Centralization and Pollution Spillovers: Evidence from River-basin Management in China

Abstract

Due to the Chinese decentralized environment policy and the free riding effect, boundaries between provinces have become full of conflicts and disproportionate pollution. The upstream provinces tend to emit more pollutant in their downstream counties to transfer pollution, which was named transboundary pollution. There have been many studies towards the transboundary pollution situation in China, but the studies towards policies' effectiveness to transboundary pollution are limited. Based on a unique dataset on water pollutant emission in counties along 15 major rivers in China from 2003 to 2012, we used difference-in-difference (DID) method and difference-in-difference-in-difference (DDD) method to represent transboundary pollution phenomenon and test if there were policy changes that influence the transboundary pollution. Results shows that 1）there was indeed transboundary pollution in China from 2003 to 2012, which leads to that the emission of COD by upstream counties is 54% more than downstream counties；2）A policy issued by central government named *"The Guidance of Preventing and Disposing Transboundary Water Pollution Conflict"* eliminated transboundary pollution phenomenon of rivers. After 2009, there was almost no transboundary pollution in China.

Key Words: transboundary pollution; decentralized policy; China

1. Introduction

Centralization and decentralization are both management manners in Management and economic tools in Economics, like art, which are also dialectical philosophy (Aucoin, 1990; Chang and Harrington, 2000; Lin and Liu, 2000; Zhang, 2006). Since ancient times, thousands and hundreds of researchers have been studying the relationship between them in so many fields, such as education, health, policy, fiscal system, water governance, supply chain and so on (Aunphattanasilp, 2018; Empinotti et al., 2018; Hawkins, 2006; He et al., 2016; Saltman, 2008; Schmitt et al., 2015), besides always on the road. The quality of decision-making (or policy-making) at these fields in one country (or one organization) deeply relies on the coordination between centralization and decentralization (Academy and Journal, 2016; Malone, 1997; Zábojník, 2002). They are the unity of opposites, require specific analysis of specific issues, and adopt the most appropriate method at different stages.

In the field of environmental governance, because of the so-called "pro-green" incentives (Zheng et al., 2014), decentralization may cause problems with the principal agent (Nalysis and Andres, 2007). In the structure of principal-agent from central governments to counties, counties strive to maximize the local or regional benefits, not the global or national (Benchekroun and Martín-Herrán, 2016; Zhang, 2012). Besides, decentralization could improve service delivery, but it could also generate externalities across jurisdictional boundaries (Lipscomb and Mobarak, 2016). Decentralization measures are like some potent drugs, however: when prescribed for the relevant illness, at the appropriate moment and in the correct dose, they can have the desired salutary effect; but in the wrong circumstances, they can harm rather than heal (Prud'homme, 1995).

Transboundary pollution is exactly one typical case of a principal-agent problem arising from decentralization. Decentralization of environmental management, at its core, constitutes a partnership (coordination) between central governments and counties in China (Agrawal, 2001). Therefore, could centralization reduce or even eliminate the transboundary pollution in the field of environmental governance?

China's rapid economic development and urban construction over the past decades has caused severe environmental pollution, such as the continual haze, deterioration of water quality and pollution-related accidents. River pollution is one of the particularly serious problems. In China, just less than 28 percent of river sections in more than 500 monitoring stations meet the requirement of class Ⅲ water quality, and more seriously, almost one-third of river sections are below class V water quality due to critical pollutions (World Bank, 2007). China's economic loss from water pollution has been around 150 billion Yuan per year (World Bank, 2007), and the loss of health and life caused by this pollution is too enormous to estimate.

Except for excessive emission and weak governance, transboundary polluting is another important reason causing pollution (Benchekroun and Martín-Herrán, 2016; Conconi, 2003; Duvivier and Xiong, 2013; Kahn, 2004; Park et al., 2004; Sigman, 2005; Silva and Caplan, 1997). Transboundary pollution is the phenomenon that the upstream provinces tend to emit more pollutant in their downstream counties to transfer pollution, epically at water environment (Chien and Hong, 2018; Yang and Shen, 2017; Yu, 2011). It connected with free riding effect (Günther and Hellmann, 2017; Konisky and Woods, 2012; Lange and Vogt, 2003; Monogan et al., 2017; Sigman, 2002) and decentralized regulatory structure (Duvivier and Xiong, 2013; EJ Ringquist, 2016; Lovo, 2014). Besides, using an old Chinese saying, this is just like "beggar-thy-neighbor" (from "*Mencius*", the great philosophy work in ancient China). As transboundary pollution leads to unwanted pollutant emission and concentrated pollution at border, it is necessary to find out its actuality and the way dealing with it.

Our paper is closely related to these emerging research fields about transboundary pollution (Bernauer and Kuhn, 2010; Cai et al., 2016; Konisky and Woods, 2012; Lipscomb and Mobarak, 2016; Sigman, 2005, 2002). Making use of variations of when states were authorized to issue pollution permits in the U.S., Sigman (2005) analyzed the strategic polluting across state borders by using DDD approach. And, Konisky and Woods (2012) used the U.S. Environmental Protection Agency's (EPA's) Integrated Database for Enforcement Analysis to study U.S. transboundary water pollution phenomenon, but the results showed not significant. Similar to Sigman (2005), Lipscomb and Mobarak (2016) focused on the overall effects of decentralization on water quality, cleverly using the county border changes in Brazil. The previous studies usually used water quality data or firms' activities data to represent the transboundary phenomenon. This is because, water quality data could represent the pollution behavior and firms' activities data could represent the polluting industries location characters.

In this paper, we used water pollutant emission data of counties to characterize the transboundary pollution phenomenon in China, which is a direct and accurate data to represent the pollution actuality of 15 major rivers in China (shown in Table 1) from 2003 through 2012. By using difference-in-differences (DID) method, we find strong evidence of the transboundary effect. When all else being equal, the most downstream county of a province has up to 82 percent more water pollutant emission than otherwise identical counties from 2003 to 2008, and up to 54 percent more of it from 2003 to 2012. The results proved that the transboundary phenomenon did existed in Chinese history in pollutant emission way. The transboundary phenomenon sheds light on a possible reason that why water quality has not improved even though the central government of China has been emphasizing environmental protection since 2003.

