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A Comprehensive Analysis of China's Water Resources Tax Reform

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Abstract: In response to the growing disparity between the supply and demand of water resources, the Chinese government has piloted a more binding and reformed water resources tax to realize the sustainable utilization of water resources. However, reasonable tax standards and their water-saving effects and economic benefits are important and worthy of attention. Therefore, in this study, we combine the virtual water theory with the price input–output model to discuss the impact of water resources taxation on the economy and its water-saving effects. The results show the following: (1) A water resources tax has a significant water-saving effect, and is predicted to save 33.12 billion cubic meters of virtual water. (2) Consumers' expected reductions in spending on food and tobacco manufacturing and agriculture are predicted to save more virtual water at a lower economic cost. (3) The collection of water resources taxes can actively and simultaneously guide water savings in terms of consumption and production. The water consumption of the construction industry is worthy of attention. The expected output value reduction accounts for 67.2% of the total output value reduction, and its water savings account for 96% of the total water savings. Other service sectors also have ample room to optimize the utilization of their water resources.

Keywords: water resources tax; water saving; economic development; virtual water; IO model

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1. Introduction

Water resources are the cornerstone of sustainable development, supporting all aspects of life globally [1]. However, chronic mismanagement and abuse have exacerbated water scarcity [2], posing a serious threat to people's basic right to safe and clean water [3]. China is one of the main countries in the world with inadequate water resources, with per capita water resources of only 2074.53 m^3 [4]. Moreover, with the rapid development of industrialization and urbanization, the demand for water resources is increasing [5,6]. Consequently, China is currently facing a serious problem with sustainable water use. In response to the growing challenge of unsustainable water supply and demand, the Chinese government has decided to replace the current water resources fee with a water resources fee to regulate water resources management. Through the price lever of mandatory fiscal and tax policies, water resources are rationally allocated and effectively utilized, thereby achieving sustainable water use.

The collection of the water resources tax in China started with Hebei Province, which served as a pilot in collecting the water resources tax in 2016 [7]. Subsequently, on 28 November 2017, the Implementation Measures for the Expansion of Water Resources Tax Reform Pilots expanded China's pilots for water resources tax reform to nine provinces, including Beijing, Tianjin, Shanxi, Inner Mongolia, Henan, Shandong, Sichuan, Shaanxi, and Ningxia [8]. Thus far, the pilot area includes a total of 10 provinces. The "Law of the People's Republic of China on Resources Tax", promulgated on 26 August 2019, and implemented on 1 September 2020, clearly states that the water resources tax should be levied on units and individuals who use surface water or groundwater [9]. As shown in Figure 1, the

pilot provinces chosen for the introduction of the water resources tax are distributed across the eastern, central, and western regions, characterized by different levels of economic development, water resources availability, and types of water intake; this essentially reflects the situation in other parts of the country. Through the pilot program, we can accumulate experience in preparation for comprehensive reform.

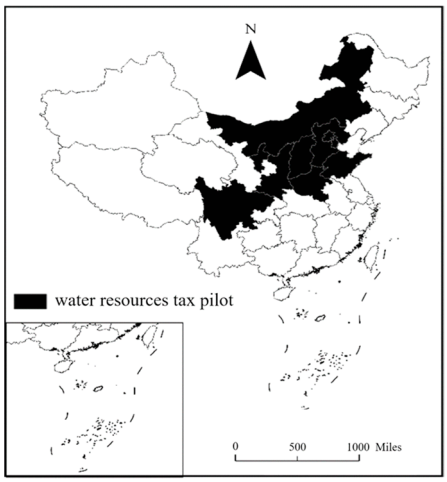


Figure 1. The pilot provinces of the water resources tax in China.

Water resources tax reform is an essential institutional innovation [10]. In this reform, the determination of water resources tax standards is a fundamental and core task. According to economic theory, taxation itself has a profound impact on the behavior of economic agents, and it is an economic means with a relatively noticeable effect [11]. Therefore, the amount of the tax is particularly critical. Too low a water resources tax rate cannot suppress water resource waste and high water consumption, and it loses its leverage to regulate water use and encourage conservation [12,13]. On the contrary, if the tax rate is too high, it will seriously increase the water cost burden to residents and enterprises, especially intensifying the burden of farmers' irrigation costs, which are not conducive to the sustainable development of the economy [14].

