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On the Environmental Effect of Free Trade Zone in China ——Empirical Analysis of DID Model based on Shanghai, Fujian, Guangdong and Tianjin

Xinyao LIN

School of Economics, Fujian normal University, Fuzhou, Fujian Province, China

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Abstract: The relationship between environment and trade is a focus of international economics. Based on the panel data of 285 prefecture-level cities, this paper empirically tests the environmental impact of establishing a free trade zone by using the dual difference method. The results show that: first, the establishment of pilot free trade zones can improve the environment; second, in terms of action mechanism, the increase of green patents and economic agglomeration are the main ways. Because the data samples are not available, this paper did not test all the pilot free trade zones. The construction of pilot free trade zone should give full play to the advantages of industrial agglomeration and increase the investment in green technology research and development. The study on the relationship between the environment of prefecture-level cities and the pilot free trade zone is helpful to realize the sustainable development of China's economy.

1. Introduction

In the process of economic globalization and integration, the importance of foreign trade to a country's economic development is self-evident [1]. The pilot free trade zones (FTZS) are an important strategic support for China to deepen reform and promote the formation of a new pattern of comprehensive opening up. The pilot FTZS in Shanghai, Fujian, Guangdong and Tianjin, as the pacesetters in the process of trade liberalization, have been exploring a series of reform measures that can be popularized and replicated by pioneering institutional innovation. According to the data from the national bureau of statistics, China's foreign trade has been growing at a high speed, especially since the accession to the WTO. Due to the financial crisis, China's total import and export volume dropped sharply in 2009, but continued to rise after the crisis. China's total imports and exports in 2018 reached 3.050813 trillion yuan, up 676.63% from 2000.

In the process of free trade, the relationship between trade and environment has become the focus of many scholars [2]. On the one hand, the contradiction between resources and environment and

production and consumption demand has aroused widespread concern in all countries in the world. In 2015, the United Nations proposed to completely solve the development problems in the three dimensions of social, economic and environmental development in a comprehensive way. As countries gradually transform to green development, they attach more importance to the relationship between economic behavior and environment. On the other hand, there is an endless stream of trade litigation and multilateral negotiations on the environment at the world trade organization. Therefore, the environmental effect of trade liberalization has once again become a research hospot.

At present, China is the third largest trading country in the world. Since China did not take the environment into full consideration when promoting trade liberalization in the past, it has paid a high price of environmental pollution and resource consumption. Therefore, it is necessary to pay more attention to the win-win situation of environment and economy in promoting a new round of comprehensive opening-up strategy. Domestic scholars have conducted empirical studies on the environmental effects of China's trade liberalization under the mainstream framework, and the results show that free trade is beneficial to the improvement of China's environmental conditions [3]. But are the environmental effects consistent? If so, what is the mechanism for establishing pilot free trade zones to improve the environment? This question has attracted the attention of policy makers and academic circles, but no scholars have directly answered it. The research on this issue will help to realize the green and sustainable development of China's pilot free trade zone.

Based on the above analysis, this paper takes the pilot free trade zones in Shanghai, Fujian, Guangdong and Tianjin as examples, USES the panel data of 285 prefecture-level cities in China from 2003 to 2017 to systematically evaluate the environmental effects of the pilot free trade zones, and explores their mechanisms as much as possible, providing empirical evidence for promoting a new round of comprehensive opening process. The innovation points of this paper are as follows: (1) the environmental effects of pilot free trade zones are analyzed based on the data of each prefecture-level city. The experience at the prefecture-level city level is conducive to the better development of China's pilot free trade zone strategy. (2) the dual-difference policy analysis model is used to test the environmental effects of free trade zones, which has important reference value and significance for how to promote the deepening reform of free trade pilot zones in other fields. (3) based on intermediary models such as economic agglomeration and green patent, the paper empirically tested the mechanism of establishing free trade zone on environment. (4) use indicators such as the number of green patents to represent the level of green innovation in the region.

