Residential Awareness and Environment Improvement: Evidence from the River Chief System in China

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Abstract

Water quality deterioration is a serious and common environmental issue in many developing countries. Over 30% of surface water in China were reported contaminated round the end of 2016. Considering this detrimental situation, China initiated a flagship institutional innovation on river governance called the River Chief System (RCS), which requires the government to disclose information on administrative responsibilities and rights to the public and invite public supervision. Using 1,156 self-collected questionnaires in 2018 and 2019 from residents in Shanghai, this paper exploits the variation in the timing when each subdistrict/township in Shanghai establishes the River Chief Office to identify the causal effect of information disclosure on rivers' environment from the perspective of public participation. Our model expands the traditional public goods theory to a discrete-choice application, and shows that the RCS can potentially lead to outcomes closer to the social optimal. Our empirical results confirm that the information disclosure under the RCS improves the rivers' environment, and further show that local residents' willingness and action to involve in river management increases due to the policy, which may play a critical role in sustainable river management.

Keyword: River Chief System, Water Pollution, Information Disclosure, Public Participation, Public Goods

1 Introduction

With sustained economic development in China during recent decades, people's demand for a better environment has been steadily increasing. However, based on China's river quality data, its seven major water systems mostly experienced further deterioration in water quality.[1] As shown in Figure 1 for the period 2015-16, the proportion of polluted river section ranges from 10.2% (the Pearl River system) to 62.7% (the Haihe River system), and the classification of water quality in many river sections are downgraded.[2] To tackle serious water pollution, some local governments in China are exploring ways to improve the water administration, and the River Chief System (RCS) was born under such situation.

The RCS is a system with which the government officials at all levels are appointed as chiefs and responsible for the governance of rivers within their jurisdiction. Meanwhile, each level of administration (including provincial, municipal, county-, township-, and village-levels) has a corresponding river chief. Local governments disclosed the information of rivers and river chiefs to the public. If pollution occurs in a river, the river chief will be responsible, which is much more straightforward compared to the previous administrative system under multiple government

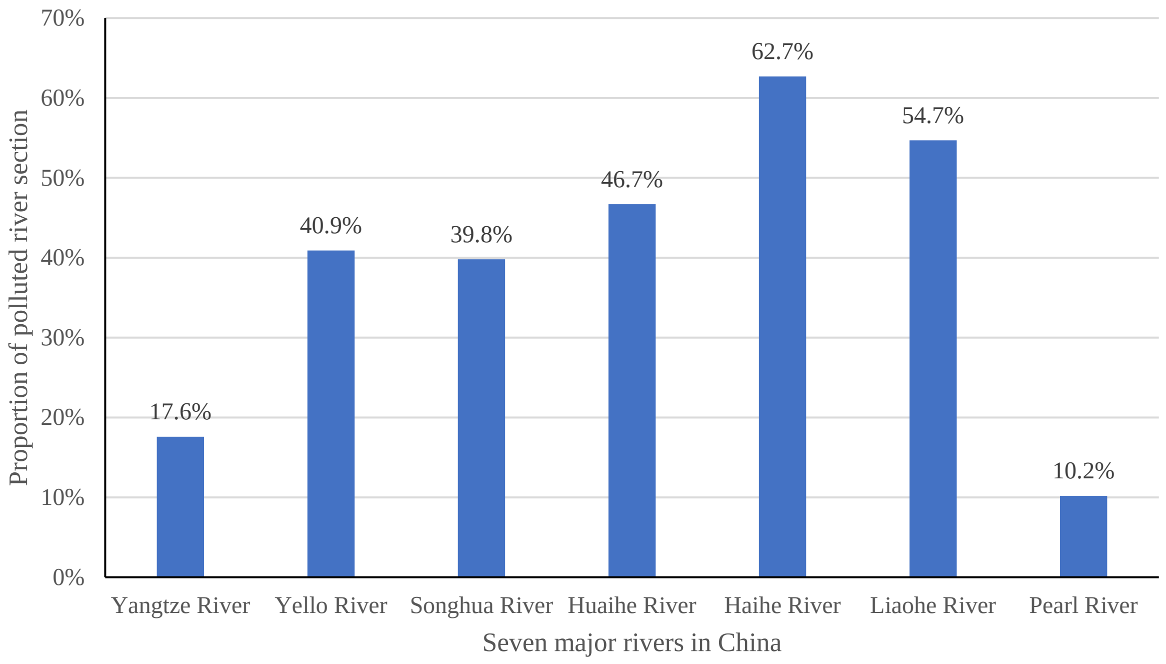

Figure 1: Proportion of polluted river section in seven major rivers in China in 2015-16

[1] River data nationwide is obtained from China's report on the status of environment.
[2] China's Surface Water Quality is classified into six levels according to its using functions, among which Class IV, Class V, Class V+ represent slight pollution, moderate pollution, and heavy pollution, respectively.

departments with overlapping responsibilities and conflicts (Wang and Chen, 2019; Liu et al., 2020; Song et al., 2010). So far, this policy has been fully implemented in China. The information disclosure of the RCS offers the residents a chance to review their preferences to the government with much lower cost than before. This makes public participation play a critical role to maintain river environment and improve long-term river management under the RCS.

This paper investigates if the RCS can form a long-term mechanism for river management with public participation. Specifically, we exam if this information disclosure promotes the local residents' participation in the supply of public goods, and the roles that the government and residents play in the provision of public goods of the river environment. Our paper confirms the positive effect of RCS on water quality, and further explores the role of public participation using self-collected survey data from local residents in Shanghai from the following steps: First, this paper employs an Ordered Probit model to analyze the effect of the policy on water quality using officially reported water quality categories. Then, to further shed light on the public participation mechanism, this paper addresses the endogeneity problem in the residents' knowledge of the RCS by exploiting the variation in the establishment of local River Chief Offices (RCOs) across different townships with a two-stage Control Function Approach. Our findings indicate that knowing the RCS increases local residents' willingness to pay and to supervise the river environment. There are also more reported actions in regulating self-behavior and monitoring the behavior of others.

Existing research have provided different views for the effect of implementing the RCS. Environmental pollution in many rivers in China has been curbed under the RCS (Zhou and Xiong, 2017; Shen, 2018; She et al., 2019). Meanwhile, local governments invested dramatically in pollution control, official supervision, and cross-departmental administration (Wang and Chen, 2019). However, Shen and Jin (2018) shows that water quality only improved in the index observable from the surface, and Li et al. (2020) even finds opposite effects when using national data versus local data. Moreover, when it comes to the long-term effect of the RCS, the management of river environment should be distinguished from temporary government invested projects in water quality improvement. To some degree, dramatic investments from the government may waste a lot of administrative resources. Liu et al. (2019) advocate that the effectiveness and efficiency of the RCS is affected by the inconsistency in implementation and the incompleteness in evaluation and responsibility system over the long run. Once the focus of the government switches, which means there would be no significant investment in the long term, it would be a question whether the RCS could still play an effective role in river management. Our paper is timely in investigating if public knowledge about the policy and participation during the RCS implementation can make river management sustainable.

Our paper provides additional insights on the theory of public goods. In the traditional economic theory of public goods, the government is the supplier while residents are the demanders. Under the assumptions of (1) a continuous and upward-sloping supply curve and (2) asymmetric information, this model typically leads the equilibrium outcome far lower than the social optimal solution. The reason for this suboptimal equilibrium is the canonical "free-rider" problem, where each individual's demand function is private information and is located much lower than the aggregate demand function that vertically sums up all individuals' demand.[1] However, practical situations may challenge the above mentioned assumptions, and our paper considers a typical case when (1) the supply curve is a discrete choice, and (2) more effective communication channels become available. More importantly, local residents may also be willing to participate in the supply of public goods under such circumstances, which also challenges the previously assumed roles that the government and residents play in public goods provision.

