ISSN 2004-2965 Energy Proceedings, Vol. 17, 2021

Paper ID APEN-MIT-2021_216
Applied Energy Symposium: MIT A+B
August 11-13, 2021 • Cambridge, USA

The Impact of the Two Control Zones Policy on Sulfur Dioxide Emissions

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Abstract—This article aims to study the impact of China's Two Control Zones policy on sulfur dioxide emissions from 1997 to 2018. First, this paper applies the DID model and uses the panel data of prefecture-level cities to preliminarily analyze the impact of the Two Control Areas Policy on sulfur dioxide. DID results show that the two control zones policy has indeed played a role in reducing sulfur dioxide emissions. After individually controlling the covariates, the two control zones policy has a minor effect on promoting the reduction of sulfur dioxide emissions. The covariates are sorted in order of reduction degree from small to large, namely Popu, GDP, industry, and FDI. By continuously adding control variables, it can be found that the addition of GDP has almost no effect on the emission reduction effect of the two control areas policy. FDI and Popu has a worsening effect on the emission reduction effect of the two control areas policy; the addition of industry can reduce sulfur dioxide The deteriorating effect of the platoon will be partially offset. Secondly, to reduce the error of DID estimation, this paper further uses the PSM-DID method for the robustness test. The PSM-DID inspection results once again confirmed that the two control areas policy has a significant role in reducing acid rain and sulfur dioxide pollution in the region. Finally, based on the analysis results of the two models, this article proposes corresponding policy recommendations on further using the two control areas policy to reduce sulfur dioxide emissions from the perspective of the government and enterprises.

Keywords—Two Control Zones, sulfur dioxide emissions, Double difference

I. INTRODUCTION

Since the reform and opening-up, China's economy has developed rapidly. Behind the rapid development is the cost of high pollution and high energy consumption, which is especially reflected in the sharp increase in sulfur dioxide pollution. At present, the annual average concentration of sulfur dioxide in China has exceeded the national air quality standards for many consecutive years. Excessive emissions have also brought severe acid rain pollution. Since the 1980s, due to the lack of awareness of green scientific development, a series of evil incidents caused by acid rain and sulfur dioxide pollution has occurred in industrialization and urbanization in China. The spread of polluted areas and the increasing degree of pollution have given it to China. It has brought substantial ecological damage and economic losses and has become one of the essential factors restricting social and economic development.

To this end, the government began to implement the acid rain pollution and sulfur dioxide (SO2) pollution control area ("two control areas") system on the eve of the 21st century, the purpose of which is to reduce the increasingly serious air pollution and acid rain pollution by controlling the emission of SO2 pollution. The two control areas include 175 cities and regions above the prefecture level, covering an area of approximately 1.09 million square kilometers, accounting for 11.4% of the country's land area. Among them, the acid rain control zone covers an area of about 800,000 square kilometers, accounting for 8.4% of the total land area, mainly in the south of the Yangtze River, including parts of the southeast coast, central and southwestern and southwestern regions; the SO2 pollution control zone covers an area of about 290,000 square kilometers, accounting for 3% of the land area is mainly concentrated in the north of the Yangtze River, especially in North China, Northeast China, Shandong and the Hexi Corridor of Gansu. Except for Tibet, Qinghai, Hainan, and Heilongjiang, other provinces and regions have cities and counties in the two control areas. Once a city is included in the "two control zones", it will be subject to strict environmental policy controls, such as shutting down heavily polluting factories, using science and technology, etc., to strengthen the management of acid rain and sulfur dioxide pollution.

The introduction of the first section of the article discusses the research significance and innovations of this article; the second section of the literature review summarizes the content and deficiencies of some documents that study the problem, and at the same time explains the reasons for the model selection in this article; the third section is the model design The part of setting and data processing; the result and analysis part of the fourth section shows our analysis process in detail; the fifth section is the conclusion and suggestion part.

