beta_2 \sum_{2001}^{t} id_i * year_t + \beta_3 lindustry_{it} + a_i + u_{it}$$

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[6] See Appendix D for three graphs

[7] See Appendix E

[8] See Appendix F

[9] See Appendix G Model 1

The result of this model is that one step forward in the emissions standards leads to a 19.72% reduction of air pollutants. This result is significant at the 99% level.

Other variations were tried, including using *lauto* and *auto* as control variables. However, the t-values for both regressions were not significant at the 95% level, and the highest level of significance comes from using the original control variable *lindustry*. The reason for the insignificance of number of automobiles may be that one important factor of the air pollutants index is SO_2. China is still a developing country with a large number of industrial cities. The impact of SO_2 is somewhat hidden in the results, which cannot be controlled for with the control variables *auto* or *lauto*. With the control variable *lindustry*, I can control for the different degree of industrial development across cities, and this variable can also explain 79% of the difference of the automobile number across cities[10].

Since China's emission standards implementation program has four different stages and I want to know the marginal effect and joint effect of each stage, so dummy variables can be incorporated in a further model. First, I test the marginal effect of each stage, and then I use an F-test to see if their joint effects are significant. The marginal effect for China II is -21.98%. For China III and China IV, the marginal effect is not significant, which may be because of the lack of observations in the dataset. Thus the significance of China II dominates the effect of the other standards. However, the F-test shows that joint effects of each stage with previous ones are all significant at 95% level.[11]

3.4 Robustness Checks

(1) Autocorrelation

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[10] See Appendix G Model 2 & Model 3

[11] See Appendix I for Model 1, 2, 3 and 4.

One important problem that must be considered is autocorrelation in the standard error for my models. Autocorrelation would not bias the estimator, but would inflate the standard errors and result in an incorrect confidence interval. The result of running the residuals on their lags is that the residual is correlated with all the lags. The reason for this result might be that each stage of standard is based on the previous one, so the residual of each stage is correlated with previous ones. To correct the autocorrelation problem, I used the Newey-West standard errors[10], and the result is still significant at the 99% level[12].

(2) Heteroskedasticity

Ordinary Least Squares (OLS) regressions assume homoskedastisity, where the error term has a constant variance. However, the above model may suffer from the problem of heteroskedasticity, which may bias the results. Thus I use robust standard errors to correct this problem.[13] The robust standard errors allows for inference without specifying the conditional second moment of thee error term. The result is that my coefficient has not changed greatly, however the p-value becomes bigger, while the results are still significant at the 95% confidence level. Although the confidence interval becomes bigger, I can conclude that the impact of emissions standards on pollutant reduction is still significant.

(3) Endogeneity

From the above discussion of most fitted econometric model for my study, I have found the problem of pre-treatment trends. The reason for this problem is that due to the limitations of data availability, there is only a full dataset from the year 2001 to the year

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[12] See Appendix J

[13] See Appendix K

2008. China's first nationwide emission standard was implemented in the year 2000. Thus there must be a pre-treatment trend which will bias the estimation. To solve this problem, I put a time trend dummy in my fixed effect regression equation, which can help me to knock out the pre-treatment trends. Thus I can see the marginal effect of each standard, and their joint effects.[14]

IV. Conclusion

Based on the above empirical study of the impact of emissions standards on air pollutant reduction using two-way fixed effect estimator, I found that the emissions standards do reduce air pollutants and improve air quality. Since the emission standards have up to now been implemented in four stages, each stage has a different marginal effect on emission reduction. Emissions standards will help to decrease the comprehensive air pollution index by about 20%. This result was supported by several robustness checks and empirical tests. In this study, I controlled for the impact of industrial development on air pollution. As the number of civilian automobiles is highly correlated with industrial development, I dropped the explanatory variable of automobile numbers, using added value of industry instead. The fourth stage of China's emission standards is not the end of the Chinese government's efforts on vehicle emissions reduction. According to the *Air Pollution Prevention Law*, China will have a more strict regulation on auto emissions and fuel quality in the future, and if the trend is consistent

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[14] See Appendix I for Model 1, 2, 3 and 4.

with this study’s findings, these standards will indeed help to reduce air pollutions in China’s urban areas.

Notes:

[1] Shuhong, Pan & Minjian, Huang, *The Present Situation of Policy of Automobile Exhaust Pollution in Chinese cities* “我国城市机动车尾气污染的现状趋势及其控制对策” College of Law, Fuzhou UJniversity, Research Paper 1.