Our paper makes the following contributions. First, this paper studies the mechanism of river chief system from the perspective of residents' participation. Unlike most existing studies that qualitatively analyze the effect of RCS, this paper investigates the internal mechanism using self-collected survey data, which helps us answer questions from a more micro perspective. Second, this paper further expands the theory of public goods. The information disclosure and public supervision policies under the RCS differs from any previous river management policies in the world, which enable us to discuss the behavior of suppliers and demanders in the provision of river management, providing theoretical implications on public goods.

The rest of the paper is organized as follows. Section 2 introduces the background of the RCS and its implementation in Shanghai, and Section 3 reviews the literature. Section 4 provides an overall framework and hypotheses to illustrate the roles of government and residents in river management. The data sets are described in Sections 5. Sections 6 and 7 explain the econometric models while presenting the empirical results. Section 8 provides robustness checks, and Section 9 concludes.

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[1] See Mas-Colell, Whinston, and Green (1995), Chapter 11.

2 Background

In 2007, Wuxi, an industrial city located on the edge of the Taihu Lake, suffered from a cyanobacterial crisis, which caused serious contamination to local residents' drinking water. To tackle this serious problem, the government of Wuxi first introduced the River Chief System. This system emphasizes the formation of a multi-level mechanism with top-down management structure (provincial, city, county and township levels) following the administrative hierarchy. Local river chiefs are appointed to take charge of daily affairs, and are supervised by their superior officials. The evaluation of these river chiefs is directly related to the river's water quality. Contrary to the straightforward responsibility under the RCS, water quality in China was previously under the joint administration of the Ministry of Water Resources and the Ministry of Ecology and Environment (MEE, the former State Environmental Protection Administration before 2018). This dual administration caused many problems due to overlapping responsibilities and departmental conflicts (Wang and Chen, 2019; Liu et al., 2020; Song et al., 2010).

After proved to be effective in Wuxi, the RCS has gradually been put into practice in various pilot areas in China, including complete coverage in 8 provinces (or direct-administered municipalities, DAM's for short) and partial coverage in another 16 provinces (or DAM's). After nearly ten years of local governments' practices, China's central government issued the policy of *comprehensive implementation of the River Chief System* on December 11th, 2016. From then on, the RCS has officially risen from local practices to national action. It is also required that all local governments in China should implement the RCS based on local situations and plans to comprehensively establish this policy by 2018. Since then, all levels of governments nationwide have been issuing relevant documents to clarify management teams, funds, and long-term measures. By the end of June 2018, 31 provinces in China established the RCS, and appointed more than 300 thousand river chiefs at the provincial, municipal, county-, and township-levels, and over 760 thousand river chiefs at the village level. More importantly, the RCS invites public supervision by disclosing the contact information of local river chiefs. The specific forms of information disclosure include setting up public noticeboards at prominent locations along the rivers, publicizing through the media, and posting the supervision telephone numbers on official websites. Among these channels, the information from the RCS noticeboards stood first at 23.8% in 2019. Meanwhile, 29.08% of residents tend to dial telephone on noticeboards to obtain the contact information of relevant departments. These are the typical channels through which the public learn about the RCS polices.

Located at the mouth of the Yangtze River, Shanghai is the largest city in China and a major commercial center with numerous waterways passing through. Regarding the comprehensive implementation of the RCS in Shanghai, it can be dated back to an official document in January 2017, which was intended to effectively improve water quality and eliminate the black odor of all small and medium-sized rivers in Shanghai by the end of 2017. Shanghai achieved full coverage of the RCS in September 2017, which is 4 months earlier than the expected deadline and 16 months earlier than national requirements. In accordance with the water quality monitored in September 2017, more than 76% of the small and medium-sized rivers in Shanghai have reached the water quality standards. Then in November 23rd, 2017, Shanghai officially released *Provisions of the Shanghai Municipality on water resources management*, indicating the legalization of the River Chief System in Shanghai. Not only the responsibilities of all-level river chiefs were clarified, but also noticeboards and relevant government websites should be published to the public and updated in time. At present, Shanghai has established a four-level River Chief System which involves 7,787 river chiefs in 43,000 rivers, 41 lakes, 6 reservoirs, and 5,037 other water bodies. It is estimated that the proportion of water bodies that falls in Class V or worse in Shanghai will be eliminated in 2020. Shanghai embraces the most developed administrative system in China, and serves as an important demonstrative role in river management. Thus, this paper takes Shanghai as the sample city, and questionnaire surveys were conducted among residents in Shanghai to obtain relevant data.

3 Literature Review

3.1 The effect of water regulation on water quality

Monitoring and enforcement in water pollution regulation has proved to play an important role in pollution prevention and environmental compliance (Gray and Shimshack, 2011). To protect water from pollution, governments worldwide have legislated and invested significantly in water governance, such as source water assessment and protection programs. Other than the River Chief System (RCS) in China, important national level programs also include the Clean Water Act (CWA) in US and the National River Conservation Plan (NPCP) in India. Most literature suggests that water quality in US has improved since the implementation of the CWA (Lyon and Farrow, 1995; US EPA, 1999). This Act focuses on limiting industrial water pollution by regulating all sources of direct emission pollutants and has provided large amount of funding to all states since 1966. Keiser and Shapiro (2019) reveals that within federal government investment in improving waste water treatment plants, every grant can decrease downstream pollution for 25 miles. Especially for lakes in urban and industrialized areas, the CWA has decreased heavy metals and toxic water pollutants as well (Andreen, 2003). However, when comparing the water quality in fresh water lakes in 2011 with that in 1975 in the US, no obvious change has been found (Smith and Wolloh, 2012). Similar to the CWA in the US, the NPCP in India is also implemented to reduce industrial pollution in rivers and create sewage treatment facilities. Yet, Greenstone and Hanna (2014) found that the institutional settings of NPCP is difficult to track the records of subordinate departments and identify the sources of funding, leading to unclear responsibilities in the implementation. Though several pollutant indicators improved in the initial few years, the NPCP is not effective in reducing water pollution concentrations.

When it comes to the effect of the RCS in China on water quality, some scholars suggest that the RCS is to clarify administrative responsibilities through accountability mechanism, which further improves the efficiency of water governance. The RCS is a contract responsibility system of officials by clarifying the responsibilities and obligations of river chiefs (Zhu, 2017). Especially with a design of “one-vote veto system”, any pollution incidence can ruin the official’s all other efforts (Liu and Chen, 2009; Liu et al., 2019). Besides, Zhou and Xiong (2017) finds that the significance of the RCS is not only about the accountability mechanism, but also forms a dynamic mechanism to force cooperation through accountability, which is beneficial to public participation and improves the water quality. In the area where the RCS was first implemented, the percentage of surface water in poor quality has decreased significantly (Shen, 2018). Based on the government records for the implementation of the RCS, the water quality of eight provinces in China has markedly improved (Wang and Chen, 2019).

On the other hand, some critics say that the RCS in China may face the responsibility dilemma, which will influence the effectiveness of water governance in the long term. It is the outside pressure that causes the better coordination of officials under the RCS, which cannot fundamentally solve the principle-agency problem. It is possible that the coordination under the external force may lack the long-lasting power and may eventually become formalistic, especially for officials lack in the internal motivation (Wang and Cai, 2011). Based on the case study of Foshan City in the Pearl River Delta, Liu et al. (2019) reveals that the proportion of water quality above the acceptable standard has been gradually increasing, but the effectiveness and efficiency of the RCS is affected by the inconsistent implementation, incomplete evaluation and accountability system over the long run. In an empirical research based on monitoring points covering all major water systems in China, Shen and Jin (2018) finds that the initial effect the RCS is statistically significant but deeper pollutants in water have not been reduced. This may indicate that the local government tends to focus on objectives that are easier to observe.