II. LITERATURE OF REVIEW

Xue (2003), Zhu (2005), and Song (2013) have sorted out the content policies and governance methods of the two control areas policy. Zheng (2006) used a follow-up survey report and Cheng (2004) to study the effects of the two control areas approach by means of simulation estimates. These reports and evaluations all pointed out that after implementing the procedure, the reduction of sulfur dioxide emissions and the overall city's, other indicators of environmental quality have improved.

This article draws on the methods of "quasi-natural experiment" and "difference analysis model" in econometrics through reading the literature. The use of the different analysis model to evaluate the effect of policies is a prevalent and practical method at home and abroad. It can compare the differences between the treatment group and the control group, and at the same time reach the ex-ante differences between the treatment group and the control group through the point of time when the policy is issued. After this double difference, the net effect of the policy can be identified.

In addition, before the research in this article, some scholars used the method of differential analysis to evaluate the effect of the "two control areas" policy, analyzed the relationship between sulfur dioxide emissions and economic growth, and obtained the sulfur dioxide emission reduction in the acid rain area of the policy. The conclusion is that the effect is not good and the cost is too high (Tang and Liang, 2012). Bao Qun et al. (2013) also used the differential method to analyze the effects of local governments' environmental legislation since the 1990s. They found no evidence that local environmental legislation can improve local environmental quality. Based on the DID model, Tanaka concluded that the implementation of the policy has improved the quality of the environment and reduced the infant mortality rate in the district by 20%. Cai et al. adopted the triple difference method and used the natural experiment of "two control areas" and found that environmental regulations have reduced the inflow of foreign capital. However, Wu Mingqin and others put forward the "Two Control Zones" policy to achieve a win-win situation for environmental regulation and economic growth, resulting in an increase of 8.3% in the per capita GDP of the cities in the zone.

A review of the existing literature on the two control zones policy found that most of the existing studies focused on the indirect effects of the implementation of the two control zones policy and paid more attention to the technical and economic aspects of the emission reduction policy. At the same time, there was less discussion on the procedure itself. And the direct estimation of the SO2 emission reduction effect is less. Based on this, this paper will use the double- difference model to examine the impact of the implementation of the two control areas policy on SO2 emissions and obtain the effect of the two control area policies on the emission reduction effects of cities in the region, especially cities in different control areas.

III. MODEL SETING AND DATA DESCRIPTION

A. *Model Setting*

In this paper, prefecture-level cities within the scope of implementation of these policies will be treated as treatment groups, and other prefecture-level cities will be regarded as control groups. Further divide the 293 prefecture-level cities in China from 1997 to 2018 into 4 sub-samples, namely the processing group before the implementation of the two control areas policy, the processing group after the implementation of the two control areas policy, and the two control areas policy. The control group before the implementation and the control group after the implementation of the two control areas policy. This paper distinguishes the above four sub-samples by setting two dummy variables of treated and time. Among them, treated=1 represents prefecture-level cities that implement the two-control area policy, and treated=0 represents other areas that do not implement the two-control area policy. Level City, time=1 represents the year after the implementation of the two control areas policy, and time=0 represents the year before the implementation of the two control areas policy.

According to the above sample definition, the benchmark regression model of the DID method can be set as follows:

$$Y_{it} = \beta_0 + \beta_1 treated_{it} + \beta_2 time_{it} + \beta_3 did_{it} + \beta_4 Z_{it} + \varepsilon_{it}$$

Regression equation 1

Among them, the subscripts i and t represent the i-th prefecture-level city and year t, respectively, did_{it} represents the interaction term $treated_{it} * time_{it}$, Z represents a series of control variables, ε is a random disturbance term, and the explanatory variable Y measures the prefecture-level city. The level of acid rain and sulfur dioxide pollution, the specific indicator is the SO_2 emissions of the prefecture-level city.