Table 1. Summary statistics for 15 major rivers in China

No.	River Name	Main Stream Length (km)	River Basin Area (10,000 km^2)	Annual Runoff (100 million m^3)
1	Yangtze River	6,300	180.85	9,513
2	Huang River	5,464	75.24	661
3	Heilong River	3,474	185.5	3,406
4	Songhua River	2,308	55.72	762

5	Pearl River	2,214	45.37	3,338
6	Lancang River	2,179	16.74	760
7	Han River	1,570	17.43	565
8	Liao River	1,390	22.9	148
9	Jialing River	1,119	16.00	683
10	Hai River	1,090	26.36	228
11	Huai River	1,000	26.93	622
12	Wei River	818	13.43	54
13	Xiang River	817	9.23	722
14	Datong River	560	1.51	29
15	Chishui River	523	2.04	101
	Total	30,826	729.01	21,592
Share of National Total		/	75.9%	83.0%

Source: China Statistical Yearbook 2009.

Another question is whether and how government solves the transboundary pollution problem. The previous studies rarely pay attention on this and most of studies just set the time range before 2008, which is the year that the most specific guidance approved by central government. Based on the recognition strategy and the DID method, we use triple differences (DDD) method to check if the *"The Guidance of Preventing and Disposing Transboundary Water Pollution Conflict"* solved the transboundary pollution. Not only have we found the strong breakpoint in the year of the guidance carrying out, but also the transboundary phenomenon was not significant after 2009.

The remainder of this paper is organized as follows. The following section "Institutional Background" provides the institutional background in China. In section "Empirical Strategy", we discuss our empirical strategy. The section "Data" describes the data we used. The section "Results" presents the main empirical results and the last section "Discussion and Conclusions" concludes.

2. Institutional Background

2.1 Regulatory structure of environmental protection in China

As the deterioration of river pollution problems, the Chinese central government has formulated a number of policies. The most rigorous and nationwide policy is the Five-Year Plan (FYP), which is released every five years. In the 10^{th} FYP (2001 to 2005), the central government added environmental protection and pollution reduction to the list of “national strategic goals” for the first time and set a target to reduce pollutant emission, including water pollution. The supporting policies include environment total amount control policy and environmental quality standards.

However, no matter what policy, each province in China was assigned a specific target and most of the concrete measures were decided by the local provincial governments. In China， the Environmental Protection Bureau (EPB) is the regulatory agency of environmental protection whose main responsibilities include setting national environmental protection policies, regulations and supervising local EPBs’ enforcements. The local government officials were to be evaluated on, which from the typical decentralized regulatory structure, which is proved to trigger transboundary pollution easily.

A typical situation is that in two provinces that cross a same river, the upstream province needs to take the results of the contamination in the pollution county and all the counties downstream. So, the province could gather the pollution firms into the most downstream county to min the contamination influence by making the downstream province take the risk, which causes the transboundary pollution because of the free riding effect. Less governance cost takes more incentives of polluting. Despite the specific resolution was taken, China's river water quality was almost not improved over the 10 years and there are no polices or rules toward transboundary put forward. Besides lower efficiency, free riding effect leads to environmental unfair phenomenon.

Downstream province has to assume extra responsibility for pollution control, and the border of two provinces suffers concentrated pollution.

2.2 The Guidance of Preventing and Disposing Transboundary Water Pollution Conflict

In 2008, Ministry of Environmental Protection, PRC (renamed to Ministry of Ecology and Environment, PRC in 2018) issued a file named *"The Guidance of Preventing and Disposing Transboundary Water Pollution Conflict"* (will be abbreviated to *"the Guidance"* below) to specifically deal with transboundary water pollution problem. The whole guidance started to be executed at 2009. The management measures include a complete set of a long-term mechanism toward transboundary pollution, including border water quality supervision and assessment to prevent the happening of the across provincial boundary disputes over water pollution at the source, to establish prevention and disposal of water pollution disputes across provincial boundary. It also put forward clear short-term measures to solve the problem particularly toward chemical oxygen demand (will be abbreviated to COD bellow) and heavy metal pollution, including making planning layout rational, promoting the adjustment of industrial structure, paying attention to the pollution source control and firms' environmental admittance, strengthening supervision and law enforcement, carrying out the responsibility of upstream provinces, enhancing the water quality assessment of boundary river sections ,asking that upstream new firms' ex-ante permits must be accepted by downstream provincial EPB and assessing upstream provinces' pollution behavior with a series of supervision and punishment mechanism.

3. Empirical Strategy

The strategy representing transboundary pollution includes two parts. The first is choosing the object of study. The second is identifying accurately transboundary pollution phenomenon from interference factors, as we only aim at the transboundary pollution caused by free riding effect but not natural or social difference.

To identify and measure the transboundary effect in China's river pollution, we choose the higher level of pollution in the border of upstream province than the downstream one as the performance of transboundary pollution. We find the most downstream county that also across the river in the upstream province and the most upstream county in the adjacent downstream province as the contrast counties.

To eliminate the distinction from the two different provinces, we portray a heuristic map to show the empirical strategy in Fig. 1 (Cai et al., 2016). Supposing a river flows from the west to the east and cross the most downstream county A in an upstream province X, the most upstream county B in a downstream province Y, we find the County a is a neighbor of county A in province X, and county b is a neighbor of county B in province Y. Just like counties A and B, counties a and b are also neighbor counties separated by the provincial border. But unlike counties A and B, counties a and b are not riverside counties. In addition, counties A and a share the same provincial characteristics and are likely to share similar geographic features; the same is true of counties B and b. We set the four counties A, B, a, and b as a county group.