Research on the water resources tax standards generally analyzes the effect of water pricing policies. Since the water supply company must maintain the same profit level, any changes to the water resources tax standards will transfer to the water price by the same extent. In other words, an increase in the tax will ultimately be borne by the water users through increased water prices. Therefore, the research results regarding the effects of water pricing policies are an essential reference to analyze the effects of a water resources tax. Realizing water-saving effects through water pricing policies requires the price of water to rise to a "threshold" level, to a point where increasing its price can restrain the demand for it by users [15]. On this basis, water price reform can significantly achieve the goal of water conservation. Tiwari and Dinar (2002) found that water pricing policy reform reduced water consumption in Israel by 50% [16]. Water resources tax reform reduces water waste, improves the utilization efficiency of water resources, and achieves the goal of saving water. If the collection of a water resources tax is mandated, it has a significant impact on the water consumption behavior of users. For example, Fan et al. (2019) and Li et al. (2019) analyzed the effects of water resources tax reform. They pointed out that water resources tax reform forced enterprises to adjust their water use structure, accelerated technological innovation and industrial transformation and upgrading, and improved the efficiency of water resources utilization [17,18].

When studying water pricing policies, it is necessary to consider the interrelated effects of industries. Changes in water resources tax standards not only affect the production costs of a single industry, but trigger the changes in all costs in the industrial chain through mutual consumption relationships among industries. Moreover, input–output analysis

(IOA) uses inter-sectoral currency transaction data to explain the inter-sectoral interdependencies [19]. Therefore, it is appropriate to use the IOA method to simulate water pricing policies [20,21]. For example, Llop (2008), when studying the economic impact of alternative water policies on the Spanish production system, found that the taxation of water use in various sectors significantly reduced intermediate water use and increased production and consumer prices [22]. Ni et al. (2013) calculated the impact of water price adjustments in Beijing based on the input–output price impact model. They concluded that an increase in water prices has a weaker effect on non-water supply sectors [23]. Hristov (2016) found that in order to alleviate the pressure on water resources in Macedonia, it is necessary to change production technology and specialization, reduce the use of water-intensive products, and expand the existing water pricing policy to cover economic, social, and environmental aspects [24].

Most of the above scholars have studied the reasonable standards of water prices and their economic impact through simulations of water pricing policies. However, they did not conduct in-depth research on the effects of conserving water resources. Currently, most evaluations of the water-saving effects of a water resources tax directly account for reductions in water resources consumption, while ignoring the changes in indirect water consumption in the industrial chain due to these changes in water resources consumption. Therefore, in order to comprehensively evaluate the water-saving effect of a water resources tax, this article introduces the concept of virtual water and adopts an input–output analysis method that is highly compatible with virtual water theory. Virtual water was first proposed by Allan, and refers to the total amount of water resources required to produce products and services [25]. It is calculated from the entire process of the production chain. The amount of virtual water includes not only the water consumption of the industrial sector itself but also the water consumption of the entire process of intermediate product consumption [26–28]. Therefore, virtual water can not only reflect the impact of industrial water consumption due to changes in water prices but also takes into account the impacts of changes in the price of intermediate products from upstream industries caused by changes in water prices.

In summary, this research combines the virtual water theory with the price input–output model to construct an input–output model of price changes from an additional water resources tax and analyzes the impact of water resources taxation policy on the output value of various national economic sectors. Then, based on the virtual water theory, the water-saving benefits of the virtual water resources taxation policy are analyzed from the perspectives of producers and consumers. Therefore, this research mainly discusses the following three questions: firstly, how the water pricing policy affects the economy; secondly, what the effect of water pricing policy is on water resources conservation; and thirdly, how the water pricing policy guides the behavior of consumers and producers.

