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CASE STUDY

Assessing the effectiveness and function of the water resources tax policy pilot in China

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Abstract
Water resources tax is an important means to strengthen the integrated water resources management and water governance. The Chinese government started the Tax-for-Fee reform (Fei Gai Shui) in 2016 and piloted the water resources tax in ten provinces. After several years of practice, it is necessary to evaluate and summarize the effectiveness and impact of the water resources tax policy pilot in China. This study first analyzes the function of the water resources tax, built on the global development of water resources tax review. And then, this study reviewed the evolution of the water resources fee/tax policy in China and evaluated the effectiveness of the water resources tax reform. In addition, this study discussed critical success factors for the water resources tax pilot and analyzed crucial questions for further study. The results show that water resource utilization efficiency improved and water use structure optimized through the water resources tax incentives. This study might contribute toward making reasonable decisions in the water policy and governance fields not only in China but in other developing countries as well.

Keywords Water resources tax · Tax-for-Fee reform · Policy evaluation · Water governance

1 Introduction

Water plays an essential role in people's lives, economic growth, and regional development. However, with industry development, rapid economic growth, and a sharp rise in population, overexploitation of water resources and resulting water scarcity have become a big challenge around the world over the past few decades (Araral & Wang, 2013). The sustainable development goals (SDGs) propose "availability and sustainable management of water" as goal 6. Economic and fiscal methods play an important role in water governance. Several economic policies and measures have been applied and studied for their effects on the integrated development of water resources (Bayliss, 2014; Hilbig & Rudolph, 2019; Pryke & Allen, 2019; Winpenny, 2015). Many countries have adopted the water resources tax as an economic tool with the purpose of regulating and protecting access to

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water resources by issuing water licenses (Berrittella et al., 2008). As a key fiscal tool for water governance, interest in the relationship between the water resources tax and sustainable water development has increased. Little work, however, has been performed on applying and evaluating the water resources tax, especially in developing countries. The role of the water resources tax in water governance and integrated water resources management remains to be elucidated.

The European Union (EU) is one of the earliest regions in the world to legislate water resources and construct a water resources tax (Valero et al., 2018). Most countries with advanced water resources tax systems are western countries with adequate legal systems. Developed countries provide experiences and role models for developing countries (Barreira, 2009). However, developing countries have different development needs and country-specific characteristics due to socioeconomic and urbanization disparities (Araral & Ratra, 2016). Therefore, it is important to conduct in-depth and detailed studies on water resources tax development in developing countries such as China.

China frequently experiences water scarcity, floods, and droughts. According to the *China Water Resources Bulletin 2018* by Ministry of Water Resources of China, China's freshwater resources total 2.8 trillion m^3, or 6% of global water resources. At the same time, China's per capita water resources are only 2300 m^3, only a quarter of the world average level. This level is one of the poorest per capita water resources worldwide. China is also the world's largest water user, which cannot go overlooked. China's total water consumption in 2018 was 601.5 billion m^3. In addition, many outstanding problems still exist regarding China's water resources, including serious overexploitation of groundwater, severe water resources pollution, and uneven spatial–temporal distribution (Yu et al., 2018). It is necessary to establish integrated water resources management to cope with the increasing challenges of water resources and to efficiently utilize water resources. The water resources tax is an important and potential tool to efficiently use and protect water resources.

In China, enterprises and individuals are free to fetch and use water until the 1980s. Some local governments began to levy the water resources fee after the reform and opening-up in 1978. Until the promulgation of the *Water Law of the People's Republic of China* in 1988, China had a legal basis for water resources charges at the national level, and the levy of the water resources fee by local governments was increasingly implemented. The water resources fee is the main form of paid water resources use in China. However, there are some issues with water resource fees, including a multi-sector levy; a low levy-standard water resources fee; irregular use of the water resources fee; and broad regional differences in the water resources fee system (Qin et al., 2012). As a result, the Chinese government started the Tax-for-Fee reform (*Fei Gai Shui*) in 2016. The purpose of the Tax-for-Fee reform is to regulate water demand with tax, guide, and encourage conservation of surface water resources, suppress groundwater overexploitation, strengthen the protection of water resources, and promote sustainable development of water resources. The Chinese government has conducted water resources tax policy pilot reform in 10 provinces in two batches. However, little research has been conducted to comprehensively assess the effectiveness of water resources tax since its adoption in China.

This study aims to assess the preliminary effect of water resources tax policy based on the policy pilot in ten provinces in China from a country-specific perspective. Drawing from analyses of the water resources tax function, this study assesses the effectiveness and progress of the water resources tax through materials obtained from the investigation in 2018. This study adopts a hybrid method includes theoretical analysis, historical analysis, field investigation, and case study. We conducted a theoretical

analysis of the functions of water resources taxes based on economic model. We also carried out a field survey about hundreds of factories and farmers in Hebei province, collected the policy documents and materials, and interviewed local officials in charge of water resources in other pilot provinces. Considering the detailed available public data are not sufficient to conduct a quantitative policy evaluation by the classical method, such as the regression discontinuity and difference in difference, the qualitative method is mainly adopted in our study. This study also discussed critical success factors for the water resources tax pilot and proposed potential key questions for further study. From both theoretical and empirical perspectives, this study finds that water resource utilization efficiency improved and water use structure optimized through the water resources tax reform in China.