The River Chief System is a unique water pollution control policy that relies on the top-down administrative structure in China. Hence, there is no exactly comparable public policy in other countries, while most existing studies in China on this specific system are hypothetical discussions and qualitative studies on the structure and details. Lacking in micro survey data on local residents, previous qualitative and quantitative studies are mostly from the perspective of government, and evaluate the effect of the RCS using water quality data. This leaves a paucity on the quantitative evaluation of its internal mechanism. Therefore, our paper provides a valuable opportunity to further shed light on the impact of information disclosure and the specific mechanisms behind the potential improvement in the quality of public goods.

3.2 Public participation in river environment management

In the context of public participation, other than the RCS in China, many other countries also adopted similar policies, such as the Integrated Water Resources Management (IWRM), the EU Water Framework Directive, etc. Studies of public participation policy indicate that the public can better improve the water management and share government responsibilities (Mylopoulos et al., 2008). Malmqvist and Rundle (2002) found that more public participation improves the efficiency of water management, and the scope of participation vastly varies. Public participation under these policies is mainly in the form of incorporating river related communities. Some of them are organized by NGOs and local communities, where citizens join together and support the integrated water management in the long run (Doolan, 2007). As part of the stakeholders in water management, citizens can also collaborate and negotiate with government and other non-government stakeholders.

In China, the public participation model is relatively rare when compared to water pollution control regulations in developed countries (Zhang et al., 2019). Writing complaint letters is a common way for residents in China to report environmental problems to local governments. With the RCS, residents can dial the local river chief's supervision telephone if they notice any river pollution. Whereas in developed countries, public participation often occurs at the decision-making stage. For example, the EU Water Framework Directive requires the public to participate in three forms: active involvement, consultation, and provision of information, whose aim is to increase the effectiveness and legitimacy of decision-making process (Mouratiadou and Moran, 2007). When citizens have access to related information, they can contribute their opinion under many scenarios and make better use of the information, which is beneficial to the decision-making process (King et al., 2003; Huitema et al., 2009). Furthermore, especially in transboundary river management, the engagement of the public generates new incentives in resolving complex conflicts (Mylopoulos et al., 2004).

Policy discussions argue that the relationship between government information disclosure and public participation can be close. One of the primary reasons for personal acceptance is transparent information (Heldt et al., 2016). Considering the premise of participation is to have the right to know the environmental situation, effective information disclosure can enhance public participation, and further contribute to water governance (Barreira, 2003).

Evidence above has shown numerous positive effects brought by public participation, yet the actual environmental contribution is still under discussion. Although public participation has an advantage in fostering decision-making, supervision and implementation, government still holds the leading position in pollution control at the current stage (Luyet et al., 2012; Tu et al., 2019). Euler and Heldt (2018) finds that the actual level of participation is relatively low due to the lack of meaningful ways to participate. Similar findings also exist in China, where the level of public participation is not equally distributed (Jingling, 2010; Tu et al., 2019).

Hence, public participation plays an important role in river management but existing literatures mostly focus on changes in management models, lacking in quantitative research on the specific mechanisms. When residents get to know the RCS through information disclosure, their participation willingness and behavior may change. Moreover, public participation might supervise government, affecting river's water quality. Based on our data from the questionnaires, this paper discusses the public participation mechanism from both subjective willingness and actual actions.

4 Theoretical Framework

Considering a situation when a cyanobacterial crisis occurs or when a restaurant dumps garbage into the river. Local authority typically has limited personnel to monitor all river sections. Hence, some local resident(s) are needed to report this to the local authority and to proactively stop any unwanted behavior, so the supply of public goods in such cases, meaning whether or not to monitor and report the crisis, is either 0 or 1.

This theoretical framework starts with a public goods model following the typical settings of Mas-Colell, Whinston, and Green (1995). Individual *i*'s utility function generated from the public good is $\varphi_i(q)$, where $\varphi(.)$ is assumed to be twice differentiable and $\varphi''(x)<0$ for all $x \geqslant 0$. q is the amount of public good, which represents the chance of the public good being supplied when q is bounded between 0 and 1. On the other hand, the cost function for q is $C(q)$, and the cost of supplying that one unit of q is $\hat{C}$. Implementing the RCS, which means disclosing administrative responsibilities and supervision information to the public, should dramatically lower $\hat{C}$, say from $\hat{C}_1$ to $\hat{C}_2$ (see Figure 2).

The marginal benefit for individual i is $\varphi'_i(q)$, so the total marginal benefit generated by the public goods is $\Sigma_i\, \varphi'_i(q)$, where $\varphi'_i(q)$ for all individuals are added up vertically. $\varphi'_1(q)$-$\varphi'_3(q)$ are exhibited in Figure 2 for three representative individuals with various levels of marginal benefit, as well as the total amount $\Sigma_i\, \varphi'_i(q)$. Note that the social optimal solution is the intersection of $C(q)$ and $\Sigma_i\, \varphi'_i(q)$, where $q^*=1$.

Before the implementation of the RCS, the cost for supplying one unit of q is as high as $\hat{C}_1$ in the graph, so the individuals can only contribute 0, as exhibited by the intersections of $C(q)$ and $\varphi'_i(q)$ for i=1, 2, 3, along the vertical axis. However, after the RCS is implemented, the cost decreases from $\hat{C}_1$ to $\hat{C}_2$, which is low enough to switch the intersection of $C(q)$ and $\varphi'_i(q)$ to where $q=1$. In this case, at least one individual has contributed the public good to its socially optimal level.

Based on the above analyses, information disclosure under the RCS may effectively improve the channels for public participation, and establish communication channels between the government and the public. As a result, public participation can effectively improve the rivers' water quality. The experience of developed countries shows that the initial motivation for environmental governance comes from the public (Wu et al., 2020). It becomes clear that improving the water quality of rivers

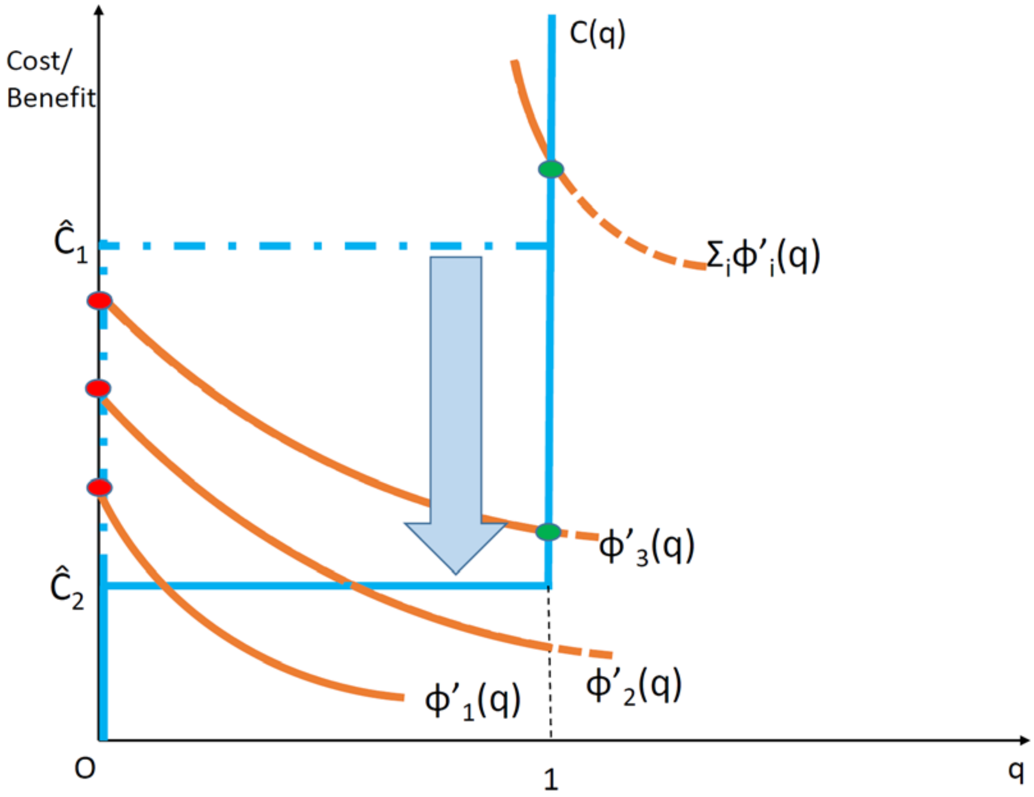

Figure 2: Modeling the Effect of Lowering Cost in Public Goods Supply

requires not only local government’s environmental governance and law enforcements, but also active public participation. Although the government plays a key role in rivers’ environmental governance, it cannot be ignored that the public can effectively participate in long-term river management. In practice, this paper divides the public participation into the following two parts: the willingness to participate at the subjective level and actual actions at the operational level.

