River Chief System and Water Pollution Prevention

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Abstract. Liaoning Province was the first provincial administrative region in China to implement the River Chief System at the provincial level in 2008. Based on the nearly 1000 water quality data of the 2006-2012 water quality automatic monitoring weekly report, this paper analyzes the effect of the River Chief System in Liaoning Province on water pollution prevention and control based on the double differential (DID) method. The empirical results show that the overall V-class compliance rate of the water quality section of the Liaohe River Basin increased significantly during 2008-2012. In 2008 alone, in the Liaohe River Basin, the V-class compliance rate was significantly increased by 9.3 percentage points compared to the Haihe River Basin. Moreover, the implementation of the River Chief System in Liaoning Province will bring greater water quality improvement to the Liaohe River Basin in the long run. From 2006 to 2012, in the Liaohe River Basin, the proportion of the V-type water quality requirements in the section was increased by 19.3 percentage points compared to the Haihe River Basin.

1. Introduction

In 2010, 1.1 billion people worldwide did not have access to clean water, and 2.6 billion people did not have suitable water treatment facilities [1]. With regard to the availability of advanced water treatment facilities and safe drinking water, there is a huge imbalance between rural and urban areas. There are as many as 1.6 million people worldwide who die each year from the safety of drinking water, and this problem is almost exclusively found in developing countries. (RP Schwarzenbach et al., 2010)

There have been many studies in recent years on the specific causes of water pollution and the specific effects on human health. Persistent organic pollutants (POPs) can affect global water systems for more than 50 years, and local areas can cause long-term pollution [2]. Chemical substances and wastewater in agricultural production will have short-term effects on local areas. (RP Schwarzenbach et al., 2010) In a study on surface water pollution in the Yangtze River Delta in China, industrial wastewater, domestic sewage, livestock manure, farmland fertilizer and sediment were the main pollution factors. (Chen Zhenlou et al., 2001) and Roland believes that groundwater pollution can be divided into industrial pollution sources, agricultural pollution sources, domestic pollution sources, and natural pollution sources. Wastewater, waste residue, waste gas in the industry, pesticides and fertilizers in agriculture, domestic garbage and domestic sewage brought about by urbanization will cause serious pollution to surface water and groundwater [3]. (Roland, 2008) Unclean water has a huge impact on people's health. Water quality diseases caused by drinking water are mainly attributed to some known pathogens and protozoa. (Ashbolt NJ, 2004)
According to a WHO report, the number of water-borne infectious diseases outbreaks was the highest in infectious diseases that erupted between 1998 and 2001. (WHO, 2002) and "endemic diseases" in some areas of China, such as Keshan disease, manicure disease, and fluorosis, are due to the poor natural background of groundwater that people drink, and toxic substances such as arsenic and fluorine exceed the standard [4]. (Roland, 2008)

The Chinese government has always been concerned about water safety issues such as drinking water sources and water quality in river basins. China's current surface water environmental quality standards were promulgated in 2002. The water quality of surface waters is divided into five categories according to their functional level [5]. The higher the functional level of the waters, the higher the water quality, the stricter the standard limits for various substances in the water. Class I water quality is mainly applicable to source water and national nature reserves. The standard restrictions on various substances in water are the most stringent (permanganate index cannot exceed 2mg/L, chemical oxygen demand cannot exceed 15mg/L). It is applicable to the first-grade protection zone of concentrated water source and the rare aquatic habitat in concentrated drinking water. The standard restrictions on various substances in water are strict [6]. Class III water quality is mainly applicable to the secondary protection zone of centralized drinking water surface water source. The permanganate index should not exceed 6mg/L, and the ammonia nitrogen index should not exceed 1.0mg/L. Waters that generally meet or exceed Class III water quality are referred to as water quality standards. When the water quality meets the standard, it is generally required that the concentration of each measured substance in the water is basically equal to or better than that of the third class. If the water body is generally IV and V, the concentration index of each pollutant in the water body is high, which is not suitable as a drinking water source, and may be suitable as agricultural water or industrial water. If the surface water quality does not reach the above five categories, it will be classified as inferior V. In the sewage treatment standard, there is a further division of the inferior V water quality. (Surface Water Environmental Quality Standard, 2002)

Since the 21st century, surface waters and large freshwater lakes in China's seven key river basins have suffered more serious pollution [7]. Although the changes in river water quality across China are related to some natural characteristics such as seasonal changes in the season, they are mainly due to human factors. The frequent river water pollution in all parts has brought great threat to the health of local residents. The water and lake protection situation in rivers and lakes is very serious.