The contributions of this study are manifold. First, the research results verify and improve the existing theoretical research. Second, the outputs of this study provide an initial but in-depth understanding of water resources tax policy in China for global researchers and practitioners. Third, this study provides a possible reference for future water resources tax policy optimization by the Chinese government. At last, the results of this study will also be helpful for other developing countries to adopt national water policies.

The rest of this article is structured as follows. The next section critically reviews the global development of the water resources tax and elaborates on its function and mechanism. The third section evaluates the effectiveness of the water resources tax pilot policy in ten provinces based on an integrated water management framework. The paper concludes by discussing and highlighting the implications of the water resources tax policy for sustainable water development in China.

1.1 Development and function of the water resources tax

Tax is a legal form of raising fiscal revenue. Fees are charged from direct beneficiaries by government departments for providing specific services to enterprises and individuals, or for being granted certain rights. The key difference between tax and fee is as follows. First, the subject of expropriation is different. Taxes are collected by tax authority, customs, or financial sector representing the state, and fees are collected by various national administrations or institutions. Second, the characteristics are different. Tax is mandatory, gratuitous, and stable. Taxpayers must pay taxes in accordance with the law, otherwise they will be punished. Once the tax law is enacted by Congress, it has nationwide and long-term effect. Fees are compensatory and flexible. Fees are used for cost compensation, and specific fees generally correspond to specific services. The collection of fees is generally determined flexibly by different institutions and regions based on conditions. Third, the uses are different. Taxes are included in the government's budget and are exclusive controlled and used by the government to provide funds for national operations. Fees are generally used for special purposes and are arranged by each charging institution according to its own business. Water resources fee is a resource compensation, which is the resource compensation charge for the development and utilization of water resources. As a kind of resource tax, the collection, use, and management of water resources tax must comply with the tax law. In general, water resources fee and water resources tax are both forms of paid use of water resources, and the biggest difference between them is mandatory. Water resources tax is more mandatory, rigid, and restrictive than water resources fee.

1.2 Global development of the water resources tax

Global water resource taxes and fees mainly include water extraction fees, sewage taxes, and tap water taxes (Pinto & Marques, 2015; Schuerhoff et al., 2013). The water extraction fee is a fee for the exploitation and use of water resources, the purpose of which is to make up for the cost of government water resources management and to protect water resources (Amundsen et al., 2014). The main taxpayers of water extraction fees are direct users of water resources; many countries such as Denmark, France, the UK, and others apply water extraction fees (Berbel et al., 2019). In those countries, justifying a water extraction fee usually rests on the nature of the water, its users, and their water usage. Therefore, the standard fees for water extraction are not equal for everyone. For example, the standard fees for water extraction in Hamburg, Germany, include a 0.31 euros per m^3 fee for commercial surface water; a 33.00 euros per year fixed fee for agricultural or personal use of surface water; and a 60.00 euros per year fixed fee for commercial surface water. Functional units such as water supply companies, water bureaus, or environmental bureaus typically apply most water extraction fees to account for management and production costs. For example, Denmark's local municipalities, managed and used by private water supply companies and municipalities in various states, regions, or counties, collect water extraction fees. In Germany, the federal ministry for the environment, nature conservation, and nuclear safety is responsible for collecting water extraction fees.

Sewage taxes/fees usually refer to taxes and fees levied on sewage-discharging individuals and enterprises, and the main purpose of the tax/fee is to raise funds for environmental governance and reduce environmental pollution (Wang et al., 2014). For example, Denmark imposes waste water tax on taxpayers such as factories and manufacturers, French levy pollution discharge fee on individuals and companies, and Quebec imposes industrial wastewater charges for industrial pollution and industrial wastewater. The subject of collection for sewage taxes/fees varies according to the tax or fee. Sewage fee collection is mainly the responsibility of the municipal's authorities, which is similar to the water extraction fee, and the collected funds are dedicated to urban municipal development, whereas the sewage tax is mainly handled by the tax bureau. For example, the Danish ministry of taxation is responsible for the sewage tax, and the regional tax and customs administration is responsible for daily management.

Tap water tax, also called the water supply fee in some countries, mainly refers to the taxation of tap water supply or consumption with the purpose of protecting drinking water (Sanders et al., 2014). Countries such as Denmark, France, and the Netherlands impose this tax. The taxpayer of the tap water tax is the water supplier, such as the running-water company. Taxpayers pay taxes based on the amount of water they use. The tax department levies the tap water tax and the government uses it. However, the government level of water management is different. For example, the local government in Denmark mainly collects and uses the tap water tax, while in the Netherlands, the federal government collects and uses the tap water tax.