First, this paper analyzes the residents' willingness to participate. Based on our model, the RCS notice board, media, and supervision telephone provide local residents with a variety of monitoring channels, which will motivate and thus increase their willingness to supervise. Compared to the case under traditional public product theory, the government and the public under the RCS are more connected through information disclosure. Further, in order to measure the relative level of the public's overall willingness to participate in the river environment, this paper employs willingness to pay to indicate whether the public who know the RCS is more willing to pay to improve the environmental quality.

Second, this paper focuses on the actual action of residents. Their awareness of environmental protection will increase when they know more about the RCS, which is reflected in their own actual action. Meanwhile, in the context of increasing knowledge and open government information, their willingness to supervise in Hypothesis 1 will be transformed into the actual action of supervising other residents. Due to lower monitoring costs and more monitoring channels, residents may be more likely to choose preferred methods to monitor others. In addition, due to the government's assessment requirements, officials need to provide timely feedback to residents' inquiries, which will further encourage residents to supervise others. As a result, this paper proposes Hypothesis 1 and Hypothesis 2 as follows.

Hypothesis 1: As the public know about the RCS, their willingness to participate will increase, which can be expressed as an increase in willingness to supervise and willingness to pay.

Hypothesis 2: As the public know about the RCS, they will take more practical action in river management, which includes regulating their own behavior, actively monitoring the river, as well as monitoring the behavior of others.

5 Data

5.1 Data Source

Surface Water Quality Data on River Sections

This paper uses the surface water quality data from the Shanghai Municipal Bureau of Ecology and Environment, which has been publishing Shanghai's surface water quality of 70 sections in 41 rivers since January 2013. [1] The assessment standard in Shanghai conforms to the national environmental quality standard for surface water formulated by China's Ministry of Ecology and Environment (MEE) on March 9th 2011. The Surface Water Quality is classified into six levels according to its using purposes, among which Class IV, Class V, and Class V+ represent light pollution, moderate pollution, and heavy pollution, respectively.

This paper applies stratified random sampling to select the river section locations for our survey based on Shanghai's Surface Water Quality Data. The specific selection methods are as follows.

First, the six levels of water quality (i.e. Class I, Class II, Class III, Class IV, Class V, and Class V+) were assigned as 6, 5, 4, 3, 2, and 1, respectively. Then, January 2017, the official beginning

[1] Shanghai Municipal Bureau of Ecology and Environment: http://sthj.sh.gov.cn/sh/list_new.jsp?channelid=2149

month of the RCS in Shanghai, was selected as the reference month of the rivers' water quality. [1] Let this initial water quality be I_1. Meanwhile, May 2018 was used as the post-treatment month, and let water quality be I_2. [2] Table 1 shows the number of rivers and sections by water quality categories in these two months.

This paper uses the following equation to measure the changes in water quality in 70 river sections after the implementation of the RCS in Shanghai.

$$D = I_2 - I_1 \tag{1}$$

If $D > 0$, it indicates that water quality improved after the implementation of the RCS; if $D < 0$, water quality deteriorated after the implementation of RCS; if $D = 0$, no change in water quality after the implementation of RCS. In this study, 70 sections from 41 rivers in all districts of Shanghai were selected, and the *D* value was calculated for each river. After eliminating suburban rivers (such as those in Chongming District, Jinshan District, Fengxian District, Qingpu District, etc.) that are mostly related to agricultural production in Shanghai, a random sampling was carried out in each group of rivers by the *D* value, and we also made sure that rivers were distributed in different areas. Finally, 14 sections from 13 rivers were selected as the sample of this study (Table 2).

Table 1: The Distribution of Surface Water Quality for All Rivers and Sections in Jan. 2017 and May 2018

Time	Class I		Class II		Class III		Class Ⅳ		Class Ⅴ		Class Ⅴ+	
	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections
Jan. 2017	0	0	4	4	10	23	12	15	5	7	18	21
May.2018	0	0	6	7	12	20	13	14	10	11	16	18

Table 2: The Distribution of Water Quality Changes (*D*) for Sampling Rivers and Sections

D	-3		-2		-1		0		1		2	
	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections	Rivers	Sections
All	2	2	3	3	7	9	27	35	14	16	4	5
Samples (2018)	1	1	2	2	2	3	4	4	2	2	2	2

[1] On January 20th, 2017, Shanghai Government officially issued the comprehensive implementation plan for River Chief System (RCS), marking the beginning of RCS in Shanghai.
[2] Due to the full coverage of RCS in Shanghai in September 2017, in the starting month of our survey, May 2018, the RCS has already covered in all river sections in our sample.

The whole survey lasted for two years. The survey in 2018 was conducted from July 2018 to August 2018 in above 14 river sections, and 50 questionnaires were collected from each section. In 2019, other than the river sections in 2018, 10 suburban rivers in Chongming District and five other urban rivers were added. During the period between July and September of 2019, 20 questionnaires were collected from each of the 29 selected locations. Among the total 1,380 questionnaires collected, 1,245 of them are valid.

River Chief Office Data

This paper also obtained the founding dates of River Chief Offices (RCOs). The data were acquired from the local governments' websites at the township- or subdistrict-levels where each river section is located.[1] For those cannot be acquired from their websites, the founding dates were acquired through calling each of the RCO's.

To demonstrate the potential exogeneity of the RCO foundation time, all our selected river sections are divided into two groups by the median founding date in May 2017. Table 3 compares the water quality and demographic characteristics of the respondents by the two groups. In terms of water quality, the reference month of official river quality is selected to be Mar. 2017 (the earliest RCO

Table 3: Comparison of River Sections before and after the median RCO foundation time (May 2017)

VARIABLES [i)]	RCO founded before 2017.05			RCO founded after 2017.05			
	Obs	Mean	S.d.	Obs	Mean	S.d.	Difference [ii)]
Official River Quality	11	3.73	0.38	18	4.11	0.36	-0.38
Subjective River Quality	560	2.97	0.043	684	3.06	0.393	-0.09
Age	559	37.35	15.67	677	37.27	15.48	0.08
Gender	559	1.53	0.50	677	1.48	0.50	0.05
Income	559	8.53	0.76	677	8.51	0.74	0.02
Education	559	13.30	3.33	677	13.44	3.31	-0.14
Distance	559	526.04	774.68	677	582.83	906.18	-56.79
Size of households	559	3.77	1.45	677	3.50	1.18	0.27***
Size of kids	559	0.52	0.79	677	0.46	0.64	0.06

Note: i) Main data source from the questionnaires

ii) *** means t-test with p-value<0.01.

[1] Among 29 river sections, the exact RCO foundation time of three river sections cannot be obtained. Hence, this paper dropped samples in these three sections.

foundation month) and the reference time for subjective river quality is selected to be 2017. Both of the two indicators show no statistically significant difference between the two groups. It can also be found that demographic characteristics show no statistically significant difference except for the size of households. Whereas, the difference in the size of households is only 0.27, which is a relatively small scale compared to the average of 3.5-3.77 persons in our sample. Hence, these statistics show that the founding date of RCO is not related to local water quality or any demographic characteristics, which provide more confidence in using this variation as an exogenous variation in our identification strategy.