The second part is literature review, the third part is data, variables and descriptive statistics, the fourth part contains econometric model, empirical test and analysis of intermediary mechanism, and the fifth part is conclusion and enlightenment.

2. Literature review

2.1 Research on pilot free trade zones

In recent years, China's pilot free trade zones have increased from one to 11, gradually covering the eastern, central and western parts of the country. Since the establishment of the first pilot free trade zone, scholars have mainly studied the strategic positioning, significance, function and economic effect of the pilot free trade zone. The main contents are shown in table 1.

Table 1. A review of research on pilot free trade zones

Data source: CNKI

Research direction	representative	Main point
Study on the strategic positioning and significance of the establishment of the pilot free trade zone	Dara Orenstein(2011), Christopher(2014), Zhao gangling, Wang Tao (2013), Tian Huimin, Xiong Chao, Tian tian (2015), Li Simin (2015)	1. The establishment of pilot free trade zones can increase employment and exports. 2. The establishment of the Shanghai pilot free trade zone is aimed at establishing China's position in the world economy. 3. The establishment of pilot free trade zones can become a driving point of economic growth 4. The establishment of China's pilot free trade zone is to explore new mechanisms and systems in line with international standards.
Study on the function of free trade test zone	Madani(1999), Trunick(2014), Hou Zhiwan (2014), Jiang Suoliang (2015), Pei Changhong,Chen Lifen (2015), Hong Lianying, Huang Ruxuan (2017)	5. Only by optimizing the management mode and reducing trade and investment barriers, can the free trade zone promote economic growth. Free trade zones have financial and trade functions and promote trade in the United States. 6. The functional orientation of Shanghai pilot free trade zone should focus on financial service innovation and investment facilitation.
study on the economic effect of pilot free trade zone	Miyagiwa(1986), Wang Haimei (2014), Chen Qi, Liu Wei (2014), Zhao Bo (2014), Xia Zemin (2015), Zhao Jing (2016), Wang Lihui, Liu Zhihong (2017), Yin Hua, Gao Heping (2017)	1. The establishment of a free trade zone will bring special preferential policies from the government, which will increase local welfare and increase the concentration degree of production factors. 2. The impact of the Shanghai pilot free trade zone on the local economy is positive, promoting trade facilitation, investment liberalization and financial internationalization, and promoting regional economic development. 3. Peripheral spillover and leaping spillover are the current situation and mechanism of industrial spillover in China's pilot free trade zone, and their essence is the diffusion of economic activity space. 4. The establishment of free trade zone attracted some wenzhou commercial capital to flow to Shanghai.

2.2 Pilot free trade zones and environmental effects

From the above analysis, it can be seen that the current research on pilot free trade zones is mainly aimed at the exploration of the pilot zone strategy itself, and there are few studies on the environmental effects of free trade. After reading the literature, the author found that the

environmental effects of world free trade zones and free trade zones are mainly studied at home and abroad, while the environmental effects of China's free trade zones are still blank.

At the earliest, gross-man[4] and Krueger established the mainstream analysis framework of the environmental effect of free trade, which divided the environmental effect of foreign trade into scale effect, structure effect and technical effect, and the total effect of trade on the environment was determined by the combined efforts of the three (gross-man Krueger, 1991). Bhagwa ti [5](1993), Lopez[6] (1994) and the World Bank[7] (1992) have also obtained similar research conclusions to that of gross-man and Krueger, holding that the comprehensive environmental effect of free trade is positive. Dean (1997) used data from Chinese provinces to observe the environmental effects of free trade from both dynamic and static perspectives by establishing simultaneous equations. Dean found that the impact of free trade on the environment has different directions. In the short term, the improvement of terms of trade will increase pollution, while in the long term, it will reduce pollution. The reason is that after a period of time, the income effect brought by free trade will promote the demand for environmental quality and reduce pollution. Generally speaking, the environmental effect brought by free trade is positive in the end.

