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Evaluation of Water Resources Tax Policy in China Pilot Areas Based on Three-Stage DEA Model

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Abstract

General Secretary Xi Jinping emphasized the policy of "water saving priority" and "two-handed efforts" in the 16-character water control policy, and the change of "fee" to "tax" for water resources is an important means and policy tool for China to implement them. According to relevant national work arrangements, water resource tax reform will be carried out nationwide. However, most of the current analysis of the policy effects of water resources taxation still remains focused in the actual observation of the reform practice, lacking scientific and effective analysis methods to compare policy performance of these pilot areas. This study is based on the principle of comprehensiveness, vertically grasping the top-down processes of the implementation of water resource tax policies, selecting documents released, capital investments, water withdrawal permitting management, and water metering monitoring as input Indicators. Meanwhile, based on the objectives of policy reform, taking water saving, water use structure adjustment and taxation as output indicators, horizontally comparing the implementation effects of water resource tax policies of 10 pilot regions from the perspective of input and output with the Three-Stage DEA Model in the form of digital efficiency. The findings reveal that the shift in the use of water resources from "fee" to "tax" is stable, and most pilot areas such as Beijing, Tianjin and Hebei still show high efficiency after excluding external environmental factors and random errors. It means that the inputs made by the local governments have achieved tangible and efficient outputs. However, there are also several pilot areas where the policy efficiency has not reached the best value, and the level of water-saving management needs to be improved to promote the implementation of the policy.

Keywords

Water Resources Tax, Policy Efficiency, Three-Stage DEA Model

1. Introduction

In order to strengthen the management of water resources protection and promote the conservation and rational use of water resources, the Ministry of Finance, the State Administration of Taxation and the Ministry of Water Resources jointly issued the "Interim Measures for the Pilot of Water Resources Tax Reform" on May 9, 2016, pioneering the pilot work of water resource tax in Hebei Province (Ministry of Finance, 2020a). One year later, the expected purpose of water resource tax was basically achieved. On December 1, 2017, the Ministry of Finance, the State Administration of Taxation, and the Ministry of Water Resources issued the "Interim Measures for Expanding the Pilot of Water Resources Tax Reform" to expand the scope of the pilot to Beijing, Tianjin, Shanxi, Inner Mongolia, Henan, Shandong, Sichuan, Shaanxi and Ningxia Province (Ministry of Finance, State Taxation Administration, 2020b).

According to relevant national work arrangements, water resource tax reform will be carried out nationwide. However, most of the current analyses of the policy effects of water resources taxation still stay in the actual observation of the reform practice in the pilot areas, and lacks scientific and effective analysis methods. How to scientifically evaluate the performance of the water resource tax policy in the pilot areas is crucial to the water resource tax reform work that will be fully launched at the national level. The specific pilot reform areas can be seen in **Figure 1**, which is drawn by the author with ARCGIS.

As a natural resource, water resources are closely related to human life and production. According to effectiveness and controllability, water resources are divided into narrow water resources and broad water resources. Water resources in a narrow sense are water sources that can be used by humans through engineering; water resources in abroad sense refer to water sources that are effective for social economic development and ecological environmental protection (Wang et al., 2004). The characteristics of water resources are complex and different from ordinary goods. It has limited exclusivity and competitiveness, depending on the specific situation. For example, water resources can be used as means of production for planting or industrial production activities, and as an output value. This part of water resources is competitive and exclusive, can be obtained from the market, and has commodity attributes (Li & Wu, 2007). Water resources also have external diseconomies in the process of development and utilization, that is, after the use of water resources, the amount of water decreases and the quality of the water deteriorates, which has a harmful impact on the ecological environment and has an impact on the use of other people. With

