Waste Import Ban and Water Pollution: Evidence from Rivers in Guangdong Province, China

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Abstract

In this study, we analyze the impacts on China's 2018 ban on waste imports, specifically focusing on its impact on water pollution using evidence from rivers in Guangdong, China. Employing a difference-in-differences methodology, we leverage variations in both time and waste imports across prefectures before the policy shift. Our findings suggest that regions previously involved in waste imports witnessed more substantial improvements in water quality after the policy implementation. Following the implementation of the ban, the concentrations of mercury decreased by 16.02%, copper by 21.47%, and zinc by 39.79%. This effect is particularly noticeable in areas characterized by lenient environmental regulations and limited waste utilization capacities. Further investigation reveals that the reduction in both the acidic pickling of recyclable waste and industrial production levels are mechanisms through which the waste import ban effectively mitigated water pollution.

Keywords: Waste import, water pollution, China’s waste import ban

JEL Code: Q56, Q58

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1. Introduction

Waste trade has been a major channel of transmitting pollution from developed countries to developing countries, since the latter usually has less stringent environmental regulations (Kellenberg, 2012). A recent study reported that from 2011 to 2020, the annual waste trade in the world is approximately 212 million metric tons (Shi & Zhang, 2023). China had been one of the largest waste importers before 2017. Data show that from 1995 to 2016, China's annual imported waste quantity expanded by more than 10 times (from 450 thousand tons to 4.85 million tons) (Shi & Zhang, 2023). In 2016, 56% of the global trade of plastic wastes ended up in China (Brooks et al., 2018). Improper waste processing, such as pickling metal waste and burning plastic waste, releases harmful pollutants to air, soil, and water, causes damaging environmental consequences, and results in higher child mortality. Previous literature suggests that the import of waste has had severe negative impacts on China's environment, there are few analyses, and there remains a significant gap in the research on the effects of the waste import ban policy on the water pollution. This study aims to investigate the changes in the concentration of various pollutants in the rivers in Guangdong Province, China from 2015 to 2019, before and after the implementation of the waste import ban policy, to explore the impact of this policy on water pollution. Guangdong Province is used as an example in this case because it processes a significant portion of recyclable waste (Liu et al., 2022).

Clean water concerns all policy makers across the globe. The United States has spent approximately $4.8 trillion (in 2017 dollars) to clean up surface water pollution and provide clean drinking water (Keiser & Shapiro, 2019). Firm choose their plant location and size based on the local environmental regulations. (Becker & Henderson, 2000). The increase of industrial wastewater discharge will lead to serious environmental pollution, which will have a serious impact on the ecological environment and people's health (Chen et al., 2019; Srivastava et al., 2020). The plastic waste pollution not only affects rivers but also eventually enters oceans (Lebreton et al, 2017). The indiscriminate Chinese policy, leading to a significant rise in total suspended particulates (TSPs) air pollution, is contributing to a loss of over 2.5 billion life years in life expectancy for the 500 million residents of Northern China (Chen et al., 2013). The impact on groundwater quality affects local residents' life expectancy. This study has important policy guidance significance and practical application value for practice.

Our research makes several contributions to the academic field, as follows. Firstly, it bridges the gap between environmental and international economics, expanding on the existing research that examines the interplay between domestic environmental policies and international economic activities as highlighted in studies by Eisenbarth (2017) and Shi and Xu (2018). While some research has started to explore the influence of trade policy on environmental outcomes, such as air quality (Antweiler et al 2001; Shapiro & Walker, 2018; Shi & Zhang, 2023), we add to the existing literature with a different perspective by examining the effects on water systems using the restriction of waste imports in a major developing nation—and demonstrating how such a policy can improve water quality domestically, thus acting as an effective environmental regulation. Our research illustrates how trade policies also function as environmental policies.

The reminder of this paper is organized into several sections as follows: Section 2 offers a background overview. Section 3 details the data and Section 4 introduces empirical strategies. Section 5 outlines the empirical findings, results of heterogeneity analysis, and Section 6 shows the outcomes from various robustness checks. Section 7 explores the underlying mechanisms. Finally, Section 8 provides the conclusion of the paper.

2. Background

2.1 The history of Chinese waste import

Due to the severe negative impact of waste import and the raised concerns about the deteriorating environment, Chinese government took several actions, including banning the waste import in 2017. Earlier literature found that the waste import ban has dramatically reduced the waste import and its resulting environmental damage, especially the air pollutants (Shi and Zhang, 2023). However, few systematic analyses examine the impacts of waste import ban on water quality. In this study, we aim to fill this gap by exploiting the difference-in-differences strategy to investigate how the waste import ban affects the levels of major water pollutants in 27 river sections in Guangdong Province in China from 2015 to 2019.