[2] *Air Pollution Prevention Law,* “中华人民共和国大气污染防治法”, NO32. Decree of Chairman of PRC.

[3] ICCT, Overview of China’s Vehicle Emission Control Program, Chapter 3, New Vehicle and Engine Emission Standard.

[4] Liang, Zhao, *Tail Gas Pollution and Decreasing Measures, “*机动车尾气污染及其减排措施”, Environmental Science and Management, Vol 33 No. 5, May 2008

[5] Automobile Emission Pollution Prevention Policy, “机动车排放污染防治技术政策”, 环发 [1999] No. 134, SEPA

[6] Analysis of China’s Automobile Emission Standards System, “我国机动车排放标准体系分析”, www.cnautonews.com, May 13th, 2010.

[7] Jiming, Hao & Lixin, Fu & Kebin, He & Ye, Wu, Civil Automobile Emission Pollution Control, “城市机动车排放污染控制”, No. 81767, China Environment Science Press, 2000

[8] Maoxian, Qiang & Magen, Hui & Liu Qing & Xingyou, Kai, An Environmental Effect Analysis for the Application of European Emission Standards of Motor Vehicle in Beijing, “北京市实行机动车排放欧洲便准的环境效果分析”, Environment Science & Technology, 2011, 34(5): 193-198.

[9] Freda Fung, Hui He, Benjamin Sharpe, Fatumata Kamakaté, Kate Blumberg, *Overview of China’s Vehicle Emission Control Program Past Success and Future Prospects*, ICCT, 2011, http://www.theicct.org/2011/04/overview-vehicle-emissions-controls-china/

[10] Ashenfelter (1978) noted a potentially serious limitation in evaluating government raining programs when he observed that the mean earnings of participants in government training programs decline in the period prior to program entry. It means that fact that the selection for treatment is influenced by individual-transitory shocks on past outcomes.

Appendix:

A. Staged entry into China's emission standards

Stage	Date	Region	Reference
China I	2000.01	Nationwide	Euro I
China II	2002.08	Beijing	Euro II
	2003.03	Shanghai	
	2004.07	Nationwide	
China III	2005.12	Beijing	Euro III
	2006.19	Guangzhou	
	2007.01	Shanghai	
	2007.07	Nationwide	
China IV	2008.03	Beijing	Euro IV
	2009.11	Shanghai	
	2011.07	Nationwide	
China V	2012	Beijing	Euro V

B. Description of Variables

Variable	Description
Year	Year (2001-2008)
id_city	City id (46 cities of China)
City	Cities
P	Comprehensive air pollution index (the higher the worse air quality)
Standard	Stages of standards (=0 if is China I, =1 if is China II, =2 if is China III, =3 if is China IV)
China2	= 1 if the city implements China II
China3	= 1 if the city implements China III
China4	= 1 if the city implements China IV
Fuel	Fuel price index
Auto	Number of civil automobiles
Industry	Added value of industry
_Iid*year*	Time trend dummies

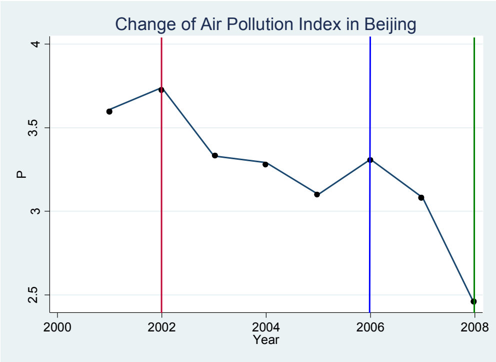
C. Simple Two-way Fixed Effect Model

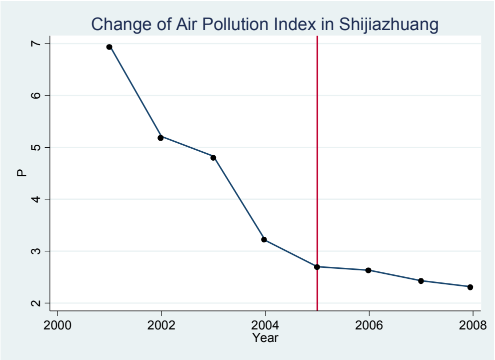
variables	Model 1	Model 2
Standard	0.00541	-0.0738
Std. Err.	(0.101)	(0.107)
lindustry		-0.0100
Std. Err.		(0.125)
lauto		-0.0575
Std. Err.		(0.162)
Constant	2.871***	3.249***
Std. Err.	(0.122)	(0.856)
Observations	354	277
R-squared	0.299	0.306
Number of id_city	45	39
rmse	0.455	0.420