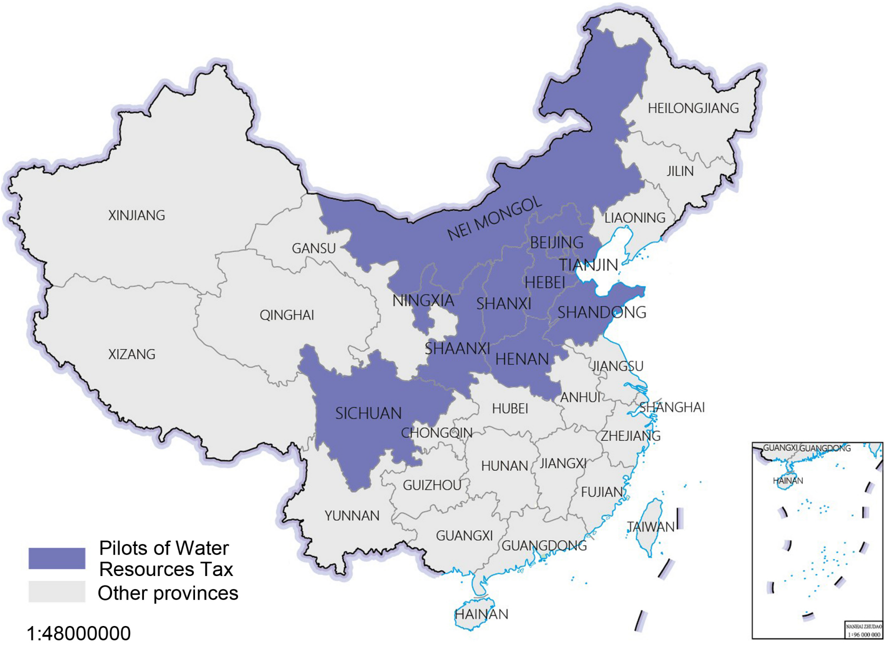

Figure 1. Pilot areas of water resources tax policy.

the rapid development of society, the utilization and protection of water resources gradually come into people's attention.

To study water resources, we must first clarify the ownership of resources. Barbier, Edward B. (Hyberg, 1990) proposed that the ownership of resources is reflected by resource ownership, which provides the basis for property rights in resource allocation. Under market economy conditions, the economic realization of resource ownership is accomplished through rents (Huang & Li, 2016). The Water resource fee is one of them. Merrett (1999) researched water withdrawal fees from the perspective of political economy, and believes that water withdrawal fees, as a form of water resource rent, are important economic tools for the government. Fang et al. (2000) analyzed the nature and composition of water resource fees based on Marx's land rent theory and labor value theory. They believe that the national ownership of water resources, the labor value of water resources and the scarcity of water resources should be taken into consideration when formulating water resource fee standards. When considering the connotation of the value of water resources, the value attributes of water resources can be evaluated from different angles, and water resource fees can be used as price levers and necessary administrative means to achieve a reasonable distribution of water resources in life, production and ecology (Gan et al., 2012). Yan et al. (2018) studied the capitalization of natural resources in terms of value form, calculated various values of natural resource capitalization through the classification and evolution of the revised Li Jinchang model, and obtained the specific formula of natural resource capitalization value accounting. Finally, they put forward the conditions for realizing the value of natural capitalization. However, it is impossible to achieve a reasonable resource utilization model only through the spontaneous regulation of the market and the self-constraint of economic entities. It is necessary to use taxation methods to force economic entities to pay attention to improving the efficiency of water resource use (Li & Ye, 2016).

Water resource tax policy is another important practice for the state to use taxation means to adjust resource allocation. Since the launch of the pilot work, the water resource tax has received widespread attention from all walks of life in the society, and discussions on the water resource tax have also been intense.

The water resource tax was born out of the "Pigou tax" policy proposed by the famous British environmental economist Pigou. The "Pigou tax" policy and the property rights theory advocated by Coase are called the two major policy camps to solve resource and environmental problems. In the field of water resources and water environment management, Coase's theorem is expressed as a water rights system and a water pollution rights system, and Pigou tax is mainly expressed as water resource taxes (fees), sewage charges (taxes),and so on (Lan, 2004). The collection of water resource taxes requires clear ownership of water resources. The property rights are clearly defined, which can clarify the responsibilities, rights and benefits of different stakeholders, reduce the externality and uncertainty of economic activities, and avoid the "tragedy of public places" (Wang, 2008). Wu Xue believes that in a society based on a market economy, to ensure the optimal use of natural resources, it is necessary to play a role as an economic tool. When the market fails, it must be supplemented by non-market mechanisms. According to the principle of "benefit beneficiaries", overuse of water resources and polluters should bear the costs of overuse and pollution of water resources, restrict the development of water resources and encourage the actions of users to promote the saving of water resources (Sun, 2016).

The purpose of this paper is to visualize the implementation effects of the water resource tax policy in the pilot areas and comparing the differences in the form of digital efficiency. The article begins by briefly reviewing some literature on water resource tax policy. The third part explains the model method, variable selection and data source. The fourth part uses the three-stage data fitting analysis model as the main analysis tool, based on the input-output perspective, the paper makes an empirical analysis of the water resource tax policy performance in 10 pilot regions. The fifth part discusses the implementation effect and the main problems of the policy combining with the survey situation, summary the transition situation of the water resource charging system to the taxation system, laying a research foundation for the country to fully push forward the water resource tax policy. Finally, we put forward some suggestions according to the empirical results.