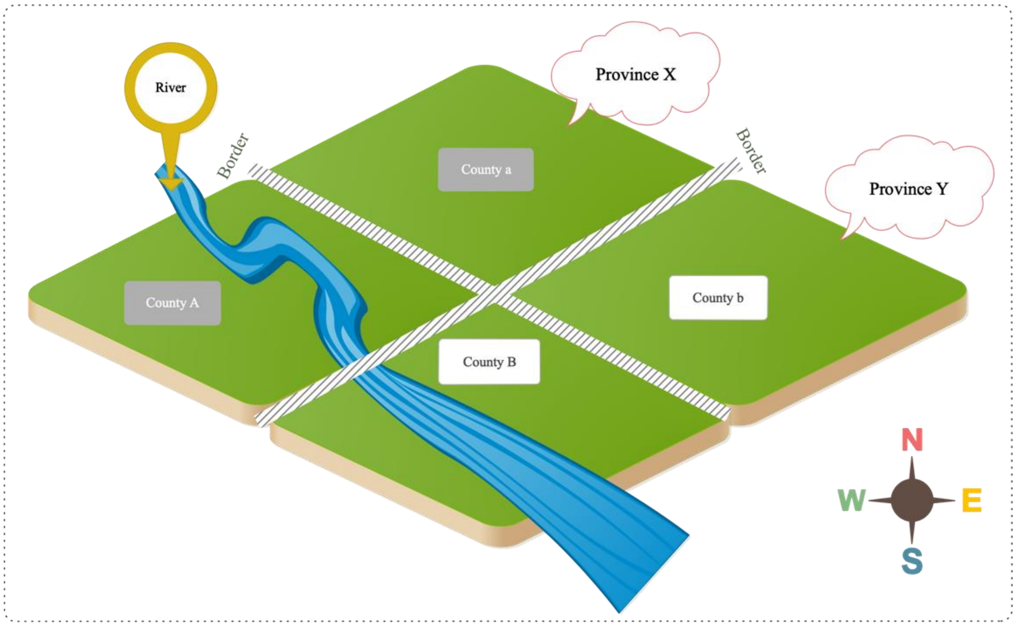

Fig. 1. Transboundary pollution of river characterization model.

As we described above, the first step is to compare the difference in water pollutant emission between county A and county B as the treatment group, then make the difference between county a and county b as the control group. The DID method removes the heterogeneities of county A and county B that are province-specific, such as geographic features, economic features and political features. After making the basic DID method, we still need add control variables to capture most about the relevant variables. The DID analysis is with the following regression：

$$Y_{it} = \beta_0 + \beta_1 DOWN_i \cdot RIV_i + \beta_2 DOWN_i + \beta_3 RIV_i + \beta_4 X_{it} + \varepsilon_{it}$$

Where i , t indicate county and designated year. $Y_{i,t}$ is the water pollutant emission, used the logarithmic form of the COD emission data in the baseline model, in county i in year t. $DOWN_i$ is a county dummy: it is set to 1 if county i is the most downstream county in its province (such as county A and county a in our heuristic example), and 0 otherwise (such as county B and county b). RIV_i is another county dummy: it is set to 1 if county i is located along a river (such as county A and county B), and 0 otherwise (such as county a and county b).

The interaction RIV term captures the riverside-specific effect on Y; and the interaction $DOWN_i$ term captures the upstream-province-specific effect. The focus of our DID analysis is the double interaction term $DOWN_i \cdot RIV_i$, so β_1 is the parameter of primary of interest to us. It both captures the two effects and it's the pure transboundary effect.

As discussed above, we include a range of county characteristics to address the problem of selection based on observable county characteristics. X_{it} is a set of control variables that represent county i's socioeconomic and demographical characteristics in year t. Even we treat the data set as pool data, some counties characters won't change in particular year or province. So, we add the fixed effect in order to catch the year fixed effect and province fixed effect. As the differences between groups, which are made up by four counties in Fig. 1, are distinct, we also added the group fixed effect. Lastly, ε_{it} is the error term.

According to two periods' DID methods, we could estimate the effect of environmental policies changes towards transboundary pollution. As we mentioned before, we test the *"the Guidance"*, which is aimed at rivers' transboundary pollution and have took actions from 2009. Making the policy assessment could answer about what kind of policies are effective to transboundary pollution.

Examining if the policy could make transboundary pollution phenomenon receded, we need to find out whether there is a significant difference from two periods before and after the breakpoint time. As we use the DID method to represent transboundary pollution phenomenon, an addition on time breakpoint makes double interaction term become the triple interaction term, which also make the baseline model by DID analysis turn to the policy effectiveness check by DDD analysis. The DDD analysis is with the following regression：

$$Y_{it} = \beta_0 + \beta_1 DOWN_i \cdot RIV_i \cdot Post + \beta_2 DOWN_i \cdot RIV_i + \beta_3 RIV_i \cdot Post + \beta_4 DOWN_i \cdot Post$$
$$+ \beta_5 Post + \beta_6 DOWN_i + \beta_7 RIV_i + X_{it} + \varepsilon_{it}$$

Where i,t indicate county and designated year. $Y_{i,t}$ is the water pollutant emission in county i in total time j. $DOWN_i$ is a county dummy: it is set to 1 if county i is the most downstream county in its province (such as county A and county a in our heuristic example), and 0 otherwise (such as county B and county b). RIV_i is another county dummy: it is set to 1 if county i is located along a river (such as county A and county B), and 0 otherwise (such as county a and county b). $Post$ is the breakpoint year dummy: it is set to 1 if time is after 2008, and 0 otherwise.

The interaction $RIV_i \cdot DOWN_i$ term captures the transboundary effect on Y_{it}; $Post$ captures if there an incident happened. The focus of our DDD analysis is the double interaction term $DOWN_i \cdot RIV_i \cdot Post$, so β_1 is the parameter of primary of interest to us. It captures the triple effects and it shows the incident affected the transboundary pollution phenomenon. The same with the rest remain.

The breakpoint we most concern is the policy that may influence the transboundary pollution phenomenon, which is the *"the Guidance"*. As *"the Guidance"* published at July, 2008 but took actions at 2009. So, we get 2009 as the breakpoint to make the DDD analysis. Before using the DDD method to make the empirical study, we should make a chart to exam if the trends before the two breakpoints are similar.

4. Data

4.1 Data Sources

For our main empirical analysis, we construct a sample at county level with data for 10 years (2003 to 2012), with information on the number of firms, industrial value, waste water discharged, COD discharged, county location type (A, B, a or b), and other county characteristics. The data we used come from the following three sources.