In order to better protect water resources, in December 2016, the General Office of the CPC Central Committee and the General Office of the State Council issued the "Opinions on the Full Implementation of the River Chief System", which marked the beginning of the implementation of the "River Chief " in all provinces and cities across the country. The River Chief, in simple terms, is the chief of the party and government at all levels in China and is responsible for organizing and leading the management and protection of the corresponding rivers and lakes [8]. The results of this new type of water quality assessment standard test are inseparable from the achievements and official achievements of the government's leaders at all levels, thus creating stronger binding and incentives for the responsible persons at all levels of the river basin. In fact, as early as 2016, some regions in China have carried out “pilots” of the River Chief System.

As a policy, the “River Chief” is still to further increase the protection of water resources and improve the current situation of frequent water pollution. Based on this, how much change will the water quality management of local rivers be brought about by the implementation of such a strict river management system for water quality managers? This article attempts to answer this question through empirical analysis. We selected Liaoning Province as the main research province and used the Liaohe River Basin as the experimental group to use the relevant water quality data to try to analyze the improvement effect of the River Chief on the water quality of the Liaohe River.
2. Influence of River Chief System on water quality in Liaohe River Basin

(1) Data and model settings

In this paper, the Liaohe River Basin is set as the experimental group, the Haihe River Basin is the control group, the experimental period is 2008-2012, and the pre-experimental period is before 2008 (excluding 2008). Regarding the experimental group Liaohe River Basin and the control group Haihe River Basin, this paper obtained the water quality weekly report data of the two groups in 2006-2012 and selected the commonly used water quality indicators such as pH, dissolved oxygen concentration (DO), and measured chemical oxygen demand. Permanganate index (COD$_{Mn}$), ammonia nitrogen index (NH$_3$-N), etc. Calculate the average index of a certain one of the two groups in a week: (water quality section) overall class III compliance rate, (water quality Section) Overall V class compliance rate, dissolved oxygen class III compliance rate, permanganate index class III compliance rate, ammonia nitrogen index class III compliance rate [9]. To determine whether the water quality has reached Class III or Class V.

Before setting the specific DID model, this paper first uses the method of graphical analysis to test whether the above two indicators of the two groups meet the parallel trend hypothesis. The time before the experiment was in 2006 and 2007 before the implementation of the River Chief System in Liaoning.

Figure 1. The overall V class compliance rate is based on the parallel trend hypothesis test of graphical analysis.

It can be seen from Figure 1 that the overall V-class compliance rate of the water quality section of the Haihe River Basin and the Liaohe River Basin is likely to meet the parallel trend assumption. This paper also makes parallel trend assumptions for other indicators and finds that the results are contrary to the assumptions. Therefore, in the follow-up study, this paper will only focus on the overall V-class compliance rate of the two groups of water quality as the core explanatory variable [10].

Based on the above analysis, we set the benchmark model as follows:

$$P_{ijk} = \alpha_0 + \alpha_1 R_j + \alpha_2 T_i + \alpha_3 (R_j * T_i) + \epsilon_{ijk}$$ (1)

In the formula (1), $P_{ijk}$ represents the overall V-class compliance rate of the basin $i$ in the $i$-th week of the $k$-year. It is worth noting that $j = 1$ represents the data of the Liaohe River Basin, $j = 2$ represents the data of the Haihe River Basin, and $R_j$ is a binary variable, $R_j = 1$ indicates the Liaohe River Basin; $T_i$ is a binary variable indicating whether the data period is before the experimental period, and $T_i = 0$ indicates that the data time is before the experimental period. $\alpha_3$ is the coefficient of the interaction term $R_j * T_i$, which is the average processing effect that this paper attempts to estimate using the double difference method.