Some scholars disagree. Internationally, Taylor and Copeland[8] (1994) established the north-south trade model and found that free trade has a negative impact on the world, and it affects poor and rich countries in different directions, as well as the south and north. Dua and Esty[9] (1997), Esty and Geradin (1997) and Barrett (1994) all point out that the liberalization of global trade may have negative effects on the environment. In China, Deng Jie and Wu Xianjin[10] (2011) verified the existence of EKC curve of carbon emissions, and the results showed that energy consumption and carbon emissions would increase with the increase of output level. Zhou Maorong et al. (2008) established the ACT model and found that the impact of international trade on China's environment is negative.

Some scholars in China have studied the environmental effects of the world free trade areas such as North America and Asia-pacific. For example, Li Liping[11] takes the trade between China and New Zealand as an example. Her research shows that regional economic and trade cooperation has both positive and negative impacts on China, but the overall impact is positive [11]. The establishment of the free trade area between China and Asean has brought greater environmental pollution pressure to both sides.

Previous studies have provided us with research ideas for analyzing the relationship between China's pilot free trade zones and the environment. However, the current research still has the following shortcomings: first, there are few studies on the environmental effects of pilot free trade zones in China, and no scholars have conducted direct research on China's pilot free trade zone policies. Second, most of the existing literature is based on the analysis of the three frameworks of environmental effects, and the analysis of other relevant mechanisms is lacking. The purpose of this paper is to explore whether the establishment of China's pilot free trade zones can bring about the effects of environmental governance, and to further explore the mechanisms through which the pilot free trade zones affect the environment, so as to supplement the research on the environmental effects of pilot free trade zones and provide Suggestions for China to carry out a new round of comprehensive opening up strategy.

3. Data, variables and descriptive statistics

3.1 Data sources

In 2013, the CPC central committee and the state council set up China's first pilot free trade zone, China (Shanghai) pilot free trade zone, followed by China (Guangdong) pilot free trade zone, China (Tianjin) pilot free trade zone and China (Fujian) pilot free trade zone. Between September 2013 and August 2019, China had approved batches of Lliaoning, Zhejiang and other 18 free trade area, the pilot from the free trade area of Shanghai in 2013 started to gradually popularized to all over the country, formed in the north and south, east and coordination, land, sea and open situation as a whole, formed a new round of overall opening pattern in our country. At the same time, the "quasi-natural experiment" of pilot free trade zones provides a valuable opportunity for this paper to study the impact of setting up pilot free trade zones on China's environmental pollution by using the double-difference method. On the one hand, since our data sample is from 2003 to 2017, the double-difference method requires a comparison of policy effects in the experimental group before and after. By 2015, China had only set up four pilot free trade zones in Shanghai, Tianjin, Fujian and Guangdong. Considering that the pollution index used in this paper is the emission of industrial pollutants from prefecture-level cities, this paper selects whether to set up a pilot free trade zone as a quasi-natural experiment. Among the samples in this paper, China (Shanghai) pilot free trade zone, China (Guangdong) pilot free trade zone, China (Tianjin) pilot free trade zone and China (Fujian) pilot free trade zone constitute the experimental group, while the other 281 prefecture-level cities are the control group. Based on this, this paper attempts to use the panel data of 285 prefecture-level cities from 2003 to 2017 to evaluate the environmental effect of setting up pilot free trade zones by using propensity score matching and double difference methods. On the basis of a series of robustness tests of the basic conclusion, this paper further explores the mechanism through which the establishment of free trade zone influences the pollution control. The data in this paper are mainly from the data from 2001 to 2007 in the statistical yearbook of Chinese cities. The panel data of 285 prefecture-level cities from 2003 to 2007 are selected to form the basic sample of this paper, and then the data sample of this paper is formed by matching the green patent data in the world intellectual property organization (WIPO) from 2003 to 2007 according to the year and the city. All the price indexes in the sample were the prices of the current year. In order to eliminate the impact of inflation, the GDP index at the provincial level (2003=100) was used for deflating. Actual utilized foreign capital is denominated in RMB after adjustment of exchange rate, the exchange rate is from the website of national bureau of statistics, and the GDP index of each province is from China statistical yearbook (2004-2017).