Being the foremost importer, China has received approximately 45% of the world's plastic waste between 1992 and 2016 (Brooks et al., 2018). Following China's ban on plastic waste imports, various regions will face the challenge of identifying alternative destinations for waste processing or rapidly enhancing their local waste treatment capacities in the short term. China’s plastic waste imports are mainly utilized for recycling and production to satisfy domestic consumption. China imported 7.3 Mt of plastic waste in 2015, and domestic consumption is responsible for 5.6 Mt (76.2%) (Huang et al., 2020). There is the greater demand in developing countries for many types of e-waste, used vehicles, and recycled materials (Bernard, 2015).

On July 18, 2017, the State Council issued the "Action Plan for Prohibiting the Entry of Foreign Waste and Advancing the Reform of the Solid Waste Import Management System." According to this plan, China aims to completely ban the import of certain pollution-intensive waste plastics, waste paper, and textiles by the end of 2017, with the list of prohibited items expanding annually thereafter (Shi, 2018). In January 2018 the Chinese Government enacted a new policy to permanently ban the import of most plastic waste into the country.

2.2 The impact of waste import pollution on water systems

The impact of imported waste on the environment includes but is not limited to water, soil and atmospheric environment. This paper mainly studies the impact of waste import on the water systems. Imported waste can significantly pollute nearby water systems in various ways, particularly if the waste includes hazardous materials or if it is not managed properly. The key pathways and mechanisms through which imported waste can lead to water pollution include leachate production, chemical disposal and runoff from waste sites. When waste decomposes, it produces a liquid byproduct known as leachate. This liquid often contains a mix of toxic chemicals, including heavy metals like mercury and cadmium, as well as organic pollutants. If a landfill or waste disposal site is not properly lined or managed, leachate can seep into the groundwater or nearby water bodies, contaminating them.

In regions where regulations are lax or enforcement is weak, the handling and disposal of imported waste may not follow safe practices (Liu et al., 2022). For example, electronic waste often contains hazardous substances such as lead, mercury, and arsenic. If this waste is dismantled or processed inappropriately—such as by burning plastics or circuit boards—pollutants can enter air and water systems. Beside the direct chemical disposal, during rainfall, water flowing over waste sites can pick up pollutants and carry them into nearby streams, rivers, or lakes. This runoff can increase the concentrations of toxins in water bodies, affecting both water quality and aquatic life.

Based on the policy background, this paper aims to explore the impact of the waste import ban on water pollution by analyzing the concentration changes of various pollutants in rivers entering the sea in Guangdong Province before and after the implementation of the ban policy from 2015 to 2019.

2.3 Imported waste processing in Guangdong Province

Guangdong Province is situated at the southern of mainland China. It lies to the south of the Nanling Mountains, along the shores of the South China Sea, and directly across from the Hong Kong and Macao Special Administrative Regions (see Fig. 1). As a frontrunner in China’s economic reform and opening-up initiatives, Guangdong Province is also the first stop for import goods. China's imported waste processing is concentrated in coastal provinces. Guangdong Province has been most heavily affected. The imports of low-quality copper scrap in Guangdong have decreased by 94% (Tian et al., 2021). For instance, Guiyu town in Guangdong Province, China, an famous hub of global e-waste recycling (Wang et al, 2022). Driven by economic profits through materials recycling, the majority of imported wastes entered into China’s informal recycling sectors. Meanwhile, waste management has become a serious problem in Guangdong Province, China due to the problems of quantity and toxicity, exacerbated by the growing consumption and shorter lifespan of electronic products.

3. Data and Descriptive Statistics

3.1 Water quality data

We collect water quality data from January 2015 to December 2019 at monthly level for 27 river sections in Guangdong Province, China, including the concentration levels of sulfides and several heavy metal elements, such as lead, chromium, mercury, cadmium, arsenic, copper, zinc. The water quality data is obtained from Government Information Disclosure Platform of Guangdong Provincial Department of Ecology and Environment (URL: https://gdee.gd.gov.cn/gkmlpt/index). This paper collected and processed the water quality monitoring data of 26 sections of 25 rivers entering the sea in Guangdong Province from January 2015 to December 2019 from the information public release platform of Department of Ecological Environment of Guangdong Province, focusing on the monthly dynamic changes of the concentrations of mercury, copper and zinc. The higher the concentration of pollutants, the worse the water quality.

3.2 Pollution plants data

We collect information of waste treatment plants and companies with pollutant discharge permits from CSMAR Environmental Research (2015-2019). It collates the data of enterprises with "emission permits" in cities in Guangdong Province from January 2015 to December 2019, including enterprise name and business address, industrial type, main pollutant type, main pollutant type in wastewater and wastewater pollutant discharge standard.