From the experience of formulating and collecting international water resources tax, the government plays a vital role in managing water resources taxes (Wang et al., 2020). The government is the only institution authorized to issue water-intaking permits and has a monopoly on water resources tax/fee policies and management. The amount of the water resources fee rests on the national policy objective. The water resources fee can be as low as zero or as high as the market can afford. For example, the UK government

levies water resources fees based on the administrative costs of the next year. The water resources fees are different for different water sources, seasons, regions, and industries. The water resources tax management is related to a specific administrative system (Berbel et al., 2019). There is a variety of water resources tax management models across the globe (Berrittella et al., 2008). Even within a country, the water resources tax management will vary between different regions. For example, the German Federal Government does not have uniform regulations on water resources tax, and each state government has great freedom in formulating local water resources tax policy, which prompted many new policy instruments and management institutions to be adopted. The water resources tax/fee is a nationally specific policy, and the policy adopted by one country may not be fit for other countries.

1.3 Function of the water resources tax

The function of the water resources tax mainly includes two aspects. On the one hand, it reduces the amount of water residents or enterprises use through increasing the cost of water consumption and reducing the actual purchasing power (Olivier, 2010). On the other hand, the tax prompts residents and enterprises to find lower-cost alternatives (Chen et al., 2019). However, water resources are a necessity with low elasticity; this substitution effect is only manifested by structural changes in water use, such as lower-cost unconventional water resources replacing higher-priced groundwater (Berrittella et al., 2008). Therefore, the water-saving mechanism of the water resources tax is mainly embodied in scale and substitution effects.

Taking groundwater as an example, assume the consumer's consumption bundle is (X_1, X_2), X_1 is the consumer's demand for groundwater, and X_2 is the demand for other commodities (including recycled water) in addition to groundwater. The price of X_1 is P_1, the price of X_2 is P_2, and the consumer's monetary income is M. Therefore, the consumer's budget constraint is: $P_1X_1+P_2X_2=M$. A water resources tax is levied on X_1 (groundwater resources), and the tax amount per unit is T, so the price of X_1 rises to $P1'$ ($P_1'=P_1+T$). As mentioned above, rising prices result in two effects. One is the substitution effect (ΔX_1^S), which refers to the substitution of X_2 to X_1 caused by the relative price change, which is expressed as consumers seek lower-priced water resources (such as recycled water), and the other effect is the scale effect (ΔX_1^M), which refers to rising prices reducing actual purchasing power and reducing consumer demand for X_1. Therefore, the total change in consumer demand for X_1 caused by tax is presented as follows:

$$\Delta X1=\Delta X_1^S+\Delta X_1^M \tag{1}$$

Let $\Delta X_1^M=-\Delta X_1^N$ and divide both sides of Eq. (1) by the price change amount ΔP_1. This results in the following:

$$\frac{\Delta X1}{\Delta P1}=\frac{\Delta X_1^S}{\Delta P1}-\frac{\Delta X_1^N}{\Delta P1} \tag{2}$$

Further combined with $\Delta P_1=\Delta M/X_1$, Eq. (2) can be further expressed as:

$$\frac{\Delta X1}{\Delta P1}=\frac{\Delta X_1^S}{\Delta P1}-\frac{\Delta X_1^N}{\Delta M}X1 \tag{3}$$

Equation (3) is the total effect of the groundwater X_1 price increase on demand, which can be expressed as the sum of the substitution and scale effect. As the price of groundwater

rises, consumers look for alternatives and their consumption decreases, so the substitution effect (ΔX_1^S) is negative. At the same time, the increase in groundwater prices also causes a decline in consumers' actual purchasing power and consumption, so the scale effect (ΔX_1^M) is also negative. To sum up, the price increase of groundwater X_1 will decrease consumer demand, so a water resources tax on groundwater can reduce the scale of groundwater use.

Figure 1 shows the substitution effect, scale effect, and total effect of the groundwater X_1 price increase. In the initial stage, the consumer's optimal consumption of groundwater X_1 under the budget constraint is X_0^1. When the price of groundwater X_1 rises due to tax, which stems from the budget bundle $P_1X_1+P_2X_2=M$, the budget line changes from B_1 to B_2. At this time, the consumption of groundwater X_1 when the consumer's utility is maximized is X_1^2, which is the total effect of the groundwater X_1 price increase caused by the water resources tax, including substitution and scale effect. The compensation budget line after taxation is B_3. The scale effect is that the price increase causes consumers to reduce the demand for groundwater X_1, which is shown as a decline from X_1^0 to X_1^1.

The substitution effect rests on the relative prices of the two commodities (P_1/P_2). When the water resources tax is low and the price rises slightly, the relative price changes minimally, therefore the substitution effect may not be significant. When the price of substitutes (such as the price of recycled water) is high, the price gap between groundwater and recycled water is small, and the substitution effect may not be significant. Especially when the water consumption of enterprises is small, using recycled water may not bring higher profits than the cost of taxed groundwater. Therefore, whether the substitution effect exists rests on factors such as the scale of the enterprise's water use and the amount of taxes. Substitution does not necessarily exist. When the substitution effect is small or nonexistent, the total effect is equal to the scale effect. When the scale of the enterprise's water use is small, or the proportion of the water use cost to total cost is low, the enterprise may maintain the original water consumption and the scale effect may not necessarily exist. At this time, the total effect is equal to the substitution effect.