(2) Basic results

For the baseline model (1), this paper first obtains the basic results using the overall V-class compliance rate of the Liaohe River Basin and the Haihe River Basin in 2007 and 2008. The data for 2007 satisfies $T_i=0$, and the data for 2008 satisfies $T_i=1$. This paper then uses this model to verify
whether the parallel trend assumption is met by conducting a falsification experiment. Specifically, in 2007, Liaoning Province began to implement the River Chief System. In 2007, the data of the Liaohe River Basin will satisfy $T_j = 1$ instead of $T_j = 0$. In the falsification experiment, this paper finds that the overall V-class compliance rate of the Liaohe River Basin has dropped by an additional 2.36 percentage points from 2006 to 2007, but the result is not significant. Therefore, this paper considers that the overall V-class compliance rate of the Liaohe River Basin and the Haihe River Basin has the same time-varying trend before the implementation of the river-long system in Liaoning Province in 2008. However, since the water quality data of the two groups before 2006 has not been obtained, the implementation of the falsification experiment in this paper needs to be improved.

According to Table 1, in the basic experiment, from 2007 to 2008, the overall V-class compliance rate of the Liaohe River Basin increased from 66.28% to 78.91%, an increase of 12.63 percentage points. The value of the Haihe River Basin has only increased by 1.01 percentage points. According to the baseline model, the increase in the overall V-class compliance rate in the Liaohe River Basin is about 11.62 percentage points higher than that in the Haihe River Basin. Further, the regional fixed effect and time fixed effect of each of the two basins were eliminated, and the overall V-class compliance rate of the Liaohe River Basin increased significantly by more than 11 percentage points. Under the premise of satisfying the assumption of DID model, this paper thinks that the difference between the two is probably caused by the river management model of the River Chief in Liaoning Province in 2008.

Table 1. Overall V-class compliance rate in the Liaohe River Basin and Haihe River Basin

| Overall V-class compliance rate | LiaoHe River Basin | HaiHe River Basin | Difference |
|-------------------------------|-------------------|------------------|------------|
| Basic experiment              |                   |                  |            |
| 2007                          | 0.6628205         | 0.6904533        | 0.0276328  |
| (0.0211266)                   | (0.007819)        | (0.0225271)      |
| 2008                          | 0.7891156         | 0.7005588        | -0.088568  |
| (0.027824)                    | (0.014263)        | (0.0312667)      |
| Difference                    | 0.1262951         | 0.0101055        | 0.1161896  |
| (0.0346842)                   | (0.0160155)       | (0.0382033)      |
| Falsification experiment      |                   |                  |            |
| 2006                          | 0.663522          | 0.6675202        | 0.0039982  |
| (0.0239648)                   | (0.0115628)       | (0.0266085)      |
| 2007                          | 0.6628205         | 0.6904533        | 0.0276328  |
| (0.0211266)                   | (0.007819)        | (0.0225271)      |
| Difference                    | -0.0007015        | 0.0229331        | -0.0236346 |
| (0.031989)                    | (0.0140095)       | (0.0349222)      |

(3) Robustness test

The process of river water treatment is often slow. Therefore, for the improvement of water quality in the Liaohe River Basin, the development of the River Chief has obvious effects in the short term, which may be unconvincing. In contrast, our research will be more convincing if we can prove that the water quality of the Liaohe River Basin is greater than that of the Haihe River Basin for a longer period of time. Therefore, we further put the relevant data corresponding to the period of the Haihe River Basin that has not been involved in the River Chief (2012 and before) into the model. In addition, although the drastic changes in water quality in a basin are often attributed to sudden anthropogenic pollution events, it cannot be ignored that in a year or a few months, the water quality of the river will naturally change due to seasonal changes. The periodic variation of the features fluctuates up and down. Considering these factors, we have rewritten the benchmark model:

$$
p_{ijk} = \alpha_0 + \alpha_1 R_j + \sum_{k=2007}^{2012} \alpha_2 k T_{ik} + \sum_{k=2007}^{2012} \alpha_3 k (R_j \ast T_{ik}) + \sum_{k=2006}^{2012} \sum_{l=1}^{3} (Q_{li} \ast T_{ik}) \beta_{1k} + \varepsilon_{ijk}
$$  (2)
If the interaction between season and year is added to the regression, the time-fixed effect of the year in (2) will only control the seasonality of the fourth quarter of the year. The results are presented in Table 2.