5.2 Variable definitions and data description

Table 4 indicates the definitions and descriptive statistics of the main variables. When evaluating the effect of River Chief System, the official water data is employed as dependent variable. Three key independent variables are defined to capture the implementation of the RCS: a dummy variable for whether a river section has the local RCO (*RCO*) established in its township/subsitrict, the number of months after local RCO foundation, and the number of days after local RCO foundation. Then, this paper further explores the mechanisms by using the micro-level survey data. The key independent variable is a dummy variable for whether an individual has learnt about the RCS (*Knowledge of RCS*). Considering the data availability, two dummy variables are employed as the key dependent variables to measure residents' willingness level, which include whether an individual is willing to participate in supervising water quality (*Willingness to Supervise*) and whether an individual is willing to pay for water management (*Willingness to Pay*). Besides, as for dependent variables on actual actions, the dummy variable *"Garbage Action"* measures whether an individual has thrown garbage into the river over the past year, the dummy variable "*Supervision*" reflects whether an individual has ever supervised the RCS implementation before, and the dummy variable *"Other's Action"* means whether an individual has ever stopped others from polluting the river. In addition, demographic features are used as control variables, including age, gender, education, income, distance to the river, the size of household, and the number of kids.

Table 4: Descriptive statistics of variables.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
		Panel 1			
RCO[i)]	1384	0.621	0.485	0	1
# of months after RCO foundation (on water quality collection date)[ii)]	1384	9.752	10.410	0	34
# of days after RCO foundation (on water quality collection date)[iii)]	1384	297.654	317.414	0	1045
Official Water Quality[iv)]	1384	4.285	1.339	2	6
		Panel 2			
Knowedge of RCS[v)]	1114	0.423	0.494	0	1
# of days after RCO foundation (on survey collection date)[vi)]	1114	591.677	228.219	142	934
Willingness to Supervise[vii)]	1114	0.516	0.500	0	1
Willingness to Pay[viii)]	1114	0.381	0.486	0	1
Garbage Action[ix)]	1114	0.218	0.413	0	1
Supervision[x)]	544	0.140	0.347	0	1
Other's Action[xi)]	1114	0.191	0.393	0	1
Age[xii)]	1114	37.694	15.771	12	88
Gender	1114	0.496	0.500	0	1
Education	1114	13.250	3.326	6	22
Income	1114	8.505	0.758	7.313	10.021
Distance	1114	535.391	843.074	0	10000
Size of household	1114	3.615	1.339	1	11
Size of kids	1114	0.464	0.701	0	8

Notes: i) *RCO* equals to 1 if river section has established RCO, and 0 otherwise.

ii) *# of months after RCO foundation (on water quality collection date)* is monthly differences between RCO foundation time and water quality monitoring time (months).

iii) *# of days after RCO foundation (on water quality collection date)* is daily differences between RCO foundation time and water quality monitoring time (days).

iv) *Official Water Quality* equals to 1,2,3,4,5, and 6, which represents Class I, Class II, Class III, Class IV, Class V, and Class V+ , respectively.

v) *Knowedge of RCS* equals 1 if individual has learnt about RCS, and 0 otherwise.

vi) *# of days after RCO foundation (on survey collection date)* is daily differences between RCO foundation time and survey time (days).

vii) *Willingness to supervise* equals 1 if individual is willing to supervise, 0, otherwise.

viii) *Willingness to pay* equals 1 if individual is willing to pay, 0, otherwise.

ix) *Garbage Action* equals 1 if individual has thrown garbage into the river within one year, 0, otherwise.

x) *Supervision* equals 1 if individual has supervised RCS implementation, 0, otherwise.

xi) *Other's Action* equals 1 if individual has discouraged others from polluting rivers, 0, otherwise.

xii) Demographic controls include *age*, *gender*, *educatio*n, *income*, *distance*, *size of household* and *size of kids*. *Age* is the age of individual (years). *Gender* equals to 1 if individual is male, 0, otherwise. *Education* is the education years of individual (years). *Incom*e is the number of individual monthly income (yuan). *Distance* is the distance between rivers and individual's home (m). *Size of household* is the number of individual's family members. *Size of kids* is the number of kids in individual's family.

To evaluate the residents' awareness, their knowledge to the RCS matters the first and foremost, without which the residents should have no voluntary action caused by the RCS. By comparing the residents' knowledge to RCS in 2018 and 2019, this paper finds that the percentage of residents who did not know the RCS declined by nearly 15%, showing the effectiveness of information disclosure. Among the various information channels from which residents in 2019 heard about the RCS, the RCS noticeboards and media reports ranked as the first (23.8%) and the second (16.6%), respectively.

6 The Impact of the River Chief System on Water Quality

Studying the role of public participation in the RCS becomes vital when the RCS has been proved to be effective. Therefore, before digging into its internal mechanism, this paper first evaluates the effectiveness of RCS policies. This serves as the foundation of our mechanism discussion, and no previous study has specifically evaluated the river quality changes in Shanghai, especially using the variation of RCO foundation time.

The incentives for local officials in China are mainly driven by their political promotions (Che et al., 2017), so the assessment method under the RCS emphasizing environmental quality can motivate local officials to control pollution (Chen et al., 2018).[1] In order to improve rivers' environment, local governments have invested a lot of manpower, material resources, and financial resources into the RCS on projects such as cleaning up river channels and river banks to control major pollutants, and coordinating across regions to guarantee local drinking water safety (Huang and Xu,

[1] Since December 2016, China government has implemented a new local official evaluation standard called "Evaluation System in the Economic Civilization Construction". By the new assessment standard, officials' evaluation is based on a comprehensive series of social and economic indicators, including economic, political, cultural, social, and environmental development, whereas previously GDP growth had been served as the only major evaluation indicator.

2019). Specifically, local River Chief Offices (RCO's) are established to manage these affairs of the RCS .

Although the RCS may seem conducive to control water pollution, its effectiveness remains uncertain in practice as many issues may hinder its function. There are too many assessment indicators in the official assessment method, and both quantifiable indicators and non-quantifiable indicators coexist, which may distort local officials' resource allocation (Li and Zhou, 2005). Meanwhile, since it is not easy for government officials to transfer resources to river management within a short time, the river's water quality may not be significantly improved in the short term. Officials may even collude with each other in the vertical environmental assessment, which may ultimately make river management a formality rather than a practical solution.

In comparatively developed areas with stronger government capabilities and higher education levels, local governments may play a more effective role in the RCS (Sun et al., 2014). If the Environmental Kuznets Curve holds, these areas' energy consumption and environmental pollution may have passed the inflection point, which can be helpful to improve the environment quality and promote the sustainable development. Therefore, it is speculated that the water quality in the comparatively developed areas, such as Shanghai, will be improved.

To identify whether water quality was affected by the RCS, this paper examines the changes in water quality since the establishment of the River Chief Office by river sections. Our estimations are based on monthly river data ($Quality_{it}$) across 29 river sections in Shanghai between 2015 and 2020. The value of $Quality_{it}$ is categorized from 1 to 6, among which "1" and "2" indicates "excellent", "3" indicates "good", "4" indicates "light pollution", "5" indicates "moderate pollution" and "6" indicates "heavy pollution".

The dependent variable $Quality_{it}$ is an ordered variable where the OLS estimate is not applicable. Therefore, this paper uses the Ordered Probit model that is widely used in the literature for estimation, with the specification as follows:

$$Quality_{it} = \beta\ RCO_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \tag{2}$$

where the dummy variable RCO_{it} is 1 if the river section i has implemented the RCS in time t, and 0 otherwise. λ_i and γ_t indicate river-section- and month-fixed effects to control for all time invariant differences across sections and monthly aggregate changes over time, respectively.