3.3 City level statistic data

The control variables are obtained from China Statistical Yearbook (2015-2019). In order to exclude other factors of economic development and regional differences, this paper collects the GDP, primary industry added value, secondary industry added value and per capita GDP of the cities where the above statistical sections are located from January 2015 to December 2019 from the Statistical Yearbook of Guangdong Province as control variables.

3.4 Guangdong River System

This paper collects geographical location data of river system in administrative divisions of provinces, cities and counties from open street map, and marks the geographical location of rivers, sections and enterprises with "emission permits" in the map, as shown in figure 1. The river in the figure only shows the main stream, first-class tributary, second-class tributary and third-class tributary of the river. Since there are many branches of the river entering the sea in Guangdong Province flowing into Haikou, the fourth-class tributary and more branch flows have not been drawn one by one. Some sections entering the sea are located at the graded tributary, so some sections in the figure are not shown above the river.

[Insert Figure 1 Here]

As shown in the Figure 1, there are many pollutant-producing enterprises near the Tan River and the Moyang River (indicated by blue circles), whereas there are no pollutant enterprises near the Luo River, Shenzhen River, and Rong River (indicated by red circles). Based on this, the experimental group and control group are distinguished in this study. The experimental group is located in areas with pollutant enterprises, engaging in the imported waste processing economy, while the control group is located in areas without pollutant enterprises and does not engage in the imported waste processing economy.

3.5 Summary Statistics

[Insert Table 1 Here]

Table 1 illustrates the summary of variable statistics. It includes 25 river sections monthly water quality data including mercury (Hg), copper (Cu) and zinc (Zn) from 2015 to 2019 and total of 1500 observations. The data also include first industry output, second industry output, GDP and population. City level statistics are important factors in the model. The growth of GDP not only indicates an increase in industrial demand but also an acceleration in the waste import (Fu et al., 2017).

4. Empirical Strategy

We select 25 river sections (samples) in Guangdong Province, China. We split those 25 samples into two groups—the samples in the treatment group have at least one company with pollutant discharge permits in the district where the river section locates, whereas the samples in the control group have no company with pollutant discharge permits in their home district[3].

$$y_{ict} = \beta_0 + \beta_1 \times post_{ict} \times treat_t + \boldsymbol{\beta X_{ict}} + \mu_t + \lambda_c + \varepsilon_{ict} \qquad (1)$$

In the formula (1), the subscript *i* represents the river-section, the subscript *c* represents the city administrative district, and the subscript *t* represents time; y_{ict} denotes the concentration of pollutants at the cross-section, including four pollutants: mercury, copper, and zinc. *Treat* is a dummy variable indicating whether the number of companies with a pollution discharge permit in the river cross-section area from January 2015 to December 2019 is zero, with 1 representing the treatment group and 0 representing the control group. *Post* is another dummy variable indicating whether the waste import ban is implemented. Given that the ban was announced in July 2017, and implemented January 2018, we denote policy is 1 after January 1, 2018, and 0 otherwise. μ_t is the year-month fixed effect.λ_c is the city fixed effect.

The key independent variable is β_1, the interaction between the treatment indicator (i.e., whether a sample is in the treatment group) and the policy indicator (i.e., whether the waste import ban is launched), which reflects the impact of the waste import ban on the water quality in the river sections where there is at least one company with pollutant discharge permits nearby. We add time fixed effects to absorb any time-specific shocks occurring in all river sections (e.g., seasonal variation of water quality) and city fixed effects to absorb any location-specific shocks (e.g., city level environmental regulations). The control variables include the economic development level (e.g., GDP), the economic structure (e.g., annual added value of the primary industry and secondary industry), and geographical control variables (e.g., area, population) of the district where sample river sections are located.

[Insert Table 2 Here]

The regression results are shown in Table 2. After the implementation of the policy, the results show that mercury (Hg), copper (Cu) and zinc (Zn) concentration in the area with pollutant

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[3] District is an administrative division under the jurisdiction of a city.

emission enterprises around the section decreases by 24.1%, 22.2% and 42.3% respectively, compared with that in the area without pollutant emission enterprises around the section, and this effect is significant at the level of 1%, which indicates that the imported waste ban has a positive deterrent effect on mercury, copper and zinc concentration.