3.2 Variables and descriptive statistics

1. Dependent variable. Since most academic circles use industrial sulfur dioxide emissions as an indicator of environmental pollution, this paper also USES industrial sulfur dioxide emissions as an alternative variable of pollution. The dependent variable data used in this paper are all from the provincial data of China environmental yearbook.

2. Core explanatory variables. The core index of this paper is the interaction variable did in China's pilot free trade zone. Did is the product of treated and wave. Treated refers to the policy dummy variable of the experimental group, while wave is the year dummy variable of the experimental group.

Cities with pilot free trade zones in China had treated equal to 1, or zero. Wave =1 when t≥ the year in which the city established the free trade zone; otherwise, it is zero.

3. Control variables. Because the level of economic development is an important factor affecting regional environmental pollution [12, 13]. In this paper, the logarithm of regional GDP per capita is controlled to test whether there is an environmental Kuznets curve in China's pilot free trade zone. Meanwhile, the impact of foreign direct investment on environmental pollution is still controversial [14], this paper tested whether the "pollution haven hypothesis" is valid in China's prefecture-level cities by controlling the actual utilization of FDI in regions. In addition, this paper controls the square of the proportion of secondary industry to identify the effect of industrial structure on environmental pollution. The change of industrial structure is an important factor affecting environmental pollution, and the impact of industrial structure adjustment on air pollution will have different effects over time, rather than a linear relationship. Finally, we also controlled the number of people in the region at the end of the year, so as to test the impact of population size and population concentration on the emission of industrial pollutants in the region.

4. Other variables. In this paper, the number of green patent applications and economic agglomeration are taken as the mechanism variables to identify the environmental effect of the pilot free trade zone. Among them, the number of green patent applications refers to the number of green technology patents applied in the region, while the economic agglomeration effect is represented by the labor force on the unit land area. The descriptive statistics of variables in this paper are shown in table 2.

Table 2 Variable descriptive statistics

Variable	Definition	Mean	Std. Dev.
so2	Sulfur dioxide emission (ton)	55947.61	57888.42
did	Double difference dummy variable	.0064625	.0801407
popu_	Year-end population (ten thousand)	5.906631	.6443054
log_gdocpi	Logarithm of per capita GDP (ten thousand yuan)	49434.99	2948547
Secondary industry proportion	Proportion of secondary industry (%)	50.4%	0.1066
Secondary industry proportion_	Secondary industry proportion squared term	26.5%	0.1099
fore_inves_	Actual amount of foreign capital used in that year (ten thousand us dollars)	9.751725	1.877499
faketreat_1	Counterfact group 1	.0118011	.108005
faketreat_2	Counterfact group 2	.0137679	.1165426
Economic agglomeration	Labour force per unit land area (m^2 / person)	60.2391	143.1358
Green application quantity	Number of green patent applications in that year	294.6961	1006.064

4. Econometric model and empirical analysis

4.1 The impact of the establishment of pilot free trade zones on sulfur dioxide emissions

Compared with foreign countries, China's free trade zone strategy started late, but it has developed rapidly since 2013, and there are some differences in the situation of setting up pilot free trade zones nationwide, which provides a valuable opportunity to evaluate the pollution control effect of setting up pilot free trade zones by using the dual difference method. In the samples of this paper, according to the specific time when the party central committee set up each pilot free trade zone, if the pilot free trade zone is set up or has been set up in the same year, the value is assigned to 1; otherwise, the value is 0. According to the regional and time differences of the pilot free trade zone, did variables can be set to test the impact of the establishment of the pilot free trade zone on sulfur dioxide emissions by constructing the following two-way -- fixed effect model:

$$\ln pollutit = \beta 0 + \beta 1\ did + \sum j\ \beta j \times Control + \gamma t + \mu i + \varepsilon it \quad (1)$$

In equation (1), the variables of the explained pollutant are regional industrial sulfur dioxide emissions. Subscripts t and I represent the year t and the ith prefecture-level city, respectively, while t. and I represent the time-fixed effect and region-fixed effect, respectively. Control refers to other Control variables, including economic development level, utilization level of foreign capital, industrial structure status, population at the end of the year, etc. The coefficient of point 1 represents the net impact of pilot free trade zones on regional industrial pollution emissions. Using model (1), this paper first examines the impact of pilot free trade zones on SO2 emissions from regional industries. Considering the strong correlation between foreign direct investment, year-end population and industrial structure in the control variables and per capita GDP, this paper USES the stepwise regression method to identify whether the correlation between the control variables will affect the estimation results of the core explanatory variables. The specific regression results of stepwise regression are shown in table 3.