From regression equation 1, it can be seen that the acid rain and sulfur dioxide pollution levels before and after the implementation of the two control areas policy are $\Delta Y_t = \beta_2 + \beta_3$, which includes the effects of the two control areas policy and other related policies. Similarly, the range of changes in acid rain and sulfur dioxide pollution levels before and after the implementation of the policy in areas not affected by the two control areas policy is $\Delta Y_0 = \beta_2$. This difference does not include the impact of the two control areas policy on regional acid rain and sulfur dioxide. By subtracting the two, the net impact of the two control areas policy on acid rain and sulfur dioxide pollution in the area can be obtained $\Delta\Delta Y = \beta_3$. If the two control areas policy has a reduction effect on acid rain and sulfur dioxide pollution, then the coefficient of β_3, should be significant. It is negative, otherwise it is positive.

The idea of PDM-DID is derived from the matching estimator. By reading the literature, this paper uses the kernel matching method to determine the weight. ① Estimate the propensity scores based on the treatment group variables and control variables, and use Logit regression to achieve; ② Calculate the changes in each prefecture-level city's outcome variables that implement the two-control area policy before and after the policy. For each prefecture-level city i of the policy, calculate the changes before and after the implementation of the policy in prefecture-level cities in other regions that match it. ③ The changes of prefecture-level cities that implement the Two Control Areas policy before and after the implementation of the policy are subtracted from the changes in prefecture-level cities in other areas after matching to obtain the average treatment effect (ATT) of the Two Control Areas policy. Effectively measuring the actual impact of the two control areas policy on the prefecture-level cities that implement the policy is also the basis for this paper to use the PSM-DID method to test.

B. Data Description

This article uses panel data from 217 prefecture-level cities in China from 1997 to 2018 to evaluate the impact of the two control areas policy. Due to the incomplete data of the China City Statistical Yearbook, this article deletes the prefecture-level cities with serious data missing, and only retains 217 prefecture-level cities with relatively complete data. All the original data comes from the China City Statistical Yearbook over the years. . The reason why the sample interval of this article is determined to be from 1997 to 2018 is based on the following two reasons: ① The two control areas policy began in 1998, so data selection should start before 1998; ② Due to the limitations of the China City Statistical Yearbook data, many important indicators (such as sulfur dioxide emissions) before 1997 are seriously missing. Considering the availability of data, this article chooses to start from 1997. In addition, this paper also controls other factors that affect acid rain and sulfur dioxide pollution. The detailed calculation methods of all variables are shown in Table 1.

Table 1 *The main variables and their calculation methods*

Variable name	Variable meaning	Calculation method
so2	Acid rain and sulfur dioxide pollution levels	Sulfur dioxide emissions in the region (ten thousand tons)
policy	"Two control areas" policy dummy variables	Dummy variable (0, 1)
time	Time dummy	Dummy variable (0, 1)
treated	Two control area dummy variables	Dummy variable (0, 1)
did	Interactive item	time multiplied by treated, dummy variable (0, 1)
gdp	Economic level	Gross Regional Product (10 billion yuan)
fdi	Level of foreign direct investment	Actual foreign investment in the region (US$100 million)
industry	Industrialization level	Regional total industrial output value above designated size (10 billion yuan)
popu	Population level	Total population of the region at the end of the year (million people)
cityno	Regional variables	Prefecture-level city number

Source: Compiled by the author.

In order to measure the level of acid rain and sulfur dioxide pollution, by the standard practice in the literature, this paper takes SO 2 emissions as the explained variable. One of the core explanatory variables of this article is the interaction term did it. Using the PSM-DID method to test the robustness later, specify the regional variable (cityno) as the individual ID, use the Logit model to estimate the propensity score and perform the kernel matching (Kernel Matching), and perform a series of tests on this basis.

To control the influence of other factors, this article refers to the practice of Xiong Bo (2019) and Li Xiaosheng (2020). It selects four control variables: regional GDP, regional foreign investment, regional industrial output value above designated size, and total regional population at the end of the year. The descriptive statistics of each variable are shown in Table 2.

Table 2 *Descriptive statistics of main variables*

Variable	Obs	Mean	Std. Dev.	Min	Max
so2	4751	16.045	51.904	0	1076.293
time	4751	.955	.208	0	1
treated	4751	.642	.479	0	1
did	4751	.614	.487	0	1
gdp	4726	15.129	25.818	.16	326.799
fdi	4397	6.722	17.825	0	308.256
industry	3879	22.168	37.555	0	324.451
popu	4743	4.522	3.66	.131	95.91
cityno	4751	363959.	13031	11000	650100

29 2.46 0

Source: The author organizes based on the results of stata15.0 software.