[Insert Figure 2 Here]

In Figure 2, we plot the average monthly mercury (Hg), copper (Cu) and zinc (Zn) concertation across all rivers and show the pre-trend difference between the treatment and control groups. Prior to July 2017, the policy announcement data, the average mercury (Hg) concentration of treatment group is higher than the average mercury (Hg) concentration of control group. Prior to April 2017, one quarter before the policy announcement data, the average copper (Cu) and zinc (Zn) concentration of treatment group is higher than the average copper (Cu) and zinc (Zn) concentration of control group. The blue dashed line represents the announcement date, and the green dashed line represents the implementation date. Overall, the concentration of the three pollutants significantly decreased after the implementation of the policy. Between the announcement date and implementation date, both mercury and copper started to show that the emission levels from the treatment group were lower than those from the control group. Although zinc concentration from the treatment group were still higher than those from the control group, there was also a trend of decreasing emissions year by year. For a period after the policy implementation, all three pollutants experienced varying degrees of emission reduction followed by a sharp increase after the import ban policy.

5. Empirical Results

5.1. Policy Implementation Effect

We first investigate the impact of waste import ban on five major pollutants, including mercury, lead, chromium, arsenic, and cadmium, all of which are the waste generated products during waste processing. Results show that for the treatment group (river sections that have at least one company with pollutant discharge permits nearby), following the implementation of the ban, the concentrations of mercury decreased by 16.02%, copper by 21.47%, and zinc by 39.79%.The estimated coefficient for the policy indicator shows that in general, all the pollutants were significantly decreased after the waste import ban was implemented. Such results are robust when adding or dropping city and time fixed effects.

5.2. Policy Announcement Effect

Since the waste import ban was announced in July 2017 and formally implemented in January 2018, we test the policy announcement effect in July 2017.

[Insert Table 3 Here]

Table 3 shows the announcement effect in the water systems including mercury, copper and zinc. After the announcement of the waste import ban, it was found that, compared to areas without pollution permit, areas with pollution permit experience a significant decrease in mercury concentrations in the rivers by 22.65%, copper concentrations by 32.86%. The decrease of zinc concentrations is not significant.

Overall, the contents of the three pollutants decreased significantly after the policy was implemented. During the policy transition period, the emissions of mercury and copper in the treatment group began to be lower than those in the control group, while the emissions of zinc in the treatment group were still higher than those in the control group, but they also began to decrease year by year.

6. Robustness Check

We carry out multiple tests to ensure the reliability of our Difference-in-Differences (DID) identification approach. First, we use an event study-style test to confirm that prefectures in both the treatment and control groups displayed similar trends in water pollution before the implementation of the policy, affirming the validity of the parallel trends assumption in our analysis. Furthermore, we show that our main results are consistent even when considering possible effects from other simultaneous policies and unaccounted-for heterogeneity between cities.

6.1. Parallel Trends Test

The key assumption for our DID strategy is that the outcome variables for prefectures with or without waste imports would have followed a similar time trend in the absence of the policy change. To test whether this assumption holds, we exploit the event-study framework to estimate the following equation:

$$y_{ict} = \beta_0 + \beta_k \cdot \sum_{k=-n}^{m} (t = k) \times post_{ict} \times treat_t + \boldsymbol{\beta X_{ict}} + \mu_t + \lambda_c + \varepsilon_{ict} \qquad (2)$$

Figure 3 plots the estimation results for Equation (2), with points representing the estimated coefficients and vertical dashed bars representing the 95% confidence intervals.

[Insert Figure 3 Here]

In Figure 3, it shows that the coefficients for the pre-policy period are statistically insignificant and small in magnitude, without a clear trend. The results provide evidence of parallel trends, thus validating our DID assumption.

6.2. Policy Effects after 6 months and 1 year

To further analyze the sustained effects of the policy, we assess the policy impacts at two intervals: six months and one year after the policy's implementation. We test the lag effects to evaluate the effectiveness of the import waste ban policy.

[Insert Table 4 Here]

Table 4 shows the policy lagging effect in the water systems including mercury, copper and zinc. In Table 4 column 1 to column 3, it shows that after 6 months of the policy implementation, the decrease in mercury concentrations in the affected rivers is 11.77%, copper concentrations reduced by 30.67%, and zinc concentrations reduced by 24.58%. In Table 4 column 4 to column 6, it shows that after 12 months of the policy implementation, the decrease in mercury concentrations in the affected rivers is not significant for mercury (Hg). And the decrease of copper (Cu) concentrations and zinc concentrations (Zn) are still significant. It reduced by 23.77%, and zinc concentrations reduced by 23.67%, respectively. It shows that the trade restriction policy effects on water quality is still effective after one year.

7. Mechanism analysis

7.1 Industrial production Level

The recyclable elements of imported waste can be utilized as raw materials in conventional industrial production. Therefore, the ban on waste imports limits the availability of waste goods that could serve as production inputs. In many industries, imported waste plays a crucial role by providing cost-effective and accessible raw materials for manufacturing processes. We divide the sample into two sub-sample with higher than median industrial output levels and lower than median industrial output levels.