Table 3 The impact of the establishment of free trade zone on environmental pollution

	so2_	so2_	so2_	so2_	so2_
did	-1.6931***	-1.7403***	-1.7390***	-1.6835***	-1.6786***
	(0.3000)	(0.3031)	(0.3034)	(0.3038)	(0.3039)
Population at end of the year		0.4209	0.4112	0.4813	0.4823
		(0.3849)	(0.3952)	(0.3959)	(0.3959)
Logarithm of GDP per capita			8.1091	21.8316	22.2159
			(74.2338)	(74.4871)	(74.4879)
The proportion of secondary industry^2				-0.0004*	-0.0004*
				(0.0002)	(0.0002)
Amount of foreign investment					-0.0281
					(0.0279)
Time effect	yes	yes	yes	yes	yes
Area effect	Yes	yes	yes	yes	yes
_cons	0.9924***	-1.4749	-1.4178	-2.1561	-1.9303
	(0.0737)	(2.2571)	(2.3174)	(2.3716)	(2.3821)

N	3557	3557	3557	3555	3555
R^2	0.7343	0.7344	0.7344	0.7352	0.7353

Note:* represents significant at the 10% level, * * represents significant at the 5% level * * *, represents significant at the 1% level.
The above is significant, and the following table is the same.

The results in table 3 show that the establishment of pilot free trade zones has effectively reduced regional industrial sulfur dioxide emissions, and the pilot free trade zones have played an obvious role in environmental pollution control. Some scholars put forward the second industry and sulfur dioxide emissions is inverted U shape, the second industry development on the role of industrial so2 emissions through the process of first rise after the fall, probably because the pollution control in the development of technology and equipment cost will decrease with the expansion of the industry and [15], industrial pollutants also increases along with the industrial scale [16]. In this paper, the proportion square of the secondary industry was controlled to test this study, and it was found that the sulfur dioxide emissions in the region were negatively correlated with the proportion square of the secondary industry, that is, the sulfur dioxide emissions decreased gradually with the development of the secondary industry. In addition, after controlling the actual use of foreign investment in this paper, it is found that there is no significant correlation between sulfur dioxide emissions and the introduction of foreign investment, which indicates that the Kuznets hypothesis of economic development and environmental pollution -- "pollution paradise" hypothesis is not valid, and the introduction of foreign investment in developing countries will not cause large-scale pollution.

4.2 Robustness test

1. Counterfactual testing. Through the above analysis, it is found that the establishment of pilot free trade zones does have the effect of environmental governance, but we still need to test whether this is an accidental phenomenon, and whether environmental improvement is not directly related to the establishment of the free trade zones? To examine whether contingency exists, a placebo test is performed here. That is, a time point before the establishment of the pilot free trade zone was randomly selected as the experimental group of the virtual policy. For example, suppose the free trade zone was established in 2007, and the period after the implementation of the policy was from 2008 to 2013, and the dummy variable of did was set as 1faketreat_1. Then suppose that the pilot free trade zone was established in 2006, and the time after the policy implementation was 2007-2013. The dummy variable 2faketreat_2 of did was set up to conduct counterfactual analysis. Under hypothetical policy to deal with, if free trade area still can effectively reduce the emissions pilot areas, instructions above pollution treatment effect of free trade area from the systemic factors, conversely indicates that setting up free trade area can promote the regional environment pollutant emissions, also verify the results and the basic logic of table 3. If at a random time point, the sulfur dioxide emissions in the experimental group are also significantly negatively correlated with the counterfactual experimental group, it indicates that the analysis in this paper is not sufficient to provide support for the environmental governance of the pilot free trade zone. To save space, table 4 shows the counterfactual placebo test results directly.