The county location data are collected by manual using GIS with the 2010

Chinese rivers and counties map. We focus on the first order stream in China and screen out those who crosses at least one provincial border. There are 15 major rivers left and 22 provinces crossed (Fig. 2). Along these 15 rivers, we first identify 116 riverside counties (such as counties A and B) located at provincial borders. Then for each of these counties, we identify a non-riverside neighbor county from the same province which is also at the provincial border (such as county a and b). The final sample has 58 riverside county pairs and 58 non-riverside county pairs. These 232 counties are classified into 58 county groups, each having four neighboring counties (as in Fig. 1).

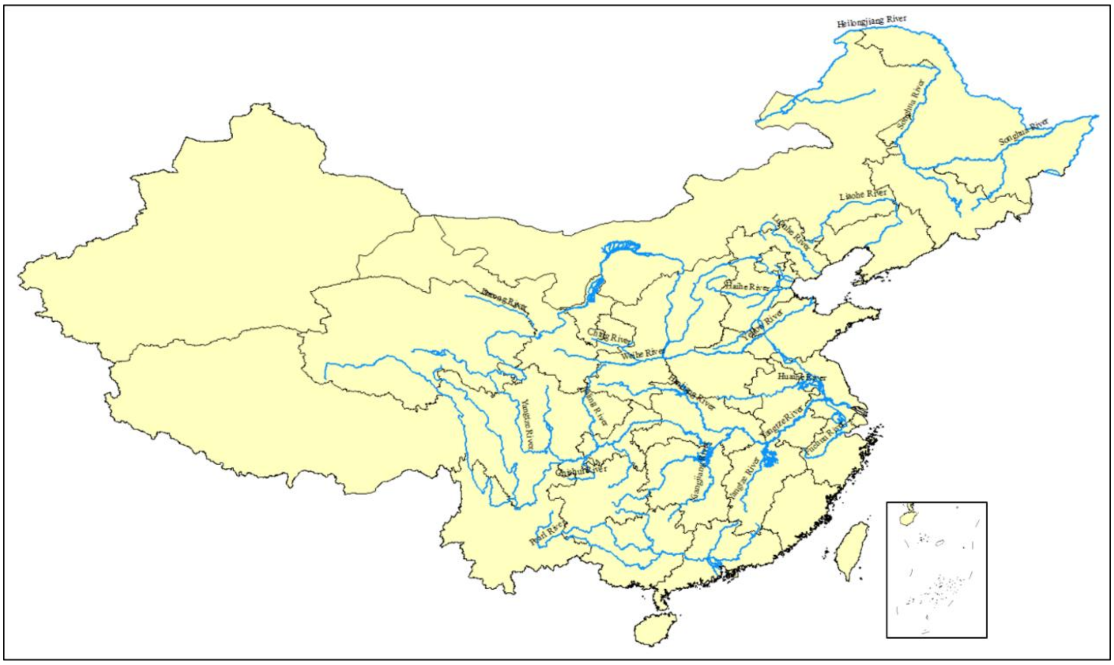

Fig. 2. China's primary tributaries in our cases.

For an example, Fig. 3 shows the transboundary pollution unit group in Lancang river, Qinghai and Tibet provinces, whose four neighboring counties are Nangqian County (county A), Changdu County (county B), Yushu County (county a), Shengda County (county b).

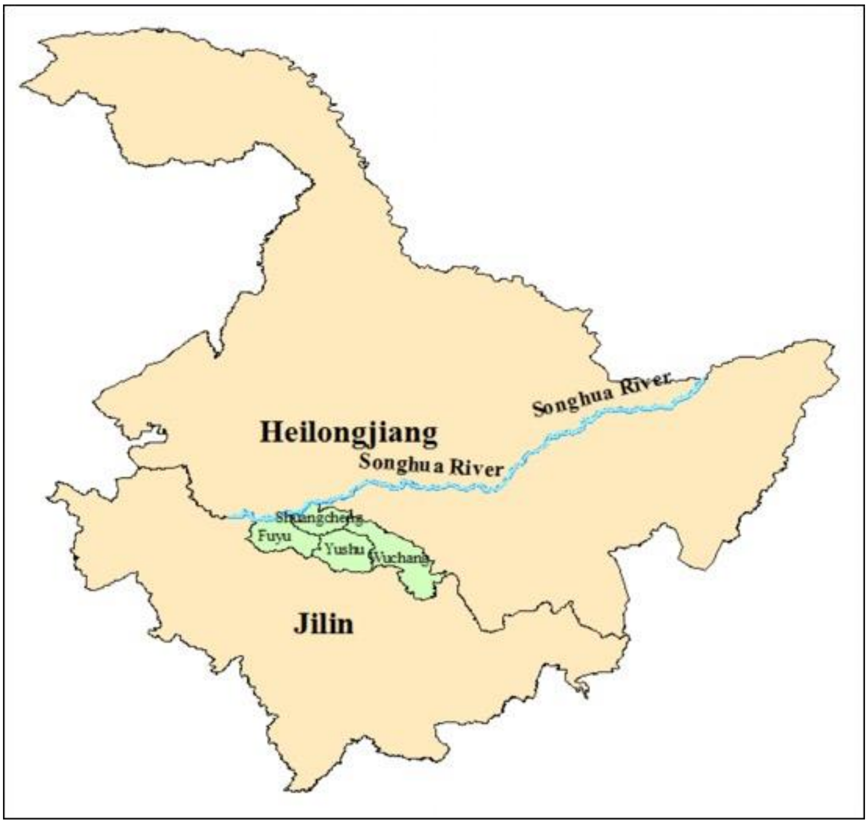

Fig. 3. Example of transboundary pollution unit group in Songhua River, Heilongjiang and Jilin provinces.

The pollutant emission data are from the Pollutant Emission Dataset at the County Level from 2003 to 2012. The dataset includes different types of pollutants' data, number of firms and industrial value data. The pollutant emission data includes COD emission, waste water emission, ammonia nitrogen emission and sulfur dioxide emission data.