The mechanism of the water resources tax can be summarized as follows: First, it promotes the rational exploitation and effective use of water resources. Levying the water

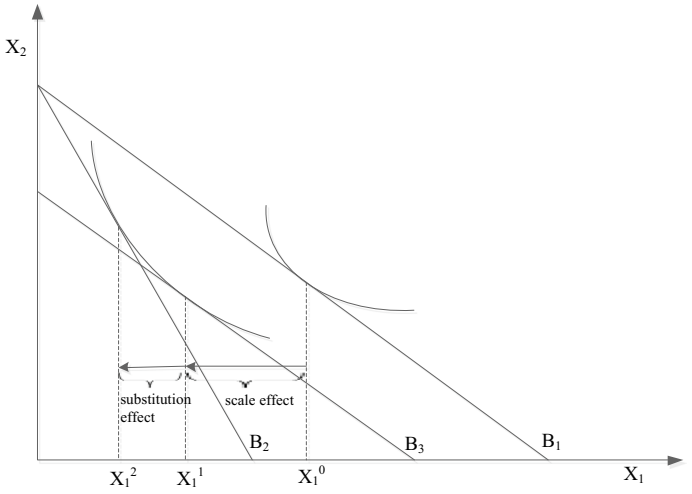


Fig. 1 The effect of the water resources tax

resources tax regulates the use ratio of groundwater and surface water, suppresses the use of groundwater, alleviates the problem of serious overexploitation of groundwater, and ensures the sustainable development of groundwater resources. Second, the tax rationally adjusts the distribution relationship between water resource owners (national government) and water resource users. By levying the water resources tax, the government participates in the distribution of water resources development benefits and promotes fair competition among water-using enterprises. Finally, the mechanism of the tax balances the relationship between tax and fee, improves the resource tax system, and standardizes the financial order.

2 Evaluating the water resources tax pilot in china

2.1 Evolution of the water resources fee/tax policy in China

Water is an indispensable and irreplaceable natural resource. The water resources tax is a kind of resource tax. When China introduced the resource tax in 1984, the tax covered only coal, oil, and natural gas. China has since expanded the resource tax to cover seven more items, but none of them contain water resources. Before 1988, only four provinces, Shanxi, Shandong, Hebei, and Tianjin, collected a water resources fee from enterprises directly taking water from underground, rivers, and lakes. Shanxi Province was the first in China to implement a water licensing system and collect a water resources fee in 1983. The *Water Law of the People's Republic of China*, promulgated in 1988, clearly stipulates that water resources fees must be collected on enterprises that directly extract underground water in cities. Since then, most of the provinces began to collect a water resources fee. In 2013, the national development and reform commission (NDRC), the ministry of finance (MoF), and the ministry of water resources (MWR) clarified the minimum standards for collecting water resources fee. Water resources are divided into surface water and groundwater, and different standards are adopted to collect water resources fees (see Table 1). Provinces can formulate their own water resources fee standards and adjust them dynamically based on local conditions, but they shall not go below the minimum standards.

In 2016, the MoF and the state administration of taxation issued the *Notice on Comprehensively Promoting the Reform of Resource Taxes,* incorporating water resources tax into the collection of resources tax. A pilot project of Tax-for-Fee reform (Fei Gai Shui) was first launched in the Hebei Province to levy a water resources tax, which included surface water and groundwater, and was levied on the basis of water consumption. In 2017, the pilot provinces were extended to include Beijing, Tianjin, Shanxi, Inner Mongolia, Shandong, Henan, Sichuan, Shaanxi, and Ningxia (Fig. 2). Table 2 presents the lowest average tax rate of the water resources tax in pilot provinces. This shows the Chinese government clearly wants to adopt taxation to manage water resources and considers water resources tax reform an important means toward implementing strict water resources management policies and strengthening ecological and environmental protections.

Before the water resources tax reform, China implemented a water resources fee system. However, there are some drawbacks to water resources fees. First, the standard of the water resources fee collection does not rely on water resource conditions in different regions, but rather on the economic development level of each region, so that an effective water resources protection mechanism cannot form. First, formulating water resources fee collection standards places too much emphasis on economic development rather than on water resources conditions in various regions. Second, when the local government formulates

Table 1 Provincial water resources fee collection standards (unit: Yuan/m^3, 2017)

Province	Average collection standard for surface water	Average collection standard for underground water
Beijing Tianjin	1.6	4
Shanxi Inner Mongolia	0.5	2
Hebei Shandong Henan	0.4	1.5
Liaoning Jilin Heilongjiang Ningxia Shaanxi	0.3	0.7
Jiangsu Zhejiang Guangdong Yunnan Ganshu Xinjiang	0.2	0.5
Shanghai Anhui Fuian Jiangxi Hubei Hunan Guangxi Hainan Chongqing Sichuan Guizhou Tibet Qinghai	0.1	0.2

the water resources fee system, rent-seeking behavior occurs for their own interests, resulting in the intensity and credibility of the water resources fee collection system to weaken. Third, the rigidity of the water resources fee policy is insufficient, and the act of collecting and managing the water resources fee is often irregular, which makes it difficult to collect the fee's revenue in full and on time.