IV. RESULTS AND ANALYSIS

As a comprehensive prevention and control plan for air pollution control, implementing the "two control areas" policy provides a quasi-natural experiment. Therefore, this article uses the DID method to evaluate the impact of the "two control areas" policy on acid rain and sulfur dioxide pollution control in the areas where the policy is implemented. The net effect. The regression results are shown in Table 3.

Table 3 *The effect of the "two control areas" policy on the level of acid rain and sulfur dioxide pollution in the region*

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	so2	so2	so2	so2	so2	so2	so2	so2
did	-38.859***	-38.072***	-36.251***	-38.477***	-37.178***	-36.771**	-36.334**	-36.787**
	(-2.895)	(-2.748)	(-2.597)	(-2.864)	(-2.757)	(-2.561)	(-2.544)	(-2.573)
time	-19.176***	-19.915***	-20.900***	-20.128***	-19.118***	-20.956***	-20.679***	-20.952***
	(-3.558)	(-3.497)	(-3.539)	(-3.666)	(-3.463)	(-3.464)	(-3.421)	(-3.461)
treated	46.539***	47.026***	45.080***	45.591***	46.011***	46.145***	45.801***	45.835***
	(3.481)	(3.408)	(3.241)	(3.412)	(3.428)	(3.228)	(3.220)	(3.219)
gdp		-0.126***				-0.188***	-0.288***	-0.263***
		(-7.639)				(-7.825)	(-7.484)	(-5.119)
fdi			-0.109***			0.096***	0.092***	0.133***
			(-4.688)			(4.346)	(3.732)	(5.392)
popu				1.084***			1.716***	1.309***
				(3.614)			(3.768)	(3.356)
industry					-0.075***			-0.014
					(-5.491)			(-0.599)
_cons	28.305***	30.238***	30.763***	24.715***	29.275***	31.863***	25.139***	26.752***
	(5.300)	(5.357)	(5.255)	(4.435)	(5.366)	(5.314)	(4.023)	(4.329)
N	4751	4726	4397	4743	3879	4380	4378	3753

*Note: t-values are in parentheses, *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.*
Source: The author organizes based on the results of stata15.0 software.

In Table 3, column (1) is the estimation result without adding other control variables, and column (2)-column (8) are the estimation results with adding different control variables respectively. Column (1) shows that the "two control zones" policy does promote the reduction of sulfur dioxide emissions. Columns (2)-columns (5) indicate that GDP, FDI, POPU, and industry have significant effects on so2, among which POPU has a positive effect on so2, and the other covariates have a negative effect on so2. Comparing column (1) with column (2)-column (5), it can be found that the absolute value of the interaction term coefficient has decreased, and GDP or POPU is added separately to enter the regression equation, and the interaction term coefficient does not change significantly; adding industry and When FDI enters the regression equation, the coefficient of the interaction term has changed significantly, and the change of industry is greater than that of FDI. This shows that after controlling these factors alone, the "two control areas" policy has less effect on promoting the reduction of sulfur dioxide emissions. The order of the covariates to the largest is POPU, GDP, industry, and FDI.

Observe column (1), column (2) and column (6)-column (8). By continuously adding control variables, you can find the interaction coefficients of whether each control variable is added to the treatment group and whether the policy impacts Impact. According to the results in Table 4, the addition of the GDP variable has basically no effect on the interaction coefficient; after adding the FDI and POPU variables, the absolute value of the interaction coefficient becomes smaller, indicating that the “two control areas” policy has an effect on sulfur dioxide emissions after controlling these factors. After the industry variable is added, the absolute value of the interaction coefficient is found to increase, indicating that after the industry is controlled, the deteriorating effect of the previous “two control areas” policy on the reduction of sulfur dioxide emissions will be partially offset. At this time, the GDP coefficient is significantly negative, which means that the higher the GDP, the lower the sulfur dioxide emissions, which may be because more environmentally friendly technologies are used to create GDP; the FDI coefficient is significantly positive, which means the use of foreign companies The more investment, the higher the sulfur dioxide emissions, which may be due to foreign factories moving heavily polluting factories into China; the POPU coefficient is also significantly positive, which has a positive impact on sulfur dioxide emissions, which is in line with common sense; the influence of industry on sulfur dioxide emissions Not obvious.