The counties character data include Gross Domestic Product (GDP), population, land area, primary industry share of GDP and the distance to provincial capital . The GDP data are from China Province Statistics Yearbook; the populations, land area, primary industry value data are from China County Social and Economic Statistics Yearbook; the distance to provincial capital data are collected by manual using GIS. All the data show the situation in the end of the year or the whole year things.

4.2 Descriptive Statistics

The descriptive statistics is shown in Table 2. The main dependent variable are normal and natural logarithm form of COD discharged, waste water discharged, ammonia nitrogen discharged, sulfur dioxide discharged, industrial value and firm number. The independent variables are county position data. Using dummy variables showing if the county is at upstream or downstream, across a river or not, the independent variables determine which type the county is: A or B or a or b. The control variable includes socioeconomic and demographical characters of counties. Including GDP, population, land area, primary industry share of GDP and the distance to provincial capital.

Table 2. Descriptive statistics of all data.

	Mean	**Std. Dev.**	**Min**	**Max**
Border Variables				
DOWN (dummy)	0.50	-	0.00	1.00
RIV (dummy)	0.50	-	0.00	1.00
DOWN · RIV (dummy)	0.25	0.43	0.00	1.00
Distance to provincial capital (km)	314.79	263.90	3.00	1774.00
Log (distance to provincial capital)	5.47	0.80	1.10	7.48
Pollutant emissions				
COD discharged (ton)	1346.91	2663.57	1.03	24022.40
Log (COD discharged)	5.79	2.00	0.03	10.09
Waste water discharged (10,000 tons)	586.32	1713.07	1.01	28521.90
Log (waste water discharged)	5.02	1.84	0.01	10.26
Ammonia nitrogen discharged (ton)	172.02	596.01	0.00	7676.04
Log (ammonia nitrogen discharged)	2.59	2.87	-8.11	8.95
Sulfur dioxide discharged (ton)	5859.90	14747.94	2.07	135056.00
Log (sulfur dioxide discharged)	6.97	1.99	0.73	11.81
County characters				
Industrial value (10,000 yuan)	267075.50	844684.70	538	1.50×10^7
Log (industrial value)	11.00	1.86	6.29	16.54

No. of Firms	29.33	33.80	1	344
GDP(10,000 yuan)	43751.40	556415.50	5282.71	6869791.00
Log (GDP)	12.51	1.24	8.57	15.74
Population（10,000 persons）	73.76	1003.24	1.80	50331.00
Log (population)	3.56	1.01	0.59	10.83
Land area（km^2）	4659.66	10953.07	173.00	280035.00
Log (land area)	7.96	0.82	5.15	12.54
Primary industry share of GDP	0.32	0.24	0.00	0.92

5. Results

5.1 Estimation results of transboundary pollution

To investigate whether there is transboundary pollution phenomenon in China's rivers, we use DID method to test the difference about pollutant emission from the double interaction terms. In total, there are 10 years with 232 counties data per year. The DID results are reported in Table 3 and Table 4.

First, we exam the transboundary phenomenon from 2003 to 2012 using the logarithmic form of COD emission data (Table 3). The reason why we choose COD emission as the dependent variable is that COD is the most important and main water pollutant in China. And we choose the results with the whole control variables (the last column in Table 3) as the final results. As the results show, there is a significant effect showing transboundary phenomenon exist. The transboundary phenomenon has added almost 54% more COD emission from 2003 to 2012.

Table 3. DID regression analysis results of China's transboundary pollution from 2003 to 2012.

Dependent Variable: Log (COD discharged)						
DOWN · RIV	0.446***	0.538***	0.523***	0.540***	0.544***	0.542***
	(0.150)	(0.153)	(0.163)	(0.165)	(0.164)	(0.164)

DOWN	-0.290**	-0.312**	-0.365**	-0.392**	-0.410**	-0.406**
	(0.141)	(0.158)	(0.177)	(0.178)	(0.177)	(0.177)
RIV	0.115	-0.0504	-0.0222	-0.0109	-0.0191	-0.0201
	(0.100)	(0.108)	(0.116)	(0.117)	(0.116)	(0.116)
Log (GDP)	/	0.637***	0.598***	0.455***	0.441***	0.406***
		(0.0817)	(0.0948)	(0.113)	(0.116)	(0.120)
Log (land area)	/	/	0.0992	0.0631	0.0722	0.0825
			(0.123)	(0.124)	(0.124)	(0.124)
Log (population)	/	/	/	0.358***	0.358***	0.379***
				(0.128)	(0.128)	(0.133)
Log (distance to provincial capital)	/	/	/	/	-0.0803	-0.0820
					(0.135)	(0.135)
Primary industry share of GDP	/	/	/	/	/	-0.226*
						(0.128)
Constant	5.048***	0.538***	-3.901***	-3.256**	-2.608	-2.275
	(0.606)	(0.153)	(1.399)	(1.437)	(1.798)	(1.818)
Year fixed effects	Y	Y	Y	Y	Y	Y
Province fixed effects	Y	Y	Y	Y	Y	Y
Group fixed effects	Y	Y	Y	Y	Y	Y
Observations	1628	1628	1628	1628	1628	1628
R-squared	0.519	0.562	0.567	0.571	0.571	0.572

Robust standard errors in parentheses

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

Then, we split the 12 years into 2 parts: 2003 to 2008 for the first, 2009 to 2012 for the second. The two parts are respectively corresponding to the periods before and after the enforcement of *"the Guidance"*, which may affect the transboundary pollution phenomenon. At the same time, we can find if the transboundary pollution phenomenon was getting change in a long term. The results are shown in the Column (1) to Column (3) in Table 4. The transboundary phenomenon in China was getting receded but still significantly exists. The transboundary phenomenon added almost 82% more COD emission from 2003 to 2008, which are much higher than the total time one. However, the phenomenon of COD emission became not significant from 2009 to 2012, which might mean transboundary pollution phenomenon was getting eliminated all-round. Thus, was this sudden change related to *"the Guidance"*?

Table 4. DID regression analysis segmented results of China's transboundary pollution from 2003 to 2012.