[Insert Table 5 Here]

Table 5 shows that the mercury(Hg), copper(Cu) and zinc(Zn) is significant reduced, 23.59%, 21.70%, 27.06% respectively, in the nearby water systems in the cities which have lower than mean industrial output level. However, in the higher than median industrial output level cities, the change of mercury (HG), copper (Cu) and zinc (Zn) are all not significant. The results indicate that the material needs of industrial production is a driving mechanism for waste processing.

8. Conclusion

The imposition of a waste import ban by the largest developing nation and primary waste importer represents a pivotal policy intervention. Consequently, a quantitative examination of its effects on water quality is crucial, providing robust empirical evidence that trade policy can exert positive externalities on the local environment. This analysis is likely to engage a diverse audience, including scholars and policy analysts concerned with environmental regulation, international trade, and aquatic ecosystem preservation. The role of waste trade in global commerce is substantial, yet its impact on environmental degradation is insufficiently understood. This deficiency is critical both for informed policy dialogue and for deepening our understanding of how pollution transfer is intertwined with international trade. This paper addresses this lacuna by empirically investigating the ramifications of waste imports on water pollution. Utilizing the waste import ban in China as a natural experiment facilitates a Difference-in-Differences (DID) analytic approach, enabling precise identification of causal effects. The study confirms that the ban not only mitigates river pollution in cities with economies dependent on waste imports but also positively influences the broader national riverine environment.

The imported waste ban is an important policy implemented to reduce and control the damage caused by foreign garbage to the ecological environment and protect the ecological environment. The pollution of imported waste to the water environment not only poses a threat to human health, but also affects the sustainable development of fisheries and tourism. Through a thorough study of the impact of the ban on the water quality of rivers entering the sea in Guangdong Province, it can provide scientific basis for decision makers of river water quality control. It can improve water environment quality, protect ecological environment, promote sustainable development, and provide a strong basis for the government to formulate relevant environmental protection policies and further improve the environmental protection system.