Besides, with the exact date of RCO foundation for each river section, this paper employs the RCS implementation time by month ($RCO\_month_{i,t}$) and by day ($RCO\_day_{i,t}$) instead of RCO_{it} to study the above impacts.

$F(\cdot)$ is a nonlinear function using this specific form:

$$F(Quality^*_{i,t}) = \begin{cases} 1 & Quality^*_{i,t} < \mu_1 \\ 2 & \mu_1 < Quality^*_{i,t} < \mu_2 \\ \vdots & \vdots \\ J & Quality^*_{i,t} > \mu_{J-1} \end{cases}, \tag{3}$$

where $Quality_{it}* = \beta\ RCO_{i\,t} + \lambda_i + \gamma_t$

$Quality^*_{it}$ is a latent variable which cannot be observed. In addition, $\mu_1 < \mu_2 < \cdots < \mu_{J-1}$ are the tangent points, which are all parameters to be estimated.

Based on Equation (2), an Ordered Probit model is performed to analyze the relationship between RCO Foundation and actual river quality. The estimated results are presented in Table 5. The

Table 5: Ordered Probit Estimation Results on Water Quality (All River Sections)

Variable	Ordered Probit Model		
	Outcome Variable: Official Water Quality i)		
RCO ii)	-0.663*** (0.0691)		
# of months after RCO foundation iii)		-0.0304*** (0.00318)	
# of days after RCO foundation iv)			-0.000995*** (0.000104)
River Section FE	Y	Y	Y
Month FE	Y	Y	Y
Observations	1,384	1,384	1,384

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Notes: i) *Official Water Quality* equals to 1,2,3,4,5, and 6, which represents Class I, Class II, Class III, Class IV, Class V, and Class V+ , respectively.

ii) *RCO* equals to 1 if river section has established RCO, 0, otherwise.

iii) *# of months after RCO foundation* is monthly differences between RCO foundation time and water quality monitoring time (months).

iv) *# of days after RCO foundation* is daily differences between RCO foundation time and water quality monitoring time (days).

Table 6: Ordered Probit Estimation Results on Water Quality by the Good and Poor Groups

Variable	The Good Group			The Poor Group		
	Outcome Variable: Official Water Quality i)					
RCO ii)	-0.276*** (0.0986)			-1.084*** (0.102)		
# of months after RCO foundation iii)		-0.00575 (0.00447)			-0.0567*** (0.00472)	
# of days after RCO foundation iv)			-0.000190 (0.000146)			-0.00186*** (0.000155)
River Section FE	Y	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y	Y
Observations	621	621	621	763	763	763

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Notes: i) *Official Water Quality* equals to 1,2,3,4,5, and 6, which represents Class I, Class II, Class III, Class IV, Class V, and Class V+ , respectively.

ii) *RCO* equals to 1 if river section has established RCO, 0, otherwise.

iii) *# of months after RCO foundation* is monthly differences between RCO foundation time and water quality monitoring time (months).

iv) *# of days after RCO foundation* is daily differences between RCO foundation time and water quality monitoring time (days).

results are presented in Columns (1) – (3), including section- and month-fixed effects. The coefficients of *RCO*, *# of months after RCO foundation, # of days after RCO foundation* are all significantly negative at 1% level. An additional month after the RCO foundation on average leads to a 3% increase in the chance of water quality improvement in Column (2), and over the whole sample period local RCO foundation increases the chance of water quality improvement by 66% in Column (1).

To investigate its heterogeneous structure, this paper further divides six water quality classifications into two groups. The grouping standard is based on water quality in Jan. 2016, among which the good group is better than Class IV (Class IV included) and the poor group is worse than Class IV. The results in the good group are presented in columns (1) – (3) of Table 6 and the results in the poor group in columns (4) – (6). It can be found the scale of RCS effect on the poor group is much larger, and the increase in probability of water quality improvement is as high as 5% per month in Column (5). Whereas the good group shows muted effects for the number of months and days in Columns (2) and (3).

7 Public Participation Mechanism under the River Chief System

To shed light on the mechanism and deal with endogeneity problems associated with the knowledge of RCS, this paper explores the public participation mechanism using instrumental variables in Section 7.1, and corresponding results are shown in Section 7.2.

7.1 Public Participation Mechanism Using Instrumental Variables

Having established the link between river quality and the RCS implementation, this paper now turns to understand the mechanism. In Shanghai, it is the residents, not the factories, that cause greater impacts on the water quality of the river. Therefore, this paper focuses on public participation mechanism. The information disclosure of the policy can be perceived by the public via various channels, further affecting the degree of public participation.

Based on the hypotheses in Section 4, public participation can be measured by *Willingness to Supervise*, *Willingness to Pay, Throwing garbage, Stopping others* and *Volunteer experience*. The first two hypotheses are the role of "*willingness*" level and the latter is related to actual individual action.

Linear Model

Since residents' knowledge of RCS is related to their willingness to participate and actual action, this paper first establishes an OLS linear regression model as follows:

$$y_{i,j} = \beta_0 + \beta_1 Knowledge_{i,j} + \beta_2 age_{i,j} + \beta_3 gender_{i,j} + \beta_4 income_{i,j} + \beta_5 edu_{i,j} + \beta_6 hhsize_{i,j} + \beta_7 kidsize_{i,j} + \beta_8 distance_{i,j} + \lambda_i + \varepsilon_{i,j} \quad (5)$$

where y indicates the outcome variable for individual *j* who lives near river section *i*. The dummy variable *Knowledge* is 1 for the residents who know the RCS, and 0 otherwise. *Age*, *gender*, *income*, *edu*, *hhsize*, *kidsize* and *distance* are the demographic characteristics of residents. λ_i is the river section fixed effect, and $\varepsilon_{i,j}$ an idiosyncratic error term. Among all the coefficients $\beta_0 - \beta_8$ to be estimated, β_1 is the variable of interest that captures the magnitude of how residents' knowledge of RCS contributes to their willingness to participate and actual action.

Nonlinear Model

The outcome variables are all discrete binary variables. Hence, this paper constructs the following discrete choice models:

$$p_{i,j} = F(y_{i,j} = 1 \mid Knowledge_{i,j}, Z_{i,j,k}) = \frac{1}{1+e^{-y_{i,j}}} \tag{6}$$

where $y_{i,j}$ indicates the outcome variable for individual *j* who lives near river section *i*, and $Z_{i,j,k}$ is a set of control variables $(k = 1,2,\ldots,m)$.

Hence，for river section i and resident *j*, this specification is:

$$\ln(\frac{p_{i,j}}{1-p_{i,j}}) = y_{i,j} = \beta_0 + \beta_1 Knowledge_{i,j} + \beta_2 Z_{i,j,1} + \beta_3 Z_{i,j,2} + \ldots + \beta_{m+1} Z_{i,j,m} + \lambda_i + \varepsilon_{i,j} \tag{7}$$

where β_0-β_{m+1} are the coefficients to be estimated. Among them, β_1 is the coefficient of interest. λ_i indicates river section fixed effect. $\varepsilon_{i,j}$ is an idiosyncratic error term.

Endogenous Issues

Our aim is to identify whether information disclosure of the RCS affects individual's participation for better water quality. Considering knowing the RCS and the willingness to participate are related to personal characters, such as an individual's interest in public affairs, which cannot be observed, estimating by ordinary least squares (OLS) will result in (potentially upward) biased parameter estimates. Therefore, this paper employs the variation in the timing of the RCOs' foundation (till the survey time) at the township/subdistrict level as the instrumental variable to address this endogeneity problem.