Table 4 Counterfact test (placebo test)

	so2_	Std. Dev.1	so2_	Std. Dev.2
faketreat_1	-0.2146	(0.2612)		
faketreat_2			0.1288	(0.2616)
Year-end population	0.1563	(0.3938)	0.1805	(0.3944)
Logarithm of GDP per capita	38.8923	(74.7715)	37.8910	(74.7829)
Secondary industry 2	-0.0004**	(0.0002)	-0.0004**	(0.0002)
Amount of foreign investment	-0.0312	(0.0280)	-0.0302	(0.0280)
Time effect	yes	yes	yes	yes
Area effect	yes	yes	yes	yes
N	3555	3555	3555	3555
R2	0.7329	0.7329	0.7328	0.7329

From table 4, we can see that the regression results of the virtual core variables faketreat_1 and faketreat_2 formed after the time point of the policy was adjusted were not significant when the experimental group remained unchanged. In other words, when the pilot free trade zone cities did not carry out the pilot free trade zone policy, their sulfur dioxide emissions did not show a downward trend, and when the policy began to implement, sulfur dioxide emissions significantly reduced. Random assumes that a free trade area established time will not find a significant reduction in the sulfur dioxide emissions, only from the free trade area established real point, free trade area was significant treatment effect is negative, it is sent the sulfur dioxide emissions decreased as a result of systemic factors, provides strong evidence for the conclusion of the paper.

Double difference is conducted after matching propensity score. In order to eliminate the endogeneity error of data samples, this paper further USES the method of psm-did to test the policy effect of the main results and ensure the robustness of the above regression results. Propensity matching scores are a statistical method used to process data from observational studies. In the observational study, due to various reasons, there are many data deviations and confounding variables, and the propensity matching method is precisely to reduce the influence of these deviations and confounding variables, so as to make a more reasonable comparison between the experimental group and the control group.

Specifically, (1) for comparison, using the above control variables to predict the probability of each area county set as free trade area (Logit regression), and nuclear matching method is used to set up a free trade area of the sample matched control group (treatment group), the treatment group and control group in setting up free trade area before the policy impact, there were no significant differences as far as possible to reduce the free trade area when setting up endogenous problems brought by the selection bias. On this basis, the DID method is used to identify the environmental impact of the establishment of pilot trade zones.

Table 5 PSM+DID

	so2_	Standard error
did	-1.5693***	(0.5805)
Control variables	Yes	Yes

Constant term	3.4011	(11.0105)
Urban fixation	yes	yes
Time fixed effect	yes	yes
N	533	533
R^2	0.7174	0.7174

Since the propensity score can solve the deviation problem of observable covariables to the greatest extent, and the double difference method can eliminate the influence of variables not observed such as time invariant and synchronous change over time, the combination of the two methods can more accurately identify the policy effect of the pilot free trade zone. In principle, if the effect of environmental governance is indeed due to the establishment of pilot free trade zones, the final estimates will not differ much regardless of the matching method. From the estimated results in table 5, it can be seen that after the propensity score matching, the system extracts observation samples according to the method of random selection. The selective bias in the establishment of the pilot free trade zone was eliminated and the interference between the experimental group and the control group was eliminated. According to the regression results, did is still significantly negative, which indicates that the main result is still robust after the trend score matching, that is, the conclusion that establishing a free trade pilot zone can reduce sulfur dioxide emissions is still valid, which provides another strong evidence for the conclusion of this paper.