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Appendix

Figure 1 Guangdong Rivers and Pollution Plants

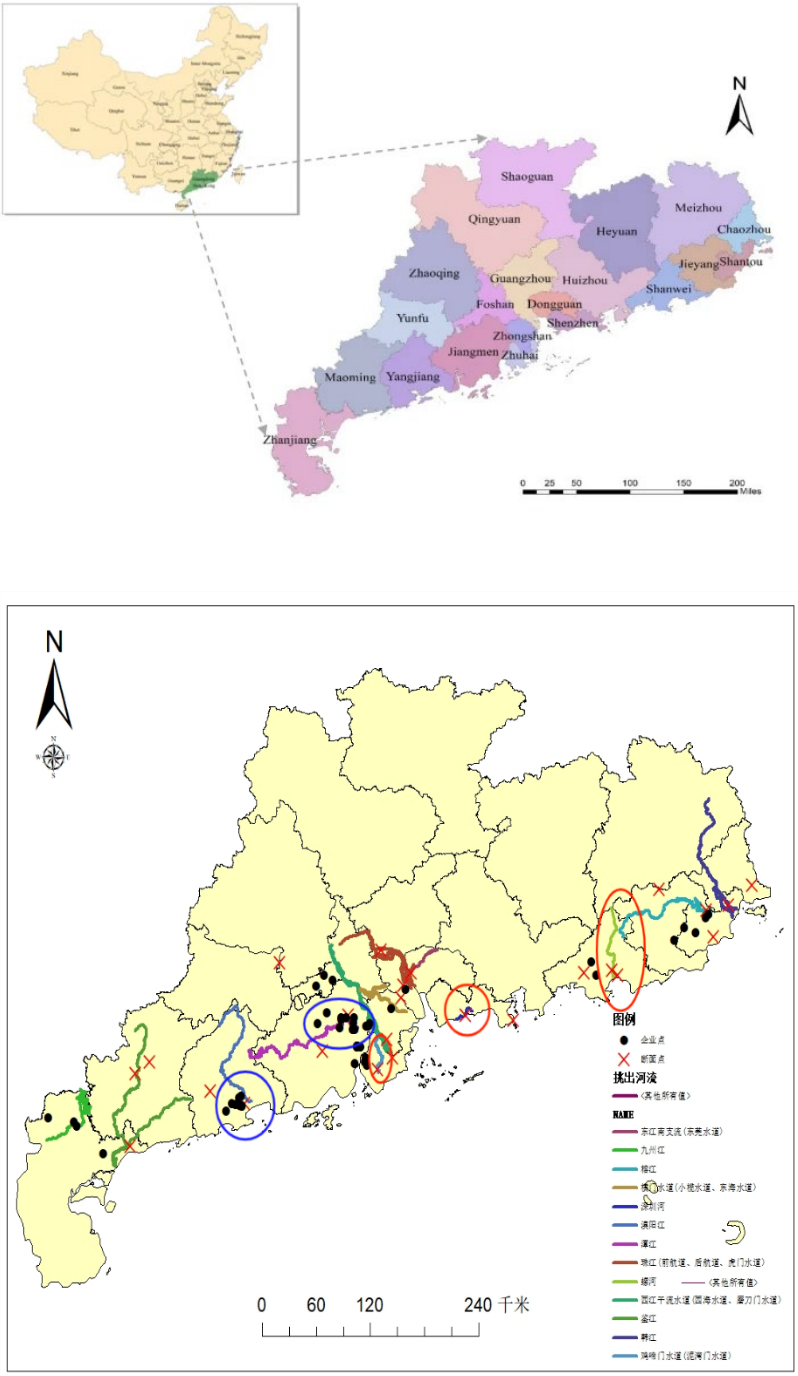

Table 1 Summary Statistic

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Definition	Mean	S.D	Min	Max
Hg	Mercury（g/L）	0.0288	0.0443	0.00487	1.41
Cu	Copper（g/L）	5.327	11.42	0.04	202
Zn	Zinc（g/L）	15.14	18.72	0.35	225
CWL	Number of Enterprises with Pollutant Discharge License	2.426	3.97	0	19
GDP	Gross Domestic Product (RMB 100 million)	47,662	72,937	2,107	269,270
FIRST	Value Added of Primary Industry (RMB 100 million)	874.1	628.4	70.01	2,505
SECOND	Value Added of Secondary Industry (RMB 100 million)	17,778	23,258	989.1	104,961
GDP_pc	Per capita Gross Domestic Product (RMB 100 million)	82.19	44.19	33.83	203.5
population	Population (100,000)	440.4	448.7	52	1,510

Table 2 Water quality and waste import ban

	(1)	(2)	(3)
VARIABLES	logHg	logCu	logZn
post_treat	-0.16020***	-0.21476**	-0.39785***
	(0.05867)	(0.09994)	(0.11006)
first	-0.00024	0.00339***	-0.00303***
	(0.00030)	(0.00052)	(0.00055)
second	-0.00002***	-0.00007***	-0.00002
	(0.00001)	(0.00001)	(0.00001)
population	0.00245***	0.00148	0.01275***
	(0.00073)	(0.00126)	(0.00133)
Constant	-4.85170***	1.63148*	-7.61850***
	(0.49463)	(0.84619)	(0.96705)
Observations	1,500	1,500	1,500
Number of river	25	25	25
Time FE	YES	YES	YES
City FE	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 2 Mercury, Copper and Zinc Concentration Time Trend