2. Method and Data

2.1. Price Input–Output Model

The IOA method was proposed by Leontief, and can reflect the direct and indirect relations between the production activities of various industrial sectors in a national economic system. According to the IOA method and the input–output table, the production activities of a complete economic system have the following balance:

$$\begin{aligned} x_1 &= z_{11} + z_{12} + z_{13} + \ldots + z_{1n} + v_1 \\ x_2 &= z_{21} + z_{22} + z_{23} + \ldots + z_{2n} + v_2 \\ &\vdots \\ x_n &= z_{n1} + z_{n2} + z_{n3} + \ldots + z_{nn} + v_n \end{aligned} \tag{1}$$

Equation (1) can be transformed into a matrix form, as follows:

$$x_i = \sum_{j=1}^{n} z_{ij} + v_i \tag{2}$$

where x_i represents the total output of sector i; z_{ij} represents the intermediate input provided to sector j by sector i; and v_i represents the column vector of the added value of the sector i.

The direct input coefficient $a_{ij} = z_{ij}/x_j$, the production unit product for the j sector, requires the direct input of the i sector to it; thus, Formula (2) can be rewritten as follows:

$$x_i = \sum_{j=1}^{n} a_{ij}x_j + v_i \tag{3}$$

Therefore, for the entire input–output table, there is the following matrix relationship:

$$X = A^T X + V \tag{4}$$

where A is the direct consumption coefficient matrix, X represents the column vector of the output value of each sector, and V represents the column vector of the added value of each sector.

The output value X can be expressed as the following product of price P and output Q of the corresponding product:

$$X = P * Q \tag{5}$$

Since the production sector will consider all factors such as technology, production, and management when dealing with price changes [29], we assumed that the production structure of the sector does not change. That is, when P changes, Q does not change. To calculate the change in P conveniently, let $Q = I$, where I is a matrix whose elements are all 1. Therefore, Equation (4) can be rewritten as follows:

$$P = A^T P + V \tag{6}$$

Equation (6) is the price input–output model.

2.2. Price Impact Model

Determining the impact of a water resources tax on economic sectors is a very complicated process [30]. However, as an important part of a system of paid water resources use, a water resources tax essentially affects water use behavior by adding a cost as leverage. Due to the interconnection between different economic sectors, the most direct and rapid impact of the implementation of the water resources tax policy is reflected in the products of the water supply sector in the production sector [30]. Therefore, to simplify the implementation process of the water resources tax and highlight the price leverage of the water resources tax, we assumed that the collection of a water resources tax only affects the products of the water supply sector in the production sector, and further affects the product prices of other sectors through interdependencies among sectors. Therefore, we used a single product price change impact model through a block matrix in this study.

If P_n changes, then we obtain the following:

$$\overline{P} = \begin{bmatrix} \overline{P_{n-1}} \\ P_n \end{bmatrix}; \overline{A} = \begin{bmatrix} \overline{A_{n-1}} & U \\ H & a_{nn} \end{bmatrix}; \overline{V} = \begin{bmatrix} \overline{V_{n-1}} \\ V_n \end{bmatrix}$$

where $\overline{P_{n-1}} = (P_1, P_2, \ldots, P_{n-1})^T$, $U = (a_{1n}, a_{2n}, \ldots, a_{n-1,n})^T$, and $H = (a_{n1}, a_{n2}, \ldots, a_{n,n-1})$.

Therefore, Equation (6) can be rewritten as follows:

$$\begin{bmatrix} \overline{P_{n-1}} \\ P_n \end{bmatrix} = \begin{bmatrix} \overline{A_{n-1}} & U \\ H & a_{nn} \end{bmatrix}^T \begin{bmatrix} \overline{P_{n-1}} \\ P_n \end{bmatrix} + \begin{bmatrix} \overline{V_{n-1}} \\ V_n \end{bmatrix} \tag{7}$$

A further calculation shows the following:

$$\overline{P_{n-1}} = \overline{A_{n-1}}^T \cdot \overline{P_{n-1}} + H^T \cdot P_n + \overline{V_{n-1}} \tag{8}$$

$$\overline{P_{n-1}} = (I - \overline{A_{n-1}}^T)^{-1} H^T \cdot P_n + (I - \overline{A_{n-1}}^T)^{-1} \overline{V_{n-1}} \tag{9}$$