4.3 Analysis of mediating effect mechanism

The empirical analysis in the previous section has verified that the establishment of pilot free trade zones can significantly reduce industrial sulfur dioxide emissions, but what is the intermediate mechanism and transmission process of policy affecting the environment? This is the concern of this article. Green patent technology innovation is an effective means to ensure the win-win situation of economic development and environmental protection. The output of green technology innovation can significantly reduce industrial pollution emissions and is a key means of energy conservation and green development of industrial enterprises [17]. Some scholars [18] have found that regional pollution emissions are affected by industrial agglomeration. With the improvement of industrial agglomeration level, pollution emissions show a phenomenon of marginal decline, and the law of marginal pollution emission decline of industrial agglomeration leads to the environmental pollution mitigation effect of industrial agglomeration. From the perspective of "dual wheel drive", the interaction between the increase of exogenous technological innovation output and the agglomeration of producer services can effectively realize the complementary advantages of the two, realize the unification of the paths of resource utilization and allocation, improve the ecological environment and curb pollution emissions [17]. This paper USES the mediation model to identify and verify the above conduction paths. Among them, technological innovation is reflected by the number of green patent applications in the region each year. The labor force on unit land area is selected to represent the economic agglomeration effect. Then the mediating effect model composed of the following three regression equations is constructed

$$y_{it} = \alpha_0 + \alpha_1 law\_c_{it} + \alpha_3 X_{it} + \eta_i + \nu_t + \varepsilon_{it} \quad (1)$$

$$Center\_c_{it} = \beta_0 + \beta_1 D + \beta_3 X_{it} + \eta_i + \nu_t + \varepsilon_{it} \quad (2)$$

$$y_{it} = \gamma_0 + \gamma_1 law\_c_{it} + \gamma_2 D_{it} + \alpha_3 X_{it} + \eta_i + \nu_t + \varepsilon_{it} \quad (3)$$

Among them, y_{it} represents for the sulfur dioxide emission level; $Center\_c_{it}$ Represents a possible mediation variable, D_{it} It mainly includes economic agglomeration and the number of green patent applications; X is a bunch of control vectors; η_i represents for the urban fixed effect; ν_t Time fixed effect; ε_{it} is the error term. According to the principle of the mediating effect model, the regression coefficient of the if coefficient α_1 β_1 and γ_1 both are significant, indicating the existence of mediating effect. The specific regression results are shown in table 6.

Table 6 The mediation effect

	so2_	Economic agglomeration	so2_	Green applications	so2_
did	-1.6786***	253.2180***	-1.7135***	2785.4057***	-0.6952**
	(0.3039)	(22.9048)	(0.3365)	(142.7265)	(0.3167)
Economic agglomeration			-0.0004*		
			(0.0003)		
Green applications					-0.0004***
					(0.0000)
Urban fixation	yes	yes	yes	yes	yes
Time fixed effect	yes	yes	yes	yes	yes
_cons	-1.9303	-639.7145***	-1.8172	-5.63e+03***	-3.9149*
	(2.3821)	(216.2603)	(3.1191)	(1118.9064)	(2.3586)
N	3555	3288	3287	3557	3555
R^2	0.7353	0.7192	0.7847	0.7017	0.7426

Table 6 reports the regression results of mediating effect. The first column is the model results, the second and third columns are the model regression results with economic agglomeration as the mediation variable, and the fourth and fifth columns are the model regression results with green patent applications as the mediation variable.

The mediating effect of economic agglomeration is established. First of all, according to the results in the second column, when economic agglomeration is selected as the intermediary variable, economic agglomeration and did show a significant positive correlation, that is, the establishment of a pilot free trade zone can promote the occurrence of economic agglomeration effect. Secondly, according to the results in the third column, when economic agglomeration was put into the model as a core explanatory variable, sulfur dioxide emissions showed a significant negative correlation with did and economic agglomeration. This suggests that emissions of sulphur dioxide will fall as economic agglomeration takes hold. It can be seen that the establishment of pilot free trade zones promotes the occurrence of economic agglomeration effect, and economic agglomeration will further

promote the reduction of sulfur dioxide emissions. Therefore, economic agglomeration is one of the reasons for promoting the reduction of sulfur dioxide emissions after the establishment of pilot free trade zones.