2. Literature Review

Up to now, the pilot work of water resources tax reform has been carried out for more than three years, and various pilot areas have issued corresponding management measures, performing differentiated management models and tax rate policies according to local conditions. Taking Hebei as an example, the Hebei Local Taxation Bureau has gradually explored a tax collection and management model of "water conservancy approval, tax declaration, local tax collection, joint supervision, and information sharing", which has led to preliminary results in water resource tax collection and management (Wang et al., 2017). In order to meet the society's need to know the implementation status and effect of the water resources tax reform, many scholars conducted field investigations more than once, summarizing the exploration, innovation and implementation experience of water resources tax reform in the pilot areas. Yu et al. (2018) stated that water resource taxation has achieved obvious results in water saving and water resourcemanagement level improvement. In particular, a higher tax rate has been set for groundwater over-exploitation areas, and the purpose of saving and protecting water resources can be achieved through economic leverage. Peng (2018) focused on the study of the implementation of water resources taxes in the western region. He believed that the regional economic development in the western region was uneven, and the conditions of water resources and social tolerance were quite different. In the process of promoting water resource tax reform, some institutional issues should be fully studied and demonstrated. At the same time, some scholars pointed out the problems that need to be solved urgently in the reform process of water resource tax policy. For example, Ni et al. (2019) believe that the measurement of drainage needs to be further scientific and the measurement of water needs to be further intelligent. Chen & Wang (2018) proposed that China's current water resource tax pilot program weakened the regulation function of water resource utilization in the tax system rules and weakened the protection function of water resources in the taxation rules. They believe that the adjustment of water savings should be strengthened in the setting of factors: on the basis of the taxpayer's reasonable burden, the tax burden of water resources should be raised. There is no consensus on the effect of water tax reform. This is mainly because most scholars present their opinions based on research results, so the results are subjective. However, the evaluation of the performance of water resources tax policy cannot only rely on theoretical analysis and an experience summary; it needs to use quantitative analysis methods to scientifically evaluate its policy performance. Therefore, this paper tries to find a model that can accurately evaluate the effect of reform and digitize it, so as to reflect the effect and difference of reform in different regions more vividly.

The research methods of policy performance mainly include econometric methods, GE (Computable General Equilibrium), fuzzy comprehensive evaluation methods envelope analysis (DEA) methods, etc. Chen et al. (2020) used the spatial DubinModel to study the spatial impact mechanism of technological innovation policies on provincial innovation performance. Chen (2020) based on the three-stage DEA model of ecological environment supervision performance evaluation index system, made a comparative analysis of the ecological environment supervision of various regions in Hunan Province. In the research field related to water resources policy, Llop & Ponce-Alifonso (2012) used the CGE model to study the impact of water resource tax policies on the economic system of Catalonia in Spain. Ma & Kan (2020) used the fuzzy comprehensive evaluation method to objectively evaluate water-saving irrigation projects. Huiling Zhang (2019) used the empirical analysis of the DEA-Malmquist model to analyze the performance of farmland water conservancy facilities in Hunan Province. Ma et al. (2018) used the DEA-Malmquist model to study the spatial effect of technological progress and efficiency catch-up on agricultural water efficiency. Pan et al. (2020) analyzed the water use efficiency in Shandong Province between 2006 and 2015 using the Malmquist productivity index. According to the above, DEA method has its unique advantages in dealing with multi-index input and multi-index output, so it is used by many scholars who study water efficiency and water resources policy. On this basis, this study will apply the three-stage DEA model to eliminate the influence of external interference factors and make the results more accurate. In general, many current studies on water resource tax mostly stay in the theoretical stage, lacking the process of digital display of policy performance, so as to more accurately locate the problems and promote the reform process. Therefore, this study uses an optimized DEA model based on input-output index to try to analyze the reform efficiency and the impact on water use structure in pilot areas.