	Log (COD discharged) 2003-2012	Log (COD discharged) 2003-2008	Log (COD discharged) 2009-2012
DOWN · RIV	0.542***	0.822***	-0.0589
	(0.164)	(0.209)	(0.260)
DOWN	-0.406**	-0.367*	0.012 6
	(0.177)	(0.214)	(0.269)
RIV	-0.020 1	-0.267*	0.308*
	(0.116)	(0.156)	(0.178)
Constant	-2.275	-2.707	-6.898
	(1.818)	(2.100)	(4.335)
Control variables	Y	Y	Y
Year fixed effects	Y	Y	Y
Province fixed effects	Y	Y	Y
Group fixed effects	Y	Y	Y
Observations	1628	964	664
R-squared	0.545	0.608	0.607

Robust standard errors in parentheses

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

5.2 Estimation results of *the Guidance* effectiveness

To investigate whether the *"the Guidance"* came into play, we used DDD method to test the difference about transboundary pollution change from the triple interaction terms. Before the regression, we make the identification assumption checking if the DDD regressions pass the time trend test. In Fig. 3, the gaps are emission between two counties in the same province but not the two counties across a same river in different provinces. Though it is the same in the DID method, the second way of showing is still with the strong influence of different provinces. Taking the transboundary pollution of river characterization model (Fig. 1) as an example, the upstream_province gap (the blue line in Fig. 3) is equal to A-a and the down_stream_province gap (the red line in Fig. 3) is equal to B-b. As we see in the Fig. 3, the gap between control group and treatment group (the gap between blue and red line) doesn't have an obviously change from 2003 to 2008. Besides, from 2003 to 2008 the county across river emits more COD than counties not across rivers in the upstream province, yet the counties in the downstream province are almost the same. More critically, the gap between control group and treatment group changes significantly before and after 2008.

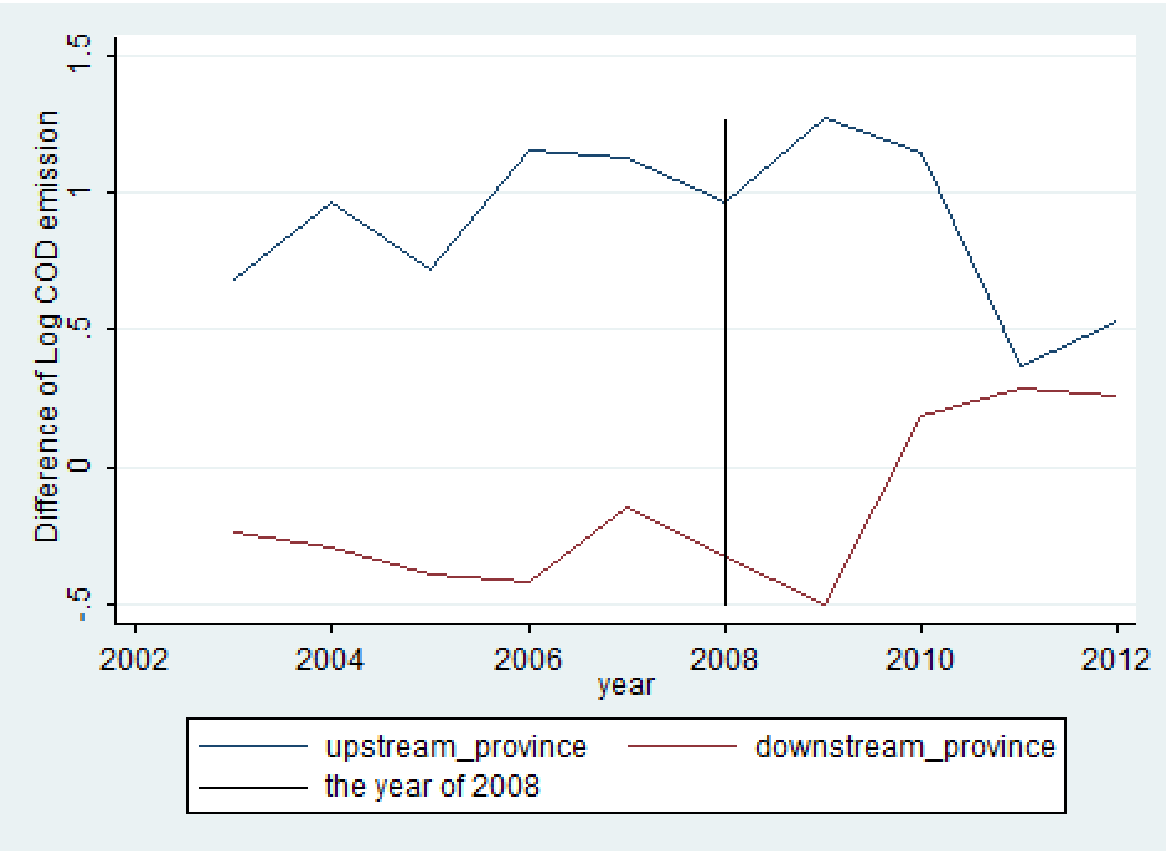

Fig. 3. COD discharged (gaps) in different situations about crossing rivers (2003-2012)

Even we make a simple chart to test if the transboundary pollution phenomenon is at a parallel trend between control group and treatment group, a time trend test is still necessary. Therefore, we added a time trend variable to control the influence of time trend. The results are shown in Table 5, which are the test of 2009. After adding the time trend dummy variables from 2003 to 2008, we find the time trend variables are all not significant. This indicates that the growth rate of the dependent variable before 2009 was similar, and the transboundary pollution did not change significantly. Besides, the DDD analysis pass the time trend test and its estimate is unbiased.

Table 5. The results of time trend test of 2009.