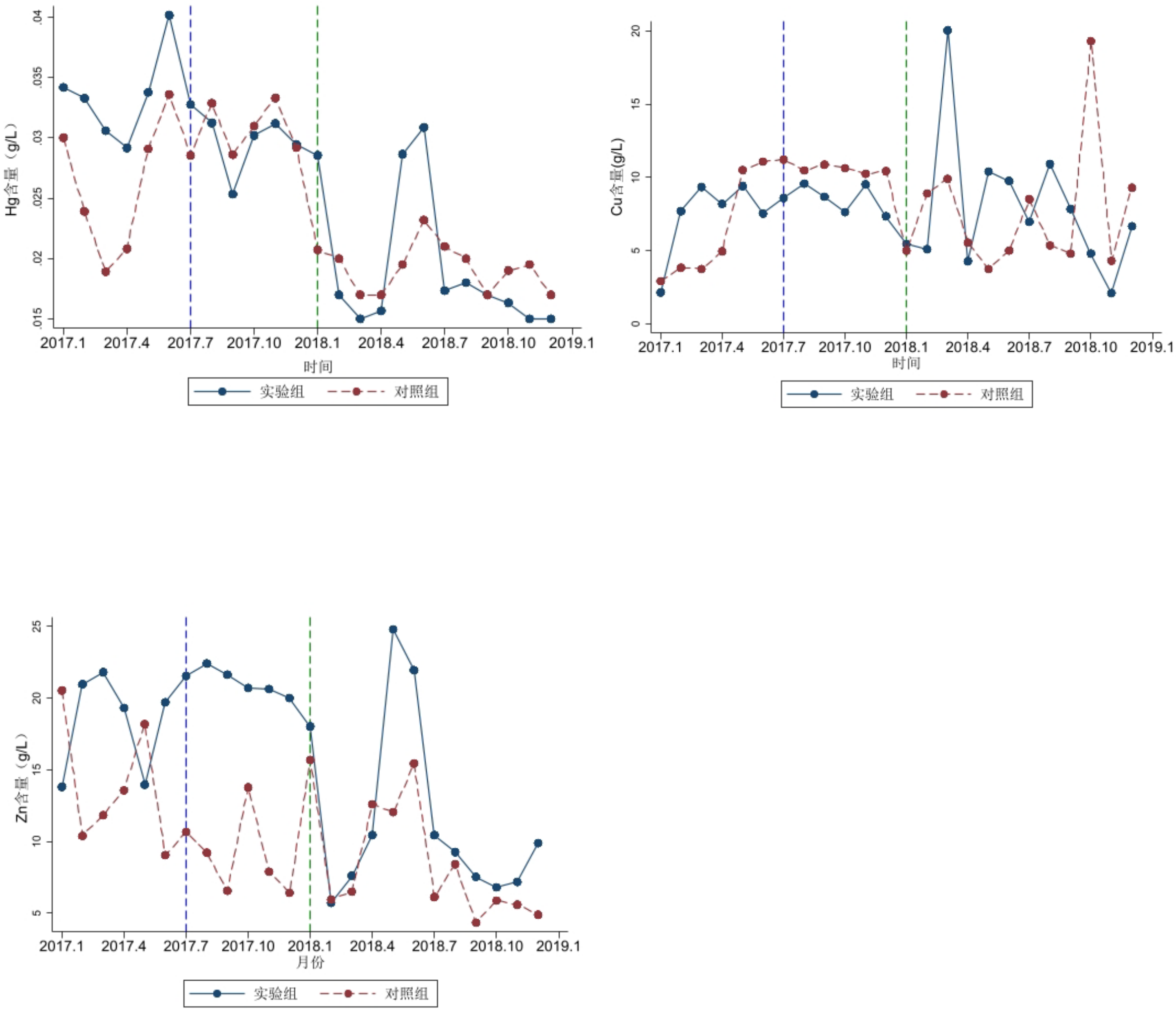

Table 3 Announcement Effect

	(1)	(2)	(3)
VARIABLES	logHg_lead6	logCu_lead6	logZn_lead6
post_treat	-0.22654***	-0.22857**	-0.07538
	(0.06265)	(0.10071)	(0.11619)
first	-0.00065**	0.00283***	-0.00410***
	(0.00031)	(0.00053)	(0.00058)
second	-0.00002**	-0.00005***	0.00000
	(0.00001)	(0.00001)	(0.00001)
population	0.00218***	0.00063	0.00816***
	(0.00078)	(0.00131)	(0.00144)
Constant	-4.47690***	1.42890	-4.32274***
	(0.53726)	(0.87497)	(0.99586)
Observations	1,494	1,494	1,494
Number of rivers	25	25	25
Time FE	YES	YES	YES
City FE	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Figure 3 Parallel Test