3. Methods and Materials

Data Envelopment Analysis (DEA) is a systematic analysis method for evaluating relative efficiency created by CHARNES and COOPER in 1978 (Chu, 2018). The basic principle is that the Decision Making Unit (DMU) has multiple inputs and multiple outputs, linearly programming these input and output indicators to obtain an efficient production frontier (outer envelope surface), and then comparing each DMU with this frontier relative efficiency. The DEA method defines the most efficient one among many DMUs as the convex production frontier, and the efficiency of other evaluated DMUs is compared with it. The DEA method is generally applicable in a widerange of situations and is close to the actual situation. The effectiveness of the DMU can be evaluated by a non-parametric linear combination estimation of actual data. Not only can the relative efficiency of the DMU be calculated, but also the root cause of insufficient efficiency (redundant input or insufficient output) and improvement goals can be identified, thereby providing a basis for the efficiency improvement of the DMU and providing more economic information for decision-makers (Wei, 2018). Therefore, the DEA method is widely used in the measurement of government public policy efficiency.

However, since the traditional DEA model cannot eliminate the influence of external interference factors on the efficiency results of each DMU, Fried et al. (2002) proposed a three-stage DEA model in 2002, trying to separate environmental factors from random errors. Three-stage DEA combines traditional DEA with the stochastic frontier analysis (SFA) method, uses SFA to strip environmental factors and random errors contained in the first DEA measurement results, and then uses DEA to perform efficiency measurement again. The resulting efficiency results can more accurately reflect the true efficiency of the DMU. At present, three-stage DEA has been widely used to evaluate various input-output efficiencies with external environmental impact.

3.1. Three-Stage DEA Model

According to whether the scale returns are variable, the DEA model can be divided into a CCR model with constant scale returns and a BCC model with variable scale returns. The BCC model is developed on the basis of the CCR model. It further decomposes the technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE). The relationship between these values is expressed as:

$$\text{SE} = \text{TE}/\text{PTE} \tag{1}$$

The DEA model can be divided into input-oriented (output oriented) and output-oriented (output oriented). Input-oriented means to minimize the input based on the established output quantity; output-oriented refers to maximizing output based on established inputs. Since this paper mainly studies the actual efficiency of water resource tax policy and whether it maximizes output, it is output-oriented.

The model is described as follows:

$$Max_{\theta,\lambda}\theta \tag{2}$$

$$\text{s.t. } \theta x_i - \sum\nolimits_{j=1}^{n} x_i \lambda_i - s^- \geq 0 \tag{3}$$

$$-y_i + \sum\nolimits_{j=1}^{n} y_j \lambda_j - S^+ \geq 0 \tag{4}$$

$$\sum\nolimits_{j=1}^{n} \lambda_j = 1 \tag{5}$$

$$\lambda_j \geq 0,\ S^-, S^+ \geq 0 \tag{6}$$

where y_i and x_i are the *i*th output and *i*th input of each DMU, respectively; *k*, *m*, and *n* represent the number of input variables, output variables, and DMUs, respectively. s^- and s^+ represent the input slack variable (insufficient input) and output slack variable (underproduction), respectively; θ represents technical efficiency of each DMU, it measures the distance between the DMU and the frontier of efficiency, the value range of θ is from 0 to 1, the closer to 1, the higher the efficiency. While $\theta = 1$ and $s^- = 0$, $s^+ = 0$, the DMU is on the frontier and is efficient; while $\theta < 1$, and at least one of s^- and s^+ is not equal to 0, it shows that the DMU is under the frontier and is inefficient. λ_j is constant vector to be estimated.

In the first stage, according to the characteristics and application scope of the

DEA model, the input-output BCC model was selected as the performance evaluation model to evaluate the effect of the water resource fee reform tax policy.

Since the input slack value calculated by DEA in the first stage is affected by the comprehensive effects of management inefficiency, environmental factors and random errors, it is impossible to accurately distinguish the effects of water resources fee reform tax policies in each pilot area, so it is necessary to enter the second stage.

The second stage decomposes the relaxation variables of the first stage by constructing a similar SFA model to eliminate the interference of environmental factors and statistical errors. The SFA model is constructed by using the input relaxation variable of each DMU as the dependent variable as follows:

$$s_{ij} = f^j\left(z_i, \beta^j\right) + v_{ij} + u_{ij} \tag{7}$$

where $i = 1, 2, \cdots, N$; $j = 1, 2, \cdots, P$; s_{ij} is the slack variable of the *j*th input of the *i*th DMU; $f^j\left(z_i, \beta^j\right)$ represents the influence of environmental variables on s_{ij}; v_{ij} is the random noise, following a normal distribution with a mean of 0; u_{ij} is the management inefficiency, following half normal distribution.