**Table 2. DID robustness test result**

|                  | Overall V class compliance rate |
|------------------|-------------------------------|
|                  | (1)  | (2)  | (3)  |
| **DID**          |      |      |      |
| **2007**         | -0.0236 | -0.0236 | -0.0236 |
|                  | (0.0356261) | (0.0308968) | (0.0327268) |
| **DID**          |      |      |      |
| **2008**         | 0.0926*** | 0.0926*** | 0.0926*** |
|                  | (0.0361724) | (0.0313706) | (0.0332286) |
| **DID**          |      |      |      |
| **2009**         | -0.0139 | -0.0139 | -0.0139 |
|                  | (0.037225) | (0.0322835) | (0.0341956) |
| **DID**          |      |      |      |
| **2010**         | 0.0399 | 0.0399 | 0.0399 |
|                  | (0.0356261) | (0.0308968) | (0.0327268) |
| **DID**          |      |      |      |
| **2011**         | 0.103*** | 0.103*** | 0.103*** |
|                  | (0.035802) | (0.0310494) | (0.0328883) |
| **DID**          |      |      |      |
| **2012**         | 0.193*** | 0.193*** | 0.193*** |
|                  | (0.0361724) | (0.0313706) | (0.0332286) |
| **Control variable:** |      |      |      |
| Regional fixed effect | YES | YES | YES |
| Year fixed effect | YES | YES | YES |
| Seasonal fixed effect | NO | NO | YES |
| Season* year fixed effect | NO | YES | NO |
| Sample size | 700 | 700 | 700 |
| $R^2$ | 0.3510 | 0.5268 | 0.4548 |

According to the regression results, it can be found that in 2008, the overall V-class compliance rate in the Liaohe River Basin increased by an additional 9.3 percentage points. Although the treatment effect of the River Chief System in 2009 and 2010 is not obvious, in 2011, the overall V-class compliance rate of the Liaohe River Basin increased significantly by more than 10 percentage points; and by 2012, the overall V of the Liaohe River Basin The rate of compliance was significantly increased by more than 19 percentage points. Therefore, we have more reason to believe that the improvement of water quality in the Liaohe River Basin by the River Chief in Liaoning Province is more obvious in the long run [11].

At the end of this chapter, we use the regression results in column (2) of Table 2 to more intuitively present the relative changes in water quality before and after the Liaohe River Basin in 2008. The result is shown in Fig. 2.

**Figure 2. DID coefficient in the confidence interval.**
3. Conclusion

Liaoning Province is the first provincial administrative region in China to implement the River Chief System at the provincial level. Although there have been some studies on the policy effects of the River Chief, there seems to be less empirical research. The first study in this paper proves that since the water quality management model of the River Chief System in Liaoning Province in 2008, the water quality of the Liaohe River Basin has shown an obvious trend. Using the double differential (DID) method, the Haihe River Basin was used as the control group. During 2008-2012, the overall V-class compliance rate of the water quality section of the Liaohe River Basin increased significantly. In 2008 alone, in the Liaohe River Basin, the V-class compliance rate was significantly increased by 9.3 percentage points compared to the Haihe River Basin. Moreover, the implementation of the River Chief System in Liaoning Province can bring greater water quality improvement to the Liaohe River Basin in the long run. In 2006, Liaoning Province did not carry out the River Chief System in 2006, and in Liaoning Province, the river extension system has been in operation for five years. In the Liaohe River Basin, the ratio of the most basic requirements for class V water quality in the section of the Liaohe River Basin is increased. 19.3 percentage points.

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