China has adopted a prudent approach in water resources tax reform, taking regional differences into full consideration, which not only meet the country's principle requirements, but also provide appropriate authorization for local government policy implementation. First, minimum average standard of water resources tax rate is basically adopted the original standard of water resources fee, and it specifies conditions of tax exemption and conditions of tax deduction, to ensure a smooth transition between the old system and the new one. Second, to promote the regulation and allocation effect of a water resources tax, the Chinese government stipulates that groundwater should be taxed 1–4 times higher than in normal areas where groundwater is overexploited; taxed 1–3 times higher in areas

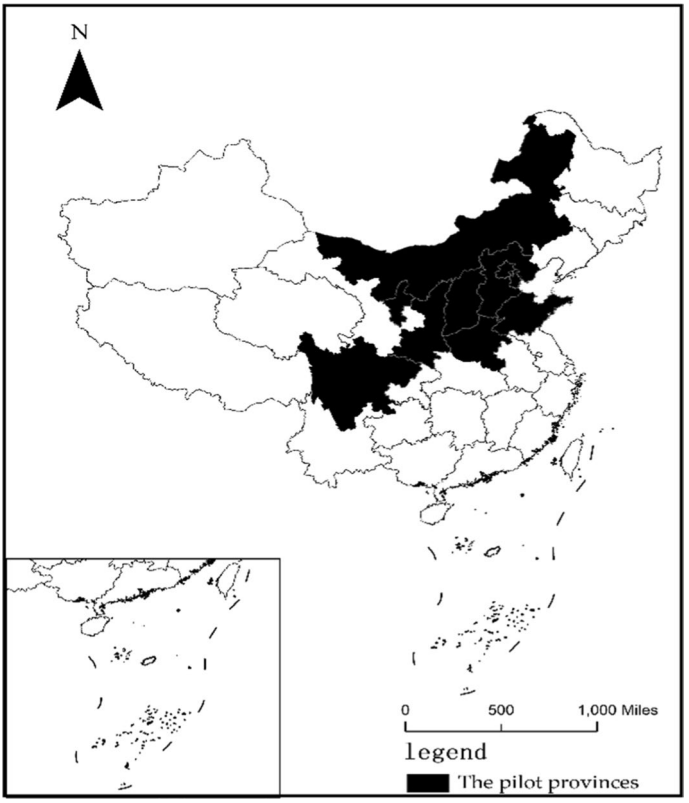


Fig. 2 The pilot provinces of water resources tax in China

Table 2 Minimum average tax amount of water resources tax in pilot provinces (unit: Yuan/m^3, 2017)

Province	Minimum average tax amount for surface water	Minimum average tax amount for underground water
Beijing	1.6	4
Tianjin	0.8	4
Shanxi	0.5	2
Inn Mongolia	0.5	2
Shandong	0.4	1.5
Henan	0.4	1.5
Sichuan	0.1	0.2
Shaanxi	0.3	0.7
Ningxia	0.3	0.7

with over-planned or over-quota water use; and that the tax on special business such as car washing, bathing, golfing, and skiing is set at a high standard. Third, based on the principles of first and second, the pilot provinces can determine the specific applicable tax amount according to their own water resources conditions and economic development. For

example, in Beijing, the water resource tax standard for surface water in general industry is 2 yuan per m^3, the standard for special business is 153 yuan per m^3, the standard for groundwater in general industry is 3.8–4.3 yuan per m^3, and the standard for special business is 160 yuan per m^3.

2.2 Effectiveness evaluation of the water resources tax

The water resources tax pilot has occurred for 3 years across ten provinces, and it is necessary to conduct a preliminary evaluation. Among the ten provinces, Beijing, Tianjin, Shanxi, and Inner Mongolia are located in northern China, where groundwater overexploitation is serious and the contradiction between supply and demand of water resources is prominent. Provinces such as Henan, Shandong, Sichuan, Shaanxi, and Ningxia are typically distributed in eastern, central, and western China, with varying degrees of water resources and various types of water extraction and use.

The ten provinces made dutiful preparations to implement the water resources tax pilot. First, local governments developed a series of guidance documents. Second, the provinces conducted statistical work on water users, and the MWR and Taxation Bureau jointly performed information verifications and transferred work to determine the water resources taxpayers. Henan and Shandong specially developed a water resources tax information system to realize the information sharing between the MWR and the Taxation Bureau. Third, each province detailed the classification and distinguished tax standards according to the local conditions. In terms of tax classification, in addition to surface water and groundwater, some provinces also make distinctions according to industry types, groundwater overextraction degree, coverage of the water supply pipeline network and city level, etc. On the whole, the tax on groundwater is higher than that of surface water; groundwater tax in severely overexploited areas is higher than groundwater tax in generally overexploited areas; and groundwater tax in areas with general over-extraction is higher than groundwater tax in areas with non-over-extraction. In terms of industry classification, special industry is highest, and agriculture is lowest.