According to the results obtained by the SFA model, the input value of the DMU is adjusted. The adjustment formula is:

$$x'_{ij} = x_{ij} + \left[\max\left\{z_i \beta^j\right\} - z_i \beta^j\right] + \left[\max_i\left\{v_{ij}\right\} - v_{ij}\right] \tag{8}$$

where $i = 1, 2, \cdots, N$; $j = 1, 2, \cdots, P$; x_{ij} is the *j*th original input of the *i*th DMU; x'_{ij} is the adjusted input; $\left[\max\left\{z_i \beta^j\right\} - z_i \beta^j\right]$ is the adjustments to environment variables; and $\left[\max_i\left\{v_{ij}\right\} - v_{ij}\right]$ is the elimination of the random errors in statistical noise.

The third stage uses the input value adjusted in the second stage and substitutes it into the traditional BCC model to obtain the relative efficiency value without environmental factors and random errors. Therefore, the DMU efficiency obtained in the third stage can more accurately and objectively reflect the differences in the implementation effects of water resources tax policies in the pilot regions.

3.2. Input and Output Indicators

The water resource tax policy is an important part of the national water-saving action, and it is a major decision-making deployment made by the Party Central Committee and the State Council to solve the problem of China's water shortage. Therefore, the water-saving effect should be used as one of the main indicators of the performance evaluation of the water resource tax policy. This paper selects the water resources tax policy as the input indicator, and the related indicators of water saving, water use structure and taxation as the output indicators, as follows:

1) Input indicators. The implementation of water resource tax policies requires a lot of preliminary work, including water withdrawal permits, water me-

tering, collection and management methods, and state capital investment. Therefore, input indicators need to be considered in terms of legislation related to water resource tax reform, the issuance of policy documents, the installation of metering equipment, capital investment, and the issuance of water withdrawal permits. Since most regions suspend the collection of water resources and water for agriculture, the non-agricultural taxpayer online measurement control rate is used as a measurement indicator for water measurement; since there is no clear data on the capital investment for water resource fees and taxes, water-saving capital investment data is used as an indicator to measure capital investment.

2) Output indicators. Considering the impact of water resource tax policy on resources the economy, and the availability of data, this paper mainly selects four representative output indicators: water consumption per 10,000 yuan of GDP, ground water consumption, water consumption per capita, and water resource tax revenue as evaluation indicators of the output efficiency of water resource tax policy.

3) Environmental variable indicators. The selection of environmental variable indicators mainly considers the following aspects: first, the local water-saving management situation. One of the implementation objectives of the water resource tax policy is to give play to the economic lever of taxation to regulate the water consumption behavior of water users. "Saving water resources" and "adjusting the water use structure" are the important goal directions for implementing the water resource fee reform tax policy. The water-saving management construction in the pilot areas can reflect the local attention to water-saving construction. The higher the importance of water-saving, the more effective the implementation of the water resource fee reform tax policy, and the more effective the policy implementation; Second, the level of economic development. The level of economic development can reflect the overall level of urban development to a certain extent. The higher the level of economic development, the more standardized the system construction, the more favorable the policy implementation, and the more obvious the effect of policy implementation; third, the level of marketization. The level of marketization reflects the degree of freedom and efficiency of resource allocation. The higher the marketization level of a region, the higher the flexibility of enterprises, which means that the resistance to the implementation of policies is relatively large, and the implementation effect is more difficult to emerge.

3.3. Data

1) Description of Input-Output Indicator Data

This study constructs panel data for ten pilot regions from 2016 to 2022. Relevant data can be obtained by collating relevant water resource tax policy documents issued by the pilot areas; non-agricultural taxpayers' online measurement control rate, number of water withdrawal permits issued, water-saving capital investment, and water resource tax revenue data can be obtained through the annual report on water resources management issued by the Water Resources Management Center of the Ministry of Water Resources; the relevant data on water consumption per 10,000 yuan of GDP, groundwater consumption and water consumption per capita are from the official website of the Statistics. The specific input and output variables and the statistical description of each variable are shown in Table 1.

2) Description of Environmental Variable Index Data

Environmental variables include the following indicators: local water-saving management, economic development level, and marketization level. The relevant data on the local water-saving management situation comes from the annual report of water resources management of the Ministry of Water Resources, the level of economic development comes from the China Statistical Yearbook, the data of marketization level comes from the Marketization Index of China's Provinces: Neri Report 2018.Combined with the previous analysis, the specific definitions and descriptions of indicators are shown in Table 2.