There is no official documentation concerning what drives this variation when each of RCOs was founded, but anecdotal evidences suggest that this is mainly determined by when each of the local governments finished the previous major task and has the administrative capacity to initiate this new RCS. This variation is unlikely to be correlated with any local individual's personal characteristics, which is further demonstrated by our comparison in Table 3. This paper finds that the water quality and demographic features are basically comparable between the RCOs founded earlier and those founded later. Specifically, this paper also controls for these demographic features as control variables $Z_{ik}(k = 1,2,\ldots,m)$, including *age*, *gender*, *income*, *education*, *size of household*, *size of* *kid* and *the distance between living place and the nearest river*.

Because the independent variable $y_{i,j}$ is binary variable and Eq. (7) is non-linear function, this paper uses the control function (CF) approach to address the endogeneity problem of the discrete variables. For models with non-continuous explanatory variables (such as binary selection models, etc.), the CF approach can more directly and effectively control endogenous problems.

Instrumental Variable Estimation with CF approach

Given the above endogeneity problems, this paper performs the instrumental variable estimations. In the first stage, the endogenous explanatory variable $Knowledge$ is used to perform logit regression on instrument variable $Difference\_day$ and all exogenous explanatory variables. Then, this paper obtains the fitted value of $Knowledge$. The first stage equation is:

$$\begin{aligned} &Knowledge_{i,j} = \beta_0 + \beta_1 Difference\_day_{i,j} \\ &+\beta_2 age_{i,j} + \beta_3 gender_{i,j} + \beta_4 income_{i,j} + \beta_5\, edu_{i,j} + \beta_6 hhsize_{i,j} + \beta_7 kidsize_{i,j} + \beta_8 distance_{i,j} + \lambda_i + \varepsilon_{i,j} \end{aligned} \tag{8}$$

In the second stage equation, this paper performs a logit regression on the fitted value, residuals, and exogenous explanatory variables:

$$\begin{aligned} &y_{i,j} = \gamma_0 + \gamma_1 Knowledge_{i,j} + \gamma_2 pKnowledge_{i,j} \\ &+\gamma_3 age_{i,j} + \gamma_4 gender_{i,j} + \gamma_5 income_{i,j} + \gamma_6\, edu_{i,j} + \gamma_7 hhsize_{i,j} + \gamma_8 kidsize_{i,j} + \gamma_9 distance_{i,j} + \vartheta_i + \delta_{i,j} \end{aligned} \tag{9}$$

where γ_0-γ_8 are the coefficients to be estimated. Among them, γ_1 is the coefficient of interest. ϑ_i is the river section fixed effect, and $\delta_{i,j}$ an idiosyncratic error term.

7.2 Results of Public Participation

Linear estimation

To test the relationship between the knowledge of RCS and public participation, this paper constructs an OLS linear estimation based on Eq. (5). As the estimated results presented in Table 7 shows, the coefficients of *Knowledge of RCS* are statistically significant at the 1% level in Columns (1) - (2). This means that when individuals percept the RCS information and know the RCS policy, they are 16% more likely to supervise and nearly 12% more likely to pay for the river management. From the actual action level, the coefficient of *Knowledge of RCS* in Column (3) is negative and

Table 7: Results on Public Participation Using Linear Probability Model

Variable	Willingness to Supervise i)	Willingness to Pay ii)	Garbage Action iii)	Supervision iv)	Other's Action v)
	(1)	(2)	(3)	(4)	(5)
Knowedge of RCS vi)	0.162***	0.116***	-0.0704**	0.0894**	0.0642**
	(0.0301)	(0.0396)	(0.0261)	(0.0326)	(0.0253)
Demographic controls vii)	Y	Y	Y	Y	Y
River Section FE	Y	Y	Y	Y	Y
Constant	0.057	-0.602***	0.303*	0.160	0.003
	(0.247)	(0.194)	(0.163)	(0.213)	(0.194)
Observations	1,234	1,231	1,234	563	1,234
R-squared	0.111	0.087	0.135	0.101	0.051

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Note: i) *Willingness to supervise* equals 1 if individual is willing to supervise, 0, otherwise.

ii) *Willingness to pay* equals 1 if individual is willing to pay, 0, otherwise.

iii) *Garbage Action* equals 1 if individual has thrown garbage into the river within one year, 0, otherwise.

iv) *Supervision* equals 1 if individual has supervised RCS implementation, 0, otherwise.

v) *Other's Action* equals 1 if individual has discouraged others from polluting rivers, 0, otherwise.

vi) *Knowedge of RCS* equals 1 if individual has learnt about RCS, 0, otherwise.

vii) Demographic controls include *age*, *gender*, *educatio*n, *income*, *distance*, *size of household* and *size of kids*. .*Age* is the age of individual (years). *Gende*r equals to 1 if individual is male, 0, otherwise. *Education* is the education years of individual (years). *Incom*e is the number of individual monthly income (yuan). *Distance* is the distance between rivers and individual's home (m). *Size of household* is the number of individual's family members. *Size of kids* is the number of kids in individual's family.

statistically significantly, indicating that individuals reduce the frequency of throwing garbage into the river by nearly 7%. In Columns (4) and (5), the coefficients of *Knowledge of RCS* is positive and statistically significantly. These results show that the knowledge of RCS has a positive impact on regulating self-action and preventing others' from polluting the river. These findings are consistent with our expectations.

Nonlinear Estimations Using Control Function Approach

This paper further uses the control function approach to estimate the corresponding parameters based on Equations (8) and (9). Table 8 shows the first stage results and Table 9 - 10 show the second stage results from the perspectives of willingness and actual action.

Table 8: First Stage Results of the Control Function Approach

Variable	Linear probability regression	Marginal effect for logistic regression
	Knowedge of RCS	*Knowedge of RCS*
# of days after RCO foundation i)	0.000377***	0.000371***
	(8.43e-05)	(9.05e-05)
Demographic controls ii)	Y	Y
River Section FE	Y	Y
Constant	-0.160	-2.823
	(0.204)	(2.248)
Observations	1,115	1,115
R-squared	0.173	

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Note: i) *# of days after RCO foundation* is daily differences between RCO foundation time and survey time (days).

ii) Demographic controls include *age*, *gender*, *educatio*n, *income*, *distance*, *size of household* and *size of kids*.

Table 9: Second Stage Results of the Control Function Approach: Willingness

Variable	Model of willingness to supervise		Model of willingness to pay	
	Linear probability regression	Marginal effect for logistic regression	Linear probability regression	Marginal effect for logistic regression
Knowedge of RCS	0.163***	0.159***	0.110**	0.109***
	(0.0325)	(0.0299)	(0.0459)	(0.0302)
Pr(Knowedge of RCS) i)	Y	Y	Y	Y
Demographic controls ii)	Y	Y	Y	Y
River Section FE	Y	Y	Y	Y
Observations	1,115	1,115	1,112	1,112

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Note: i) *Pr(Knowledge of RCS)* is the predicted value of *Knowledge of RCS* from the first stage.

ii) Demographic controls include *age*, *gender*, *educatio*n, *income*, *distance*, *size of household* and *size of kids*.

In Table 8, the results show that *# of days after RCO foundation* has a positive effect on individual’s knowledge of RCS, which means that the foundation of RCO plays an important role in the RCS information disclosure to enhance individuals’ knowledge of RCS. The coefficient of

Table 10: Second Stage Results of the Control Function Approach: Action

Variable	Marginal effect for logistic regression		
	Garbage Action	Supervision	Other's Action
Knowledge of RCS	-0.0722**	0.0947**	0.0521**
	(0.0309)	(0.0375)	(0.0255)
Pr(Knowledge of RCS)	Y	Y	Y
Demographic controls i)	Y	Y	Y
River Section FE	Y	Y	Y
Constant			
Observations	1,076	504	1,115

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Note: i) Demographic controls include *age*, *gender*, *educatio*n, *income*, *distance*, *size of household* and *size of kids*.

instrument for a linear probability regression and the marginal effect for a logistic regression in the first stage are both statistically significant at 1% level, so the problem of weak instruments does not exist.