From Equation (7), we can observe that, when P_n changes, the change in $\overline{P_{n-1}}$ is the following:

$$\Delta\overline{P_{n-1}} = (I - \overline{A_{n-1}}^T)^{-1} H \cdot \Delta P_n \tag{10}$$

The complete input coefficient of the input–output model is $(I - A)^{-1} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ & & \vdots & \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix}$, therefore, $(I - \overline{A_{n-1}}^T)^{-1} = \begin{bmatrix} b_{11} & b_{21} & \dots & b_{n-1,1} \\ b_{12} & b_{22} & \dots & b_{n-1,2} \\ & & \vdots & \\ b_{1,n-1} & b_{2,n-1} & \dots & b_{n-1,n-1} \end{bmatrix}$.

Therefore, Equation (10) can be rewritten as follows:

$$\begin{bmatrix} \Delta P_1 \\ \Delta P_2 \\ \vdots \\ \Delta P_{n-1} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{21} & \dots & b_{n-1,1} \\ b_{12} & b_{22} & \dots & b_{n-1,2} \\ & & \vdots & \\ b_{1,n-1} & b_{2,n-1} & \dots & b_{n-1,n-1} \end{bmatrix} \begin{bmatrix} a_{n1} \\ a_{n2} \\ \vdots \\ a_{n,n-1} \end{bmatrix} \Delta P_n = \begin{bmatrix} b_{n1} \\ b_{n2} \\ \vdots \\ b_{n,n-1} \end{bmatrix} b_{nn}^{-1} \cdot \Delta P_n \tag{11}$$

Equation (11) is the price impact model of a single price change.

2.3. Output Impact and Virtual Water Change Model

Since the prices of products in each sector change, the costs also change, resulting in changes in unit output income for each sector [31]. The change in income per unit output should be equal to the change in income minus the change in cost. Equation (12) expresses this relationship.

$$\overline{\Delta X_i} = \Delta R_i - \Delta C_i \tag{12}$$

where $\Delta R_i = \Delta P_i \cdot \sum_{j=1}^{n} A_{ij}$, and $\Delta C = \Delta P^T A$.

As a result, the changes in the revenue of the total output value of each sector are as follows:

$$\Delta TOP_i = \overline{\Delta X_i} X_i \tag{13}$$

The complete input coefficient for water resource expansion can be expressed as follows:

$$L = D(I - A)^{-1} \tag{14}$$

where $D = (d_1, d_2, d_3, \dots, d_n)$, $d_i = \frac{w_i}{x_i}$, w_i is the direct water consumption of the sector i, and x_i is the total output value of sector i.

The effect of a water pricing policy on virtual water savings can be divided into two cases. The first is from the perspective of consumers. Due to the change in product income, if the manufacturer transfers the change in income to the consumer by adjusting the product price, the tax cost is passed onto consumers. However, since the elasticity of demand for all products is not zero, the change in the final consumption output value should be equal to the expected consumption change of consumers, as shown in Equation (15).

$$\Delta E_i = \Delta F_i = \overline{\Delta X_i} F_i \tag{15}$$

Since L_i represents the virtual water consumption in unit output, the change in virtual water driven by final consumption is as follows:

$$\Delta VWF_i = L_i \Delta E_i = L_i \overline{\Delta X_i} F_i \quad (16)$$

The second case is from the perspective of producers. If the production sector keeps the production income of current products unchanged, it needs to actively adjust the production structure, as shown in Equation (17).

$$\overline{\Delta R} - \overline{\Delta C} = 0 \quad (17)$$

From the perspective of producers, the specific adjustment ratio of their production structure cannot be directly measured using mathematical formulas; however, after adjusting the production structure, the adjustment of the unit output value of the sector should be equal to the change in the unit output value income. Therefore, this research shows this change in production structure through Formula (18), as follows:

$$\overline{\Delta AX_i} = \overline{\Delta X_i} \quad (18)$$

Therefore, the expected change in the output value of each sector due to an adjustment of industrial structure is shown in Equation (19), as follows:

$$\Delta ATOP_i = \overline{\Delta AX_i} X_i = \overline{\Delta X_i} X_i = \Delta TOP_i \quad (19)$$