In order to reduce the error of DID estimation, this paper further uses the PSM-DID method for robustness test. When using the PSM-DID method, Logit regression is performed on the control variables through treated to obtain a propensity score. The regression results show that the estimated ATT value is -1.46502868, which is not significant, indicating that the "two control areas" policy does reduce sulfur dioxide emissions effect.

At the same time, the model needs to test whether the distribution of each variable in the treatment group and the control group becomes balanced after matching, and whether the mean of the covariate is still significantly different between the treatment group and the control group. If there is no significant difference, the application of the PSM-DID method is supported. The covariate test results show that the standardized deviation (%bias) of all variables after matching is less than 5%. The t-test results of all variables do not reject the null hypothesis that the treatment group and the control group are not systematically different. Each variable is between the treatment group and the control group. The distribution becomes even, indicating that the PSM-DID method is more appropriate.

V. CONCLUSIONS AND SUGGESTIONS

A. *Conclusion*

This paper uses the panel data of 217 prefecture-level cities in China from 1997 to 2018, and uses the DID method and the PSM-DID regional method to test whether the two control areas promote the reduction of acid rain and sulfur dioxide levels.

First, apply the DID model and use the panel data of prefecture-level cities to preliminarily analyze the impact of the two control areas policy on sulfur dioxide. DID results show that the wo control zones policy has indeed played a role in reducing sulfur dioxide emissions. After individually controlling the covariates, the two control zones policy has a smaller effect on promoting the reduction of sulfur dioxide emissions. The covariates are sorted in order of reduction degree from small to large, namely POPU, GDP, industry, and FDI. By constantly adding control variables, it can be found that GDP has almost no effect on the emission reduction effect of the "two control area" policy; FDI and POPU have a worsening effect on the emission reduction effect of the "two control area" policy; industry's deterioration of sulfur dioxide emission reduction The effect will be partially offset.

Secondly, in order to reduce the error of DID estimation, this paper further uses the PSM-DID method for robustness test. The PSM-DID inspection results show that the "two control areas" policy has a significant role in reducing the level of acid rain and sulfur dioxide pollution in the region, which further supports the previous analysis results.

B. *Suggestions*

According to the empirical analysis of this article, we give the following suggestions from the perspective of the municipal government: ① Reasonably control the regional population level and economic development speed, population growth will bring economic growth, and economic growth is important to government performance It is extremely important, but the empirical results show that the growth of population and economy will bring about the increase of sulfur dioxide emissions. Therefore, the speed of population and economic development should be controlled reasonably, and the contradiction between pollution and economic development should be balanced; ② According to the level of local investment in fixed assets, the government can attract the inflow of investment in fixed assets by simplifying approval procedures and tax incentives; ③ Promoting the transformation of regional industrial structure and the development of the tertiary industry can effectively reduce sulfur dioxide pollution. As a result, local governments can provide Develop the tertiary industry in ways such as loans and lowering the barriers to entry for enterprises.

From the perspective of enterprises, the key to reducing sulfur dioxide emissions is enterprises. Companies need to realize that in the short term, adding equipment and management measures to prevent environmental pollution will increase costs and reduce profits. But in the long run, companies need to combine the goal of pursuing profit with legal ethics and social responsibility. Enterprises can deal with the problem of sulfur dioxide emissions from the level of technological upgrading and technological innovation, and increase investment in pollution control, not only for pollution control, but also increase of new technical means and equipment, moreover, the use of clean energy. Source pollution should be controlled to realize the combination of corporate economic and social benefits.

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