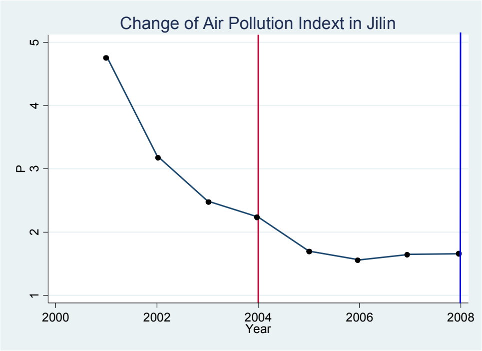
Model 1: simple two-way fixed effect without control variables

Model 2: simple two-way fixed effect with control variables

D. Three Graphs of Changes of Air Pollution Index







🟥 The Implementation of China II
🟦 The Implementation of China III
🟩 The Implementation of China IV

E. Pre-treatment Trends Model

Variable	Model 1
Standard	-0.163**
Std. Err.	(0.0715)
lindustry	0.207*
Std. Err.	(0.117)
Constant	48.96
Std. Err.	(82.78)
Observations	277
R-squared	0.697
Number of id_city	39
rmse	0.298

F. Correlation between “lindustry” and “lauto”

	lindus~y	Lauto
lindustry	1.000	
lauto	0.7947	1.000

G. Pre-treatment Trends Models

Variables	Model 1	Model 2	Model 3
Standard	-0.197***	-0.155*	-0.142*
Std. Err.	(0.0672)	(0.0633)	(0.0645)
lindustry	0.206*		
Std. Err.	(0.157)		
lauto			0.202*
Std. Err.			(0.107)
auto		0.00717*	
Std. Err.		(0.00397)	
Constant	64.90	49.91	68.51
Std. Err.	(79.70)	(51.97)	(43.35)
Observations	316	315	315
R-squared	0.736	0.683	0.683
Number of id_city	40	44	44
rmse	0.314		

Model 1: Model with only “lindustry”
Model 2: Model with only “auto”
Model 3: Model with only “lauto”

H. Hausman Test

Variables	Fixed effect	Random effect	Difference
Standard	-.19172904	-.1223515	-.0749389
lindustry	-.205663	.1031966	-.3088597
Chi2 = 386.93		Prob>chi2 = 0.0000	

I. Marginal Effect of Each Standards

Variables	Model 1	Model 2	Model 3
China1	-0.208***	-0.205***	-0.195***
Std. Err.	(0.0636)	(0.0639)	(0.0639)
lindustry	0.177*	0.176*	0.210*
Std. Err.	(0.158)	(0.158)	(0.159)
China2	-0.220***	-0.237***	-0.241***
Std. Err.	(0.0705)	(0.0747)	(0.0745)
China3		-0.0669	-0.0694
Std. Err.		(0.0972)	(0.0968)
China4			-0.675
Std. Err.			(0.414)
Constant	84.27**	73.99*	70.08
Std. Err.	(40.70)	(43.41)	(43.36)
Observations	315	315	315
R-squared	0.683	0.683	0.687
Number of id_city	44	44	44
rmse	0.288	0.288	0.287

F-test for the Significance of Joint Effect

(1) Test china2 = 0

F(1, 233) = 10.04

Prob > F = 0.0017

(2) Test china2 + china3 = 0

F(1, 232) = 4.90

Prob > F = 0.0278

J. Test and Correction for Autocorrelation

Variable	Result
L.ehat	-0.182*
Std. Err.	(0.103)
L2.ehat	-0.494***
Std. Err.	(0.0853)
L3.ehat	-0.367***
Std. Err.	(0.0696)
L4.ehat	-0.343***
Std. Err.	(0.0702)
L5.ehat	-0.169**
Std. Err.	(0.0661)
L6.ehat	-0.344***
Std. Err.	(0.0545)
Constant	0.0119
Std. Err.	(0.0156)
Observations	63
R-squared	0.637
rmse	0.116

Newey-West Test

Newey-West				
p	Coef.	Std. Err.	t	P>|t|
standard	-.1827857	.0760549	-2.40	0.017

K. Robust Model Fixed Effect

Variable	Result
Standard	-0.197**
Std. Err.	(0.0834)
Lindustry	0.206
Std. Err.	(0.147)
Constant	64.90
Std. Err.	(85.20)
Observations	316
R-squared	0.736
Number of id_city	40
rmse	0.291