The change in virtual water caused by the change in the output value of each sector is shown in Equation (20), as follows:

$$\Delta VWP_i = L_i \Delta ATOP_i = L_i \overline{\Delta X_i} X_i \quad (20)$$

2.4. Data

The input–output data of this study refer to the 2017 China Input–Output Table [32], which is a critical accounting system. China publishes input–output data every five years, and the 2017 China Input–Output Table shows China's most recent input–output data. It not only shows the total output of each industrial sector but also describes in more detail where this output flows, such as the intermediate products of other industries, water exports, and final consumption. Therefore, input–output tables are beneficial for this study to analyze the impact of water resources tax policies on the economy, as well as their effects on water savings. To ensure the homogeneity of economic activities and consider the availability of water data across various sectors in China, 149 sectors in the table were consolidated into 44 sectors according to the national standards of China's national economic industry classification [33]. The names and abbreviations of these sectors after consolidation are shown in Table 1. The water consumption data of each sector come from the *China Statistical Yearbook 2018* [4]. Since the water consumption data of the industrial sector are not subdivided into each sector, we used the indirect method to obtain the water consumption data of each sector. We allocated the water consumption data of the industrial sector to each subdivided sector according to a certain proportion [34,35]. Since the input–output model is constructed using linear equations, the calculation results show a linear change trend. Thus, we only need to set a water price change amount in advance. We analyzed the hypothetical scenario of a 10% increase in water price, and provided a reference for the impact caused by other changes in water price. The process of this analysis is shown in Figure 2.

Table 1. Abbreviations of 44 sectors.

No.	Sector	Abbreviation
1	Agricultural, Forestry, Animal Husbandry and Fishery products and services	AFAHF
2	Mining and Washing of Coal	MWC
3	Extraction of Petroleum and Natural Gas	EPNG
4	Mining and Processing of Metal Ores	MPMO
5	Mining and Processing of Non-Metal Ores	MPNMO
6	Manufacture of Foods and Tobacco	MFT
7	Manufacture of Textile, Wearing Apparel and Accessories	MTWAA
8	Manufacture of Leather, Fur, Feather and Related Products and Footwear	MLFFRPF
9	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm and Straw Products	PTMWBRPSP
10	Manufacture of Paper and Paper Products	MPPP
11	Processing of Petroleum, Coal and Other Fuels	PPCOF
12	Manufacture of Chemical Products	MCP
13	Manufacture of Non-Metallic Mineral Products	MNMMP
14	Smelting and Pressing of Metals	SPM
15	Manufacture of Metal Products	MMP
16	Manufacture of General Purpose Machinery	MGPM
17	Manufacture of Special Purpose Machinery	MSPM
18	Manufacture of Transportation Equipment	MTE
19	Manufacture of Electrical Machinery and Apparatus	MEMA
20	Manufacture of Computers	MCOMP
21	Manufacture of Communication	MCOMM
22	Manufacture of Other Electronic Equipment	MOEE
23	Manufacture of Measuring Instruments and Machinery	MMIM
24	Other Manufacture	OM
25	Utilization of Waste Resources	UWR
26	Repair Service of Metal Products, Machinery and Equipment	RSMPME
27	Production and Supply of Electric Power and Heat Power	PSEPHP
28	Production and Supply of Gas	PSG
29	Production and Supply of Water	PSW
30	Construction	CONS
31	Wholesale and Retail	WR
32	Transportation, Storage and Post	TSP
33	Hotels and Catering Services	HCS
34	Information Transmission, Software and Information Technology Services	ITSITS
35	Financial Services	FS
36	Housing	HOUS
37	Leasing and Business Services	LBS
38	Scientific Research, Technical Services	SRTS
39	Water Conservancy, Environment and Public Facilities Management	WCEPFM
40	Residential Services, Repairs and Other Services	RSROS
41	Education	EDU
42	Health and Social Work	HSW
43	Culture, Sports and Entertainment	CSE
44	Social Organizations	SO