The water resources tax shows significant effectiveness in regulating water use and improving water efficiency after several years of pilot in the ten selected provinces. First, groundwater consumption in the overexploited area began to decline. The Tax-for-Fee reform increased the tax gap burden between groundwater and surface water and the tax gap burden between overexploited areas and non-over-extraction areas, which prompted enterprises to adjust their water use structure. For example, a thermal power plant in Beijing used groundwater before the Tax-for-Fee reform. After the reform, the plant prefers to use surface water for cost reasons and used 30,000 m^3 less groundwater within a half year, a 64% decrease year-on-year. The groundwater use in the overexploited areas of the ten pilot provinces fell by 9.28% within a half year.

Second, the total water consumption of high water-consuming industries is under control. The Tax-for-Fee reform stipulates that a water resources tax should double on overplanned water use, prompting high water consumption enterprises to strengthen their water use management, increase their investment in water-saving facilities, and strictly control the total amount of water they use. For example, the six large-scale paper-making enterprises in the Sichuan province that the Water Resources Bureau have monitored reduced their total water consumption by 63% year-on-year. A paper mill in Shandong is located in a region where groundwater is seriously overexploited, therefore the factory used groundwater before the Tax-for-Fee reform. The factory strictly implemented quota control on

water use after the reform, and built a recycled water film treatment and reuse project. The factory reduced 2.28 million m^3 of groundwater in half a year, the rate of decrease was 61%, and the total water consumption decreased by 1.14 million m^3, a year-on-year decrease of 12%.

Third, water use efficiency has further improved. The Tax-for-Fee reform exempts unconventional water sources such as recycled water from the water resources tax and guides enterprises to increase investments in sewage treatment facilities and actively use unconventional water sources. For example, a coal chemical enterprise in the Shaanxi Province has reused 770,000 tons of recycled water, accounting for 7.45% of the company's total water consumption, using a number of technical improvement measures such as reforming the condensate water recovery equipment of the production system and improving the water treatment's operation efficiency. According to statistics from the Water Resources Bureau of the Shaanxi Province, industrial enterprises in Shaanxi utilized more than 100 million m^3 of recycled water in the first half of 2018, an increase of 9.47% year-on-year.

Finally, the water usage of special industries has gradually changed. The Tax-for-Fee reform raised the cost of water resources use for special industries such as golf, forcing the special industries to change the way they use water and strengthen water conservation. For example, water consumption fell by nearly 30% after the Tax-for-Fee reform in 13 special industries in Tianjin.

In addition, the formalization of tax administration has improved. The water resources and taxation bureaus in the ten pilot provinces strengthened their cooperation, and they continue to tighten strict water use management. In the first half of 2018 alone, about 16,000 new taxpayers of water resources taxes were added in the ten pilot provinces, which not only blocked the loopholes in tax management, but also helped the Water Resources Bureau improve water resource management, and achieve win–win results through cooperation.

3 Discussion

Water shortage is already one of the major challenges facing China and the world. Optimizing and controlling water resources allocation through fiscal and taxation methods is a development trend (Wang et al., 2010). It is undoubtedly necessary and urgent for China to promote the rational use and management of water resources through Tax-for-Fee reform. The initiation of water resources tax has proved effective from the ten pilot provinces in China in recent years.

Agriculture, industry, and households consume the most water. Water resources tax has different tax rates and strategies for different sectors, and the impact is also different. Agriculture is the largest consumer of water, but the water resources tax has little impact on agriculture because only excess of water consumption is taxed in consideration of farmers' financial affordability. Industry is currently the most impacted by water resources tax. According to the above theoretical model, the effect of water tax includes substitution effect and scale effect. Although there is no exact data at present, the substitution effect of water resources tax in the industrial sector is more significant based on our field investigation. Because the tax rate of groundwater is higher than that of surface water, a lot of water-intensive enterprises have begun to replace groundwater with surface water and recycled water. However, the scale effect is not significant, and the total water consumption has

not dropped significantly (Fig. 3). The water resource tax is not directly levied on household, but is levied on water plants, and the amount is the same as the water resource fee. In other words, water resources tax does not currently have any direct impact on household.

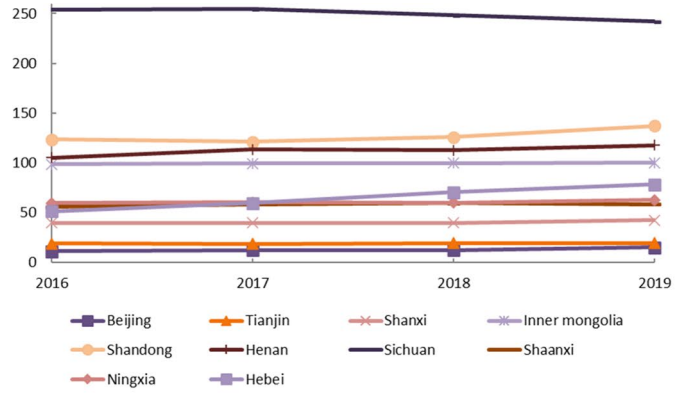
Based on interviews of experts, combined with theoretical analysis, we believe the following critical success factors are important.