4. Results

4.1. Stage 1: Traditional DEA Results

In this paper, the DEA-BCC model in the DEAP2.1 software is used to empirically

Table 1. Description of input-output variables of water resources tax policy performance evaluation.

Index	Variable	Number of observations	Average	Standard deviation	Maximum	Minimum
Input indicators	Related legislation and policy documents on water resource tax reform (copy)	70	11	7	29	5
	Non-agricultural taxpayer online measurement control rate (%)	70	94.87	3.28	99.42	90.58
	Water saving capital investment (ten thousand yuan)	70	139274.80	102205.75	311111.00	12902.00
	Number of water licenses issued (sets)	70	3845.90	2107.92	8285.00	441.00
Output indicators	Water consumption per 10,000 yuan of GDP (100 million cubic meters)	70	59.13	47.85	178.67	12.96
	Groundwater consumption (100 million cubic meters)	70	48.79	41.52	116.00	4.40
	Water resource tax revenue (100 million yuan)	70	19.03	8.72	32.53	3.27
	Water consumption per capita (100 million cubic meters)	70	354.32	260.84	966.42	181.75

Source: Author.

Table 2. Environmental variable index explanation table.

Variable	Indicator symbol	Indicator description
Local water-saving management	z1	Number of water-saving management institutions
The level of economic development	z2	per-capita GDP
Marketization level	z3	Marketization index

Source: Author.

analyze the input and output data of water resource tax policies in ten locations (**Table 3**).

From the perspective of comprehensive efficiency, the comprehensive efficiency of the seven pilot areas of Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Henan and Ningxia reached 1, indicating high policy performance. On the other hand, the comprehensive efficiency of Shandong, Sichuan and Shaanxi is relatively low compared to other pilot areas, especially in Shaanxi Province, which is far below the level of other areas. This is a manifestation of investment redundancy. From the perspective of overall efficiency, there are certain differences in the effectiveness of the implementation of water resource tax policies among the pilot regions, but in general, the average of the comprehensive efficiency of water resources tax policies in the ten pilot areas is close to 1, suggesting that the policy has achieved good results in the pilot phase.

From the perspective of pure technical efficiency, except Shandong Province, the other pilot areas' pure technical efficiencies are all reach the maximum, all on the frontier of pure technical efficiency. Although the pure technical efficiency of Shandong Province has not reached 1, it is close to the frontier. Overall, the average technical efficiency of the pilot areas reached 0.995, indicating that the water resource tax policy has exhibited high input allocation efficiency and has effectively utilized existing inputs.

From the perspective of scale efficiency, the difference in scale efficiency between the pilot regions is more consistent with the difference in comprehensive efficiency. It can be seen that the difference in the comprehensive efficiency of the water resources tax policy in the pilot regions is largely due to scale efficiency, if local government wants to improve comprehensive efficiency, scale efficiency needs to be valued. In theory, the three provinces of Shandong, Sichuan and Shaanxi should reduce policy input, but from a practical perspective, it should be considered from the perspective of maximizing output targets, and local government departments should increase policy output under a given total input.

4.2. Stage 2: SFA Regression Results

Take the slack variables of the input indicators of water resource tax policies of

Table 3. Average efficiency of 10 pilot regions from 2016 to 2022.

City	Comprehensive efficiency	Pure technical efficiency	Scale efficiency
Beijing	1.000	1.000	1.000
Tianjin	1.000	1.000	1.000
Hebei	1.000	1.000	1.000
Shanxi	1.000	1.000	1.000
Inner Mongolia	1.000	1.000	1.000
Shandong	0.932	0.950	0.980
Henan	1.000	1.000	1.000
Sichuan	0.943	1.000	0.943
Shaanxi	0.804	1.000	0.804
Ningxia	1.000	1.000	1.000
Average	**0.968**	**0.995**	**0.973**

Source: Author.

each pilot area obtained in the first stage as the explained variables, and take local water saving management, economic development level and marketization level as explanatory variables, performing SFA regression analysis with Frontier 4.1, to analyze the impact of three environmental variables on four relaxation variables. The results are shown in Table 4.