	(1) **Log (COD discharged)**
DOWN · RIV · Post	-1.070***
	(0.402)
DOWN · Post	0.683***
	(0.243)
RIV · Post	0.684***
	(0.222)
DOWN · RIV	1.048***
	(0.291)
DOWN	-0.618***
	(0.185)
RIV	-0.233*
	(0.134)
Post	-0.0666
	(0.273)
DOWN · RIV · Year2003	-0.319
	(0.372)
DOWN · RIV · Year2004	-0.160
	(0.353)
DOWN · RIV · Year2005	-0.705
	(0.374)
DOWN · RIV · Year2006	-0.206
	(0.368)
DOWN · RIV · Year2007	-0.237
	(0.355)
DOWN · RIV · Year2008	-0.0695
	(0.318)
Constant	0.734
	(1.367)
Year fixed effect	Y
Province fixed effect	Y
Group fixed effect	Y
Observations	1628
R-squared	0.547

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

An observation is a county–year combination. The log (GDP), log (population), log (land area), log (distance to provincial capital) and primary industry share of GDP are included but not reported. Standard errors clustered at county-year level are reported in parentheses.

The results of the baseline model by DDD method showing in Table 6 prove the conclusion again. In the results, there is a significant change at 5% in 2009 of the transboundary pollution elimination (COD emissions are reduced by nearly 56%), which verifies *"the Guidance"* was took actions from 2009.

Table 6. The results of DDD analysis on the breakpoint of 2009.

	(1) **Log (COD discharged)**
DOWN · RIV · Post	-0.819**
	(0.340)
DOWN · Post	0.682***
	(0.243)
RIV · Post	0.684***
	(0.222)
DOWN · RIV	0.800***
	(0.186)
DOWN	-0.625***
	(0.186)
RIV	-0.233*
	(0.134)
Post	-0.0422
	(0.260)
Constant	0.330
	(1.367)
Year fixed effect	Y
Province fixed effect	Y
Group fixed effect	Y
Observations	1628
R-squared	0.548

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

An observation is a county–year combination. The log (GDP), log (population), log (land area), log (distance to provincial capital) and primary industry share of GDP are included but not reported. Standard errors clustered at county-year level are reported in parentheses.

5.3 Robustness check

After making the DDD regression, we find strong evidence that at 2009 transboundary pollution has a significant change. But whether it was caused by the *"the Guidance"* still need further robustness check. We use waste water emission, ammonia nitrogen emission, sulfur dioxide emission, industrial value and firm number data to make the falsification check.

Waste water emission data reflect the quantity of diluted water pollutant, which can also reflect the pollutant because the dilution ratio won't have the too big change as most firms only need and dilute it just reach the standard. Ammonia nitrogen is ubiquity in industrial and domestic water pollution. It has been regarded as the second important water pollutant and be monitored earlier than 2003. Sulfur dioxide is the first binding controlled air pollutant and also has been monitored early. The difference is that sulfur dioxide belongs to air pollution, whose flow directions are not certain enough. But there are many industries firms that emit both air pollution and water pollution, such as steel and cement sectors. The industrial value data and frim number data are typical industrial activity data, which is another indirect kind of reflection and phenomenon about transboundary pollution. So, we choose these three pollutants data and two industrial activity data to have the robustness check. Pollutants data and industrial value data are logarithmic form. The data are also from the counties and methods are the same too. The results are reported in Table 7.

Table 7. The robustness check for DID analysis

	(1) Log (waste)	**(2) Log (NH)**	**(3) Log (SO_2)**	**(4) Log (Value)**	**(5) No. of firms**
DOWN · RIV	0.400***	-0.0120	0.490***	0.456***	-4.494**
	(0.138)	(0.282)	(0.178)	(0.101)	(2.234)
DOWN	0.00195	-0.667***	-0.210	-0.0605	-1.117
	(0.143)	(0.255)	(0.145)	(0.0937)	(1.702)
RIV	0.344***	0.322*	-0.0994	0.187***	2.871*
	(0.102)	(0.183)	(0.121)	(0.0716)	(1.628)
Log (GDP)	0.846***	1.174***	0.787***	1.011***	7.962***
	(0.0981)	(0.217)	(0.109)	(0.0787)	(2.051)
Log (land area)	0.425***	0.564**	0.158	0.402***	2.623*
	(0.107)	(0.225)	(0.133)	(0.0809)	(1.477)
Log (population)	-0.154	0.149	-0.101	-0.360***	2.143
	(0.104)	(0.214)	(0.116)	(0.0935)	(1.504)

Log (distance to provincial capital)	-0.522***	0.607***	-0.863***	-0.675***	-3.637
	(0.130)	(0.223)	(0.167)	(0.0983)	(4.414)
Primary industry share of GDP	0.0947	-0.337*	-0.194	-0.280**	-1.609
	(0.121)	(0.177)	(0.241)	(0.131)	(1.963)
Constant	-7.662***	-22.39***	1.429	-1.434	-96.18*
	(1.595)	(3.452)	(1.669)	(1.118)	(58.40)
Year fixed effect	Y	Y	Y	Y	Y
Province fixed effect	Y	Y	Y	Y	Y
Group fixed effect	Y	Y	Y	Y	Y
Observations	1688	1367	1364	1740	1749
R-squared	0.695	0.481	0.634	0.938	0.521

Robust standard errors in parentheses

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

The Colum (1) to Colum (5) respectively are waste water emission data, ammonia nitrogen emission data, sulfur dioxide emission data, industrial value data and firm number data. Toward the results of robustness check, we find except the ammonia nitrogen emission data, the four others are significant to the transboundary phenomenon, which verify our investigation above and shows the transboundary pollution phenomenon is connected with other factors. The not significant results of ammonia nitrogen emission data may be another prove to the mechanism of transboundary pollution. The low-level control to the pollutant made governments a low willing to "free-ride".

At the same time, we use the same variables as DID robustness check to test the results of DDD. A most obvious difference is that the result of DDD method shows the change as time past of transboundary pollution, so the consistency may not similar to DID robustness check. The results are shown in Table 8, which are respectively in 2009.