First, the interests of all parties should be reasonably considered. All stakeholders have their own interests and needs to meet in water resources tax and management. For example, governments must balance economic growth with water conservation; enterprises need low-cost water, and residents want access to clean drinking water. The water resources tax is actually a redistribution and coordination of the interests of all parties. Reasonable distribution of water resources tax revenue is helpful to reduce the conflicts of interest among various subjects. For example, the revenue distribution of the water resources tax, according to the ratio of 1:9 between central and local governments, follows the previous regulations of the water source fee.

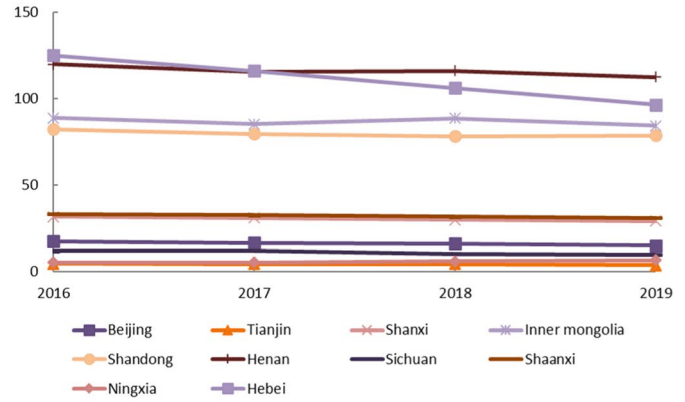
Second, the taxation basis must be reasonably considered. China's water resource tax mainly relies on the actual water consumption of water-using enterprises or individuals and differentiates tax rates for different industries and regions. Taxes shall be calculated on the basis of water consumption for direct access to surface water and groundwater (except mineral water, etc.). Mineral water and geothermal water have special commercial value, and their prices vary greatly with market fluctuation. If a water resources tax is levied on them, the tax rate should rely on price.

Thirdly, local governments are endowed with certain discretionary power. The cost fluctuation of water resources occurs due to the difference of local objective conditions. These conditions are not only affected by direct factors such as local water resources endowment and development difficulty, but also by local characteristics such as economic development and user affordability. It is therefore difficult to establish rigid standards at the national level. Based on the principle of fairness and equity, local governments should be given the power of flexible pricing within a certain range, determined in advance, so as to better compensate the cost of water resources and efficiently promote the maximization of water resources use.

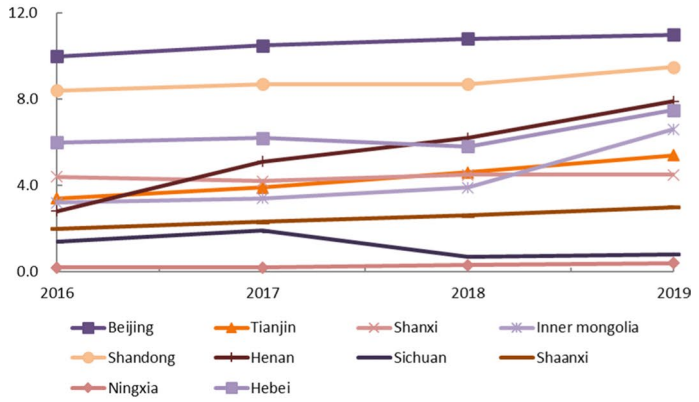
Finally, strengthening inter-departmental cooperation is important. Water resources management is highly technical, and water resources tax collection faces technical problems such as water resources measurement. It requires the cooperation of the Water Resources Bureau and the Taxation Bureau to jointly complete the task of collecting the water resources tax. Since the data of water resources distribution, storage, and water extraction are all held by the Water Resources Bureau, a water resources tax information database must be established to realize the sharing of information such as water-intaking licensing, intake quantity of water, and water resources tax declaration and collection to avoid tax losses from information asymmetry, and improve the efficiency and quality of water resource information service. In addition, the water resources tax supervision must also be jointly responsible for the two departments. However, as an important institutional reform and policy shift, there are some subtle but crucial questions which require further study. Taxing urban public water supplies is worthy of further consideration. It is controversial whether tax is calculated on the water inlet end or the water sales end. Some provinces believe the tax should be calculated at the water inlet end. Distinguishing different tax rates of surface water and groundwater, and using the economic leverage of a water resources tax to reallocate the proportion of water from different sources, is conducive to curbing groundwater overexploitation. Some provinces believe by distinguishing water resources tax rates of different water users, the tax will transmit to the water price, and



a Surface water consumption



b Underground water consumption



c Other water consumption

Fig. 3 Water consumption in 10 pilot provinces, 2016–2019. **a** Surface water consumption, **b** Underground water consumption and **c** Other water consumption. *Note* Other water is mainly recycled water, the data came from the water resources bulletin of the Ministry of Water Resources

the water cost of high-consumption and high-pollution industries will increase from the water supply price, which is conducive to promoting water conservation and protection. However, the effect of a water resources tax in curbing groundwater overexploitation is weakened because the tax no longer distinguishes water sources.

Another topic worthy of further consideration concerns whether the water resources tax on drain drainage in mining and water source heat pumps (WSHP) should be reduced. The ten pilot provinces set tax rates, respectively, for the water used in drain drainage in mining and WSHP according to recycling and direct drainage. The low tax on recycling of drain drainage in mining and WSHP aims to guide enterprises to recycle water and reduce water waste and pollution. Some provinces believe that low taxation is necessary for recycling drainage. However, other provinces believe drain drainage in mining and WSHP all have a negative impact on groundwater, and there is no need to levy a low tax on recycling drainage.