The mediating effect of green patent application quantity is established. First of all, according to the results in the third column, when green patent applications were selected as the mediation variable, there was a significant positive correlation between green patent applications and did, that is, the establishment of pilot free trade zones could promote the increase of green patent applications. Secondly, according to the results in the fifth column, when the green patent application quantity was put into the model as the core explanatory variable, sulfur dioxide emissions showed a significant negative correlation with did and green patent application quantity. This suggests that as the number of green patent applications increases, so2 emissions will decrease. Thus, the establishment of pilot free trade zones has promoted the increase of green patent applications, which in turn will further promote the reduction of sulfur dioxide emissions. The increase in the number of green patent applications means that enterprises invest more in technological innovation, and the output of green technology innovation significantly reduces the emission of industrial pollution. Therefore, the number of green patent applications representing the output of green technology innovation is the second reason for the reduction of sulfur dioxide emissions after the establishment of pilot free trade zones.

According to the judgment principle mentioned above, both green patent application quantity and economic agglomeration meet the judgment criteria of intermediary variables. From the above mediating effect model, the following conclusions can be drawn: economic agglomeration and the number of green patent applications are the ways to influence environmental pollution in pilot free trade zones. Thus, in the process of China's pilot free trade zone reform, the number of green patent applications and economic agglomeration effect are the reasons for the reduction of sulfur dioxide emissions in prefecture-level cities. However, some scholars have shown that the environmental effect of economic agglomeration is u-shaped, and the inverted u-shaped effect of economic agglomeration on the efficiency of green economy is mainly transmitted through three channels, namely, infrastructure, the advanced degree of labor market and environmental regulation (Lin Boqiang, Tan Ruipeng, 2019). Due to the limitation of space, no further test is made in this paper.

5. Conclusion

In recent years, under the implementation of the strategy of accelerating the promotion of comprehensive opening up, China's free trade has been developing rapidly. While opening up has promoted economic growth, environmental pollution has become a major concern of policy makers and academic circles. What impact will China's pilot free trade zone strategy have on the environment while steadily advancing? To answer this question, this article is based on China's 2003-2017, 285 Chinese regional and panel data, using the double difference of the reentry after propensity score matching identification strategy in Shanghai, Guangdong, Fujian and Shenzhen of China free trade area of the quasi natural experiment to test and evaluate free-trade area in local governance effect of sulfur dioxide emissions in the process of practice, to find and verify the effect of several possible paths, and the results are a variety of robustness testing. The results show that the establishment of pilot free trade zones can significantly increase regional economic agglomeration and the number of

green patent applications, thus reducing sulfur dioxide emissions, which is still true after considering a series of robustness tests. The intermediate effect model finds that in the process of continuous improvement of China's pilot free trade zone, the economic agglomeration effect and the improvement of green technology are the main reasons for the environmental governance effect of prefecture-level cities.

In the context of increasingly tight environmental constraints, the research on the relationship between the environment of prefecture-level cities and pilot free trade zones in this paper is helpful to achieve a win-win situation between economic development and environmental protection. The construction of pilot free trade zones should further give play to the advantages of "competitive incentive effect" and "economies of scale" of industrial agglomeration, increase the investment in green patent research and development in pilot free trade zones, and further improve the quality of economic development in pilot free trade zones.

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Since the reform and opening up in China, urbanization has developed at a high speed, with rural labor constantly flocking to cities, regional economy has developed by leaps and bounds, and people's living standards have been greatly improved. Urbanization has become an important engine for China's rapid economic growth. As the support and carrier of urban development, land resources play a very important role in the process of urbanization in China. With the population migration, industrial agglomeration and improvement of infrastructure, the city scale needs to continue to expand, so it is inevitable to expropriate and use a large amount of surrounding land as construction land for urban development. As a result, the reasonable structure of the urbanization process is rational layout of land and the process of rational utilization of land resources, the relationship between the propulsion of urbanization and cultivated land protection, is to ensure smoothly promote the urbanization process, and to make a scientific and rational planning of land resources, improve the utilization efficiency of land use intensity and, in order to promote the sustainable development of urban economy.

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