It can be seen from Table 4 that the γ values are close to 1, indicating that the estimated values of each parameter meet the requirements of the significance test, and it is necessary to strip off the influence of environmental variables and statistical errors. The regression coefficient represents the degree of influence of environmental variables on input variables. If the coefficient is positive, it means that the increase of environmental variables will increase the relaxation value of input indicators, resulting in an increase in input waste under constant output or a decrease in output under constant input, and vice versa. Take the influence of three environmental variables on the relaxation variable of water saving capital investment (x3) as an example, the regression coefficients of the three environmental variables all passed the 1% significance test. Among them, the regression coefficient of the marketization level (z3) to the x3 relaxation variable is positive, indicating that the higher the marketization level, the more likely it is to over-invest in water-saving funds; The local water-saving management situation (z1) and economic development level (z2) are negative for the regression coefficient of the x3 relaxation variable, indicating that the local government has increased its emphasis on water-saving management and accelerated regional economic development. The efficiency of implementation is conducive to reducing the redundant investment of government water-saving funds.

Table 4. SFA regression results of the efficiency of water resources tax policies.

	x1 relaxation variable	x2 relaxation variable	x3 relaxation variable	x4 relaxation variable
Constant	−2.20E−02***	−3.18E+00**	−8.06E+03***	−2.64E+03***
	(−12.96)	(−3.18)	(−8062.08)	(−2643.08)
z1	−3.01E−04**	1.85E−02**	−1.14E+02***	−3.72E+01***
	(−2.71)	(3.17)	(−113.52)	(−37.22)
z2	−1.22E−07***	−1.22E−05***	−1.44E−02***	−4.72E−03
	(−5.06)	(−9.87)	(−6.31)	(−0.63)
z3	4.01E−03***	4.54E−01***	1.13E+03***	3.70E+02***
	(11.28)	(4.88)	(1129.22)	(370.20)
σ^2	2.41E−02	4.95E+00	3.17E+07	3.40E+06
γ	0.99	0.99	0.99	0.99
likelihood	1.12E+01	−1.38E+01	−9.24E+01	−8.12E+01
LR	1.18E+01	7.45E+00	7.23E+00	7.30E+00

Note: which in parentheses are t test values, ** and *** indicating that they are significant at 5% and 1% significance levels, respectively. In the pilot process of water resource tax reform, the government levied taxes according to the principle of tax translation to reduce the burden on residents and enterprises, so the coefficient is relatively small. Source: Author.

4.3. Stage 3: Adjusted DEA Results

Using the input indicators and original output indicators adjusted in the second stage, recalculate the efficiency of implementing the water resource fee reform tax policy in the ten pilot areas. By observing the changes in efficiency values before and after the adjustment, it is possible to compare the improvement or reduction of the implementation efficiency of the water resources fee tax reform policy in the pilot areas.

It can be seen from Table 5 that the adjusted implementation efficiency of the water resource tax policy is different among different regions. Pilot areas with a policy efficiency of 1 before adjustment still have an efficiency of 1 after adjustment, indicating that the high efficiency level of water resources tax policies in these areas is not due to their good external environment, but the targeted work input of local governments. In the three pilot areas where the efficiency did not reach 1, after the adjustment of the input indicators, various efficiencies have changed.

After the adjustment, the comprehensive policy efficiency of Shandong Province increased from 0.932 to 0.94, which is a slight increase. The pure technical efficiency has also increased from 0.950 to 0.960, also slightly improved, however, the scale efficiency dropped from 0.980 to 0.979, indicating that the scale effect of Shandong Province was overestimated in the first stage, and the external

Table 5. The average adjusted efficiency of 10 pilot regions from 2016 to 2022.

City	Comprehensive efficiency		Pure technical efficiency		Scale efficiency	
	before	after	before	after	before	after
Beijing	1.000	1.000	1.000	1.000	1.000	1.000
Tianjin	1.000	1.000	1.000	1.000	1.000	1.000
Hebei	1.000	1.000	1.000	1.000	1.000	1.000
Shanxi	1.000	1.000	1.000	1.000	1.000	1.000
Inner Mongolia	1.000	1.000	1.000	1.000	1.000	1.000
Shandong	0.932	0.940	0.950	0.960	0.980	0.979
Henan	1.000	1.000	1.000	1.000	1.000	1.000
Sichuan	0.943	0.945	1.000	1.000	0.943	0.945
Shaanxi	0.804	0.802	1.000	1.000	0.804	0.802
Ningxia	1.000	1.000	1.000	1.000	1.000	1.000
Average	**0.968**	**0.969**	**0.995**	**0.996**	**0.973**	**0.973**

Source: Author.

environment promoted the improvement of policy scale efficiency. The comprehensive efficiency and scale efficiency of the policies in Sichuan Province have increased slightly, indicating that the efficiency of the policy in the first stage was underestimated due to the impact of the external environment. After excluding environmental factors and random errors, the comprehensive efficiency of policy in Shaanxi Province dropped from 0.804 to 0.802, which is the only area in all the pilot areas that declined, this shows that the comprehensive efficiency of policy in Shaanxi was overestimated by the external environment in the first stage, and the actual effect still has a certain gap with other pilot areas.