Tables 9 and 10 present the second stage results from Control Function Approach, controlling for the predicted value of *Knowledge of RCS* from the first stage, demographic features and river section fixing effects. In Table 9, the coefficients of *Knowledge of RCS* are all statistically significant at 1% level. These results imply that individual's knowledge of the RCS has positive effects on both their willingness to supervise and their willingness to pay. The above results validate Hypothesis 1 from Section 4

Correspondingly, Table 10 reports that *Knowedge of RCS* also has positive impacts on public actual action (at the 5% level). As for *Garbage Action*, the negative coefficient of *Knowedge of RCS* indicates that the action of throwing garbage into rivers can be reduced after knowing the RCS. Meanwhile, when individuals know about the RCS, the probability of regulating self-action and stopping others' from polluting the river will increase. Therefore, these results validate Hypothesis 2 from Section 4.

8 Robustness Checks

Besides the aforementioned IV Control Function Approach to analyze public participation mechanism, this session uses Propensity Score Matching (PSM) to do the robustness checks. This paper uses three matching methods below.

First, the whole sample is divided into two groups: the treated group—knowing the RCS, and the control group—not knowing the RCS. Then this paper calculates the propensity score of five participation indicators based on the following logit model:

$$p(X_i) = \Pr(L_i = 1 | X_i) = \frac{\exp(\beta X_i)}{1 + \exp(\beta X_i)} \tag{10}$$

where X_i represents each participation indicator, which include *Willingness to Supervise*, *Willingness to Pay*, *Garbage Action*, *Supervision* and *Other's Action*. β is the coefficient of X_i. Then, this paper calculates the average treatment effect for the treated (ATT) to estimate whether *Knowledge of RCS* affect public participation. The ATT equation is as follows:

$$\begin{aligned} ATT &= E[Y_{1i} - Y_{0i} | L_i = 1] = E\{E[Y_{1i} - Y_{0i} | L_i = 1], P(X_i)\} \\ &= E\{E[Y_{1i} | L_i = 1, P(X_i)]\} - EY_{0i} | L_i = 1, P(X_i)] \end{aligned} \tag{11}$$

Y_{1i} and Y_{0i} represent the treated group and control group, respectively. Using the nearest neighbor matching, kernel matching and radius matching, this paper compares the ATT of residents' Y_{1i} and Y_{0i} based on the data before and after matching. The results are shown in Table 11 and Table 12.

When comparing the ATT before and after the matching, it can be found that the average net effect of ATT after matching has been reduced than the former, which shows that just using the logit model will overestimate residents' knowledge of the river system. For all five indicators, the directions of ATT are consistent with previous regression results, with a 1% significant level. Meanwhile, the estimation results are similar across all the three matching methods. Hence, the results of PSM method are stable.

Table 11: Robustness Check: Willingness

Variable	Matching Method	Matching Type	Treated	Controls	ATT Value	T-stat
Willingness to Supervise	Nearest Neighbour Matching	Without matching	0.6127	0.4322	0.1805	6.36***
		With matching	0.6127	0.4740	0.1387	3.42***
	Kernel Matching	Without matching	0.6127	0.4322	0.1805	6.36***
		With matching	0.6127	0.4424	0.1704	5.14***
	Radius Matching	Without matching	0.6127	0.4322	0.1805	6.36***
		With matching	0.6132	0.4418	0.1713	5.15***
Willingness to Pay	Nearest Neighbour Matching	Without matching	0.4286	0.3310	0.0976	3.51***
		With matching	0.4286	0.3050	0.1236	3.12***
	Kernel Matching	Without matching	0.4286	0.3310	0.0976	3.51***
		With matching	0.4286	0.3280	0.1005	3.1***
	Radius Matching	Without matching	0.4286	0.3310	0.0976	3.51***
		With matching	0.4283	0.3284	0.0999	3.07***

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

Table 12: Robustness check: Action

Variable	Matching Method	Matching Type	Treated	Controls	ATT Value	T-stat
Garbage Action	Nearest Neighbour Matching	Without matching	0.1503	0.2629	-0.1126	-4.79***
		With matching	0.1503	0.1940	-0.0437	-1.3
	Kernel Matching	Without matching	0.1503	0.2629	-0.1126	-4.79***
		With matching	0.1503	0.2107	-0.0604	-2.2**
	Radius Matching	Without matching	0.1503	0.2629	-0.1126	-4.79***
		With matching	0.1489	0.2108	-0.0618	-2.25**
Supervision	Nearest Neighbour Matching	Without matching	0.1937	0.0932	0.1005	3.43***
		With matching	0.1937	0.0962	0.0974	2.45**
	Kernel Matching	Without matching	0.1937	0.0932	0.1005	3.43***
		With matching	0.1937	0.0957	0.0980	2.85***
	Radius Matching	Without matching	0.1937	0.0932	0.1005	3.43***
		With matching	0.1937	0.0967	0.0969	2.8***
Other's Action	Nearest Neighbour Matching	Without matching	0.2312	0.1678	0.0634	2.78***
		With matching	0.2312	0.1599	0.0713	2.25**
	Kernel Matching	Without matching	0.2312	0.1678	0.0634	2.78***
		With matching	0.2312	0.1757	0.0555	2.09**

Radius Matching	Without matching	0.2312	0.1678	0.0634	2.78***
	With matching	0.2302	0.1752	0.0550	2.06**

Standard errors in parentheses are clustered at the prefecture level: *significant at 10%; **significant at 5%; ***significant at 1%.

9 Conclusions

Water quality deterioration is a serious and common environmental issue in many countries. To solve this problem, China has implemented the RCS policy nationwide. In the RCS, related information disclosure is open to the public, which to some extent improves the asymmetric information problem in the traditional public goods theory. Most existing studies on the program are hypothetical discussions or qualitative analysis on the structure and details of the policy, leaving a paucity on the quantitative evaluation of information disclosure effect. This paper adapts a canonical public goods model with a discrete choice setting, which shows that the information disclosure under the RCS may potentially lead to social optimal level of public participation.

Based on the official water quality categories from 2015 to 2020, this paper employs an Ordered Probit model to investigate the water quality effect of information disclosure after the establishment of the River Chief Office across different township/neighborhood in Shanghai. Then, this variation in the timing of local RCO's foundation is exploited to identify the causal effect of information disclosure on public participation. A two-stage control function approach is used to test the hypotheses predicted by the theoretical model. The main conclusions are as follows.

First, a positive relationship exists between the RCS implementation time and the improvement of water quality. The RCOs of local governments play a vital role in the RCS daily affairs, so this paper sets the foundation time of the RCOs as the date when the RCS has been exactly implemented. As the RCS implementation time increases, the government can take more active action in river management, thus improving the river quality.

Second, the foundation of RCOs indicates a higher probability for the public to know the RCS. After a river section established its RCO, the government could effectively disclose information and advance daily RCS work. Among various channels which residents can know about the RCS, the information on the RCS noticeboards stood first at 23.8% in 2019, and these boards can only be set up after the local RCO begins to function.

Finally, a higher knowledge of the RCS can significantly increase public participation. For one thing, residents' willingness to supervise and willingness to pay greatly increase when they notice the information disclosed under the RCS. For another, individuals who knows the RCs also tend to take practical action like not throwing garbage into river, supervising the government, and stopping others from pollution behavior.

The findings of this paper have important policy implications to the improvement in river environment. First, government should strengthen the information disclosure of their policy, making more people understand the administrative rights and obligations, basic information of the river and relevant regulations. For example, the noticeboard of the RCS should be set up in a prominent position, and the responsibility information of the government and the river leader shall be clearly announced. Second, when the government has achievements in water management, the public should be vigorously encouraged to participate in supervision. This contributes to the long-term effectiveness of those potentially short-term environmental improvement projects. By disclosing information and simplifying public supervision procedures, government can increase public participation in environmental management activities, which can further save government investment and relieve administrative pressure.

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