Preferential taxation for rural centralized drinking water works is another important topic to consider. The rural centralized drinking water works improved the drinking water quality of rural residents in China and is also an important measure to implement the sixth Sustainable Development Goal, which states, "ensure availability and sustainable management of water and sanitation for all." After implementing the water resources tax, rural centralized drinking water works face the question of whether to give preferential treatment and recognition standards. The current standard is that the scale of the rural centralized drinking water works reaches 1000 m^3 per day or the water supply target is more than 10,000 people. However, judging from the pilot regions, many of the eligible rural centralized drinking water works currently provide water to villagers for free, and the water works are in a serious loss and need local government subsidies. The cost of the water works still increased, despite some tax incentives, after the Tax-for-Fee reform.

Considering the rationality of the tax rate setting is important. The core element of the tax design is the tax rate. The tax rate reflects a proportional relationship between the tax amount and the tax object. It is an important sign of tax burden, and an embodiment of the principles of science and fairness. The water resources tax rate is related to the regional economic development, tax policy, income level, water resource conditions, and the historical tax burden level, which characterizes the disparity between different water sources, industries, and regions. The rationality of the tax rate determines whether and to what extent the regulating effect of a water resources tax can be realized. Judging from the tax rates of the ten pilot provinces, there are differences between the provinces, different water sources, and different industries. The next step is to evaluate the current tax rate standards and strive to be fair and equitable.

A water resources tax on agricultural water is also important to consider. Agricultural water is a major sector in the annual water use of economies and society. According to the bulletin of the First National Census for Water, agricultural water accounts for 67% of total water use (Ministry of Water Resources and National Bureau of Statistics, 2013). In contrast, agricultural water accounts for about 40% of total water use in developed countries. Therefore, saving water and promoting water efficiency is a key challenge in China's agricultural water, and one of the important targets of the water resources tax. The pilot water resources tax stipulates a quota institution for agricultural water. No tax will be levied below the quota and a water resources tax will be levied in excess of the quota. However, considering the current situation of insufficient agricultural water management capacity, none of the ten pilot provinces levied a water resources tax on agricultural water that exceeds the quota. With the maturity of the water resources tax and the improvement in management ability, agricultural water will become the next focus of a water resources tax.

4 Conclusion and policy implication

The water resources tax reform is the key work of integrated water resources management and water governance in China. To better understand and evaluate the water resource tax reform policy in China, we investigated the effectiveness, function, and impact of the water resources tax policy pilot in China. We conducted survey and analysis on the implementation of a water resources tax in ten pilot provinces. We demonstrated that a water resources tax regards water resources reallocation and stakeholders' interest, which is in line with theory and empirical expectations. After empirical analysis, we concluded that China's water resources tax pilot reform is successful. Through tax incentives, water resources utilization efficiency has improved and water use structure has optimized. The critical success factors of the water resources tax in China include satisfying the reasonable interests of stakeholders, reasonably considering the taxation basis, endowing local governments with certain discretionary power, and strengthening inter-departmental cooperation.

The Chinese government has adopted a cautious and gradual promotion strategy in water resources taxation, and ten provinces were selected for pilot projects. After several years of a water resources tax pilot, experience has accumulated and some problems have been exposed, which must be summarized and improved. As a policy, the experience of the water resources tax in China showed some principles that must be carefully noticed. First, the affordability of different water users and enterprises should be needs to be carefully considered. "Equal transfer of tax for fee" is the first principle of the Tax-for-Fee reform. A water resources tax must insist the burden of urban public water supply enterprises, the burden of residents' daily water consumption, and the burden of industrial and agricultural water production all remain unchanged after the reform. Second, differential taxation for water resources must occur through the regulation and incentive effect of a water resource tax, which promotes the restriction of overexploitation of groundwater, promotes the rational use of surface water, and increases the use of unconventional water such as recycled water. Differential taxation occurs by levying high taxes, increasing the tax burden on groundwater mining in overexploited regions, increasing the tax burden on water used in special industries with high water consumption, and increasing the tax burden on water used beyond the quota. Third, developing specific policies based on local conditions is necessary. A variety of factors such as endowment of water resources, resources of water use, and economic development impact a water resources tax. Those impacts differ according to the considered policy purpose. Therefore, on the basis of a unified tax policy at the national level, it is appropriate to authorize local governments managing power such as to determine region-specific tax amounts, so as to encourage local government initiatives, and make policy more reasonable and suitable.

A sharp increase in water pollution and water crises will result in more challenges for developing countries. The results of this study might largely contribute toward making reasonable decisions related to the fields of water policy and water governance not only in China but in other developing countries as well. Some limitations exist in this study. Our results from the empirical analysis and estimations must be carefully considered because we have a small number of observations. In addition, it is necessary to conduct a comparative study using macro-level, cross-country data to identify whether the findings are generalizable to other developing countries and developed countries.

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