5. Discussion

Through the analysis of the three-stage DEA model, it can be considered that the implementation of water resources tax policies in most pilot areas such as Beijing, Tianjin and Hebei are better, and it still shows higher efficiency after excluding the external environment and random errors, which is consistent with most research. This suggests that the input made by the local government to implement the water resource tax policy has achieved a tangible and efficient output. Combined with the survey results of the region, it was found that through the reform of water resources tax, the society's awareness of water conservation has increased significantly. Especially for water users and special industries in groundwater over-exploitation areas, actively adjusting the water use structure, increasing water saving input, and the groundwater over-exploitation is gradually suppressing.

In addition, this study examines the change of water use structure. It is found that the reform has increased the tax gap between groundwater and surface water, the groundwater tax gap between over-exploitation areas and non-over-extraction areas, motivating enterprises to optimize their water use structure. Many enterprises began to adjust their water sources, adjusting the original groundwater sources to surface water. The overexploitation of groundwater was gradually reduced, promoting the use of water from the South-to-North Water Transfer Project, which effectively encouraged companies to increase the use of unconventional sleeping water such as reclaimed water. The water resource allocation was further optimized.

However, there are some pilot areas where the policy efficiency has not reached the highest value, indicating that there is still some redundancy in the investment. They can refer to the analysis results of the second stage to promote the effect of policy implementation by improving local water-saving management and economic development. In addition, from the survey of these areas, the water resources tax reform still has technical or operational problems such as unsound policies and obstacles to specific operations.

Through quantitative research, we can clearly compare the reform effect of each pilot region, and analyze whether the existing problems are mainly caused by scale efficiency or technical efficiency, which provides many guidance for the comprehensive implementation of water resource tax reform. For example, the decline of comprehensive efficiency in Shaanxi Province mainly comes from the decline of scale efficiency, and there is a phenomenon of high input and low output. In the follow-up policy implementation, it is necessary to change the extensive management mode and establish a systematic and refined management mechanism for fee and tax reform. To solve these problems, in addition to further exploration according to the actual situation of each province, it also requires the state to give certain authority and policy support from the aspects of reform and innovation of systems, mechanisms and systems. For example, local governments can create detailed and specific laws, regulations, policies, and implementation methods for specific issues in the region without violating the basic guidelines and policies of water resources tax reform. Alternatively, allow the local government to independently determine whether to set the tax amount for the coverage of the urban public pipe network or not, and to independently explore the measurement methods for drainage and so on.

6. Conclusion

This study takes the preliminary work of the implementation of water resource tax policies as input indicators, and takes water saving, water use structure adjustment and taxation as output indicators based on the objectives of policy reform, horizontally comparing the implementation effects of water resource tax policies of 10 pilot regions from the perspective of input and output with the three-stage DEA model in the form of digital efficiency, which laid a foundation for the expansion of water resource tax reform across the country. In the first stage, the comprehensive efficiency, pure technical efficiency and scale efficiency of the policy are calculated, and the SFA regression analysis is performed in the second stage to eliminate the external environment and random errors. After correction, the efficiency of the water resource tax policy in the third stage is obtained. The results show:

1) After excluding the external environment and random errors, the efficiency of the water resource tax policy in most pilot areas such as Beijing, Tianjin and Hebei still reached the highest value, indicating that the local government's investment in implementing the water resource tax policy is efficient.

2) The policy efficiency of several pilot areas has not reached the highest value, the investment is redundant, the management methods and levels need to be further improved and enhanced. The performance of water resources tax policies in Shandong and Sichuan Province is subject to the external environment. Shaanxi Province needs to pay more attention to solving the specific problems in policy operations, coordinating the division of responsibilities between the tax department and the water conservancy department, reducing input redundancies as much as possible.

3) Overall, the water resource tax policy in the ten pilot provinces performs well. A smooth transition was achieved, and the expected purpose of reform was generally achieved. It is recommended to improve the relevant policies in response to the existing problems, and once the conditions are ripe, it can be rolled out across the country.

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Conflicts of Interest

The authors declare no conflicts of interest.

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