Table 8. The robustness check of DDD analysis in 2009

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	Log (waste)	**Log (NH)**	**Log (SO_2)**	**Log (Value)**	**No. of firms**
DOWN · RIV · Post	-0.331	-0.235	-0.219	0.313*	-1.462
	(0.275)	(0.469)	(0.378)	(0.187)	(5.136)
DOWN · Post	-0.00225	0.182	0.351	-0.283**	2.314
	(0.205)	(0.325)	(0.244)	(0.140)	(3.222)

RIV · Post	0.135	0.285	0.329	-0.123	12.06***
	(0.196)	(0.297)	(0.256)	(0.127)	(3.294)
DOWN·RIV	0.495***	0.0706	0.813***	0.365***	-3.923*
	(0.164)	(0.341)	(0.243)	(0.118)	(2.279)
DOWN	0.00549	-0.733**	-0.714***	0.0209	-1.759
	(0.160)	(0.301)	(0.168)	(0.104)	(1.822)
RIV	0.303**	0.225	-0.346**	0.222***	-0.617
	(0.123)	(0.231)	(0.158)	(0.0808)	(1.719)
Post	0.0621	-0.274	-0.454**	-7.851***	15.06***
	(0.231)	(0.436)	(0.185)	(0.158)	(3.519)
Constant	-7.586***	-22.20***	-0.933	-1.591	-93.95
	(1.600)	(3.454)	(1.379)	(1.119)	(57.91)
Year fixed effect	Y	Y	Y	Y	Y
Province fixed effect	Y	Y	Y	Y	Y
Group fixed effect	Y	Y	Y	Y	Y
Observations	1688	1367	1153	1521	1521
R-squared	0.695	0.480	0.627	0.938	0.527

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

An observation is a county–year combination. The log (GDP), log (population), log (land area), log (distance to provincial capital) and primary industry share of GDP are included but not reported. Standard errors clustered at county-year level are reported in parentheses.

The robustness check shows reliable evidence to our DDD result at waste water emission data, ammonia nitrogen emission data, sulfur dioxide emission data and firm number data are not significant on the 2009 breakpoint. Comparing with the check of DID, all these factors connected with COD emission are not significantly changed at 2009. Compared with the significant change of COD emission of DDD method, these results show that all these data had little change in 2009, which shows the change was made by a policy not related to other type of pollutants. The industrial value data get a significant change at 10% but the trend is opposite to transboundary pollution, which shows not the economic policies made the change in 2009. This is a strong evidence to be the policy influence of *"the Guidance"*.

6. Discussion and Conclusions

As transboundary pollution phenomenon has been confirmed by several studies, this paper mainly considers about if the central government governance could deal with it. We test at what point the transboundary pollution phenomenon got change. As the baseline model of the study, the DID analysis shows clearly that China did have the transboundary pollution phenomenon in history. The pollution started at least from 2003 and last for more than 6 years. The phenomenon got obvious and serious at first, so we find that the transboundary phenomenon added almost 54% more COD emission from 2003 to 2012. By calculation using the existing data, it means more than 35,500 tons COD because of the remiss dispose toward transboundary pollution. According the DDD analysis, we could find that the *"the Guidance"* made the specific help to solve the transboundary pollution.

The results show that at the time from 2003 to 2012, which cross the 10^{th} FYP and the 11^{th} FYP, China did had the transboundary pollution phenomenon in Chinese main rivers. The upstream counties emitted more pollution than downstream counties. Even they were close in geography and both at the province border. The transboundary pollution embodied at many aspects, including COD emission, waste water emission and industrial firms' value. The upstream provinces truly polluted more to their downstream provinces.

As we eliminate the difference caused by natural features and pollution haven using DID method, the local government must be responsible to the transboundary pollution phenomenon. In the basic model we first compare the upstream counties and downstream counties, which eliminate their features of border and natural condition. Then we eliminate their difference caused by different provinces and the fixed geographical position. After adding the control variables and fixed effect, the equation makes the multi-factor spillover effect turn to the transboundary pollution effect, which are made by the government deliberately pollute at the upstream border to the downstream. This is so called "free riding effect", which makes the unfair phenomenon between upstream and downstream provinces at pollutant emission and environment quality. In other words, even at the strict and up to the emission standard at the provincial level, there are still 35,500 tons COD being emitted highly-centralized at the provincial border per year, which may make a severe concentrated pollution phenomenon at provincial border.

The assessment of *"the Guidance"* shows that this policy has made a significant work at the transboundary pollution problem at rivers. We find the transboundary pollution phenomenon is weaker at 2009 to 2012 than 2003 to 2008, *"the Guidance"* is the driving force. In the robustness check in DID method, we found so many factors related to transboundary pollution. Concerning about Table 7, we found some evidences about the transboundary pollution structure. The Colum (5) in Table 7 is the DID results of firm numbers of counties from 2003 to 2012, which shows significant negative influence. Yet the Colum (4) in Table 7 is the results of industrial value, which shows significant positive influence. The upstream provinces set their downstream counties not more firms but bigger and dirtier industrial values, which mean there are more large-scale firms at the downstream counties of upstream province.

The robustness check of DDD shows us exact information that the most specific policy solved this problem. As there are so many factors related on COD emission in the check of DID, but the breakpoint of 2009 only changed COD transboundary pollution phenomenon but not any other including firm numbers at the Colum (5) in Table 8. It's the strong evidence that the elimination of transboundary pollution was made by *"the Guidance"*. As the first regulation policy issued aimed at transboundary pollution, *"the Guidance"* was carried out and supervised by the central government. Comparing with the FYP or total emission control policies, centralized governance eliminated the regional protectionism problem for the first time. It shows an obvious conclusion that the decentralized problem shall be solved by central governance, but not the stricter decentralized supervision or management.

At the time of the policy made, the central government set pollution reduction targets for each province but failed to anticipate the provincial governments' responses in how they would meet the targets. At the same time, the provincial governments have enough power over the enforcement of environmental matters. Caused by the decentralized policy and the pressure from the central government, provincial governments utilize the externalities inherent in river pollution, but at first, the central government didn't take effective and specific action to supervise and control it. Therefore, provinces tend to exert the least enforcement efforts in the most downstream counties. As the results, using the same DID method after 2010 we find the transboundary phenomenon negligible, which shows the transboundary pollution is made by decentralization regulatory structure of EPBs. The effective way to deal with transboundary pollution is to enhance the central governments' management and change the simplex structure of decentralized.

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