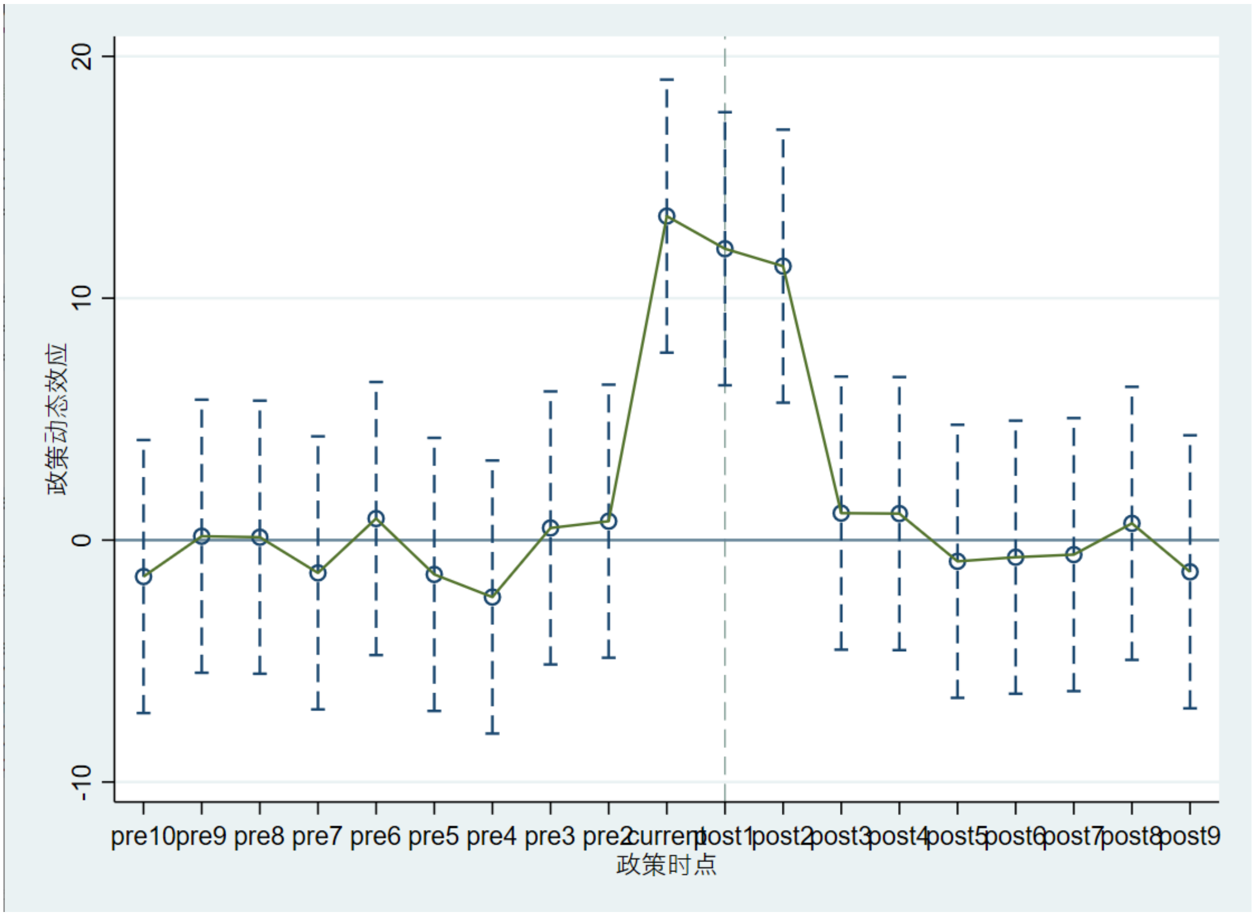

Table 4 Policy Effect after 6 month and 1 year

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	logHg_l6	logCu_l6	logZn_l6	logHg_l12	logCu_l12	logZn_l12
post_treat	-0.11766*	-0.30668***	-0.24580**	0.06060	-0.23772**	-0.23663*
	(0.06109)	(0.09921)	(0.12034)	(0.06094)	(0.09744)	(0.12378)
first	0.00003	0.00213***	0.00083	0.00109***	0.00138***	0.00225***
	(0.00031)	(0.00053)	(0.00060)	(0.00031)	(0.00054)	(0.00062)
second	0.00000	-0.00005***	-0.00002	0.00002***	-0.00004***	-0.00003*
	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
population	-0.00024	-0.00080	0.00686***	-0.00240***	-0.00022	0.00365**
	(0.00076)	(0.00129)	(0.00146)	(0.00076)	(0.00131)	(0.00151)
Constant	-4.28626***	3.51328***	-4.26866***	-3.33611***	3.22056***	-1.12952
	(0.51473)	(0.85903)	(1.03637)	(0.51324)	(0.86828)	(1.05437)
Observations	1,494	1,494	1,494	1,488	1,488	1,488
Number of rivers	25	25	25	25	25	25
Time FE	YES	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES	YES

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5 Industrial Output

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	logHg	logCu	logZn	logHg	logCu	logZn
	High Industrial Level			Low Industrial Level		
post_treat	-0.23589***	-0.21697*	-0.27057**	0.10800	0.01807	0.24683
	(0.06130)	(0.12155)	(0.12709)	(0.13781)	(0.13787)	(0.17909)
first	0.00035	0.00392***	-0.00560***	-0.00016	0.00094	-0.00182**
	(0.00035)	(0.00071)	(0.00072)	(0.00078)	(0.00076)	(0.00083)
second	-0.00004	-0.00017***	-0.00008	-0.00004***	-0.00004***	0.00000
	(0.00003)	(0.00005)	(0.00005)	(0.00001)	(0.00001)	(0.00001)
population	-0.00605**	0.00424	0.06030***	-0.01202***	0.00378**	0.00067
	(0.00297)	(0.00601)	(0.00607)	(0.00183)	(0.00177)	(0.00195)
Constant			-0.37122	7.00222***	0.42546	2.01569
			(0.40501)	(1.44445)	(1.40323)	(1.69167)
Observations	1,200	1,200	1,200	300	300	300
Number of river	20	20	20	5	5	5
Time FE	YES	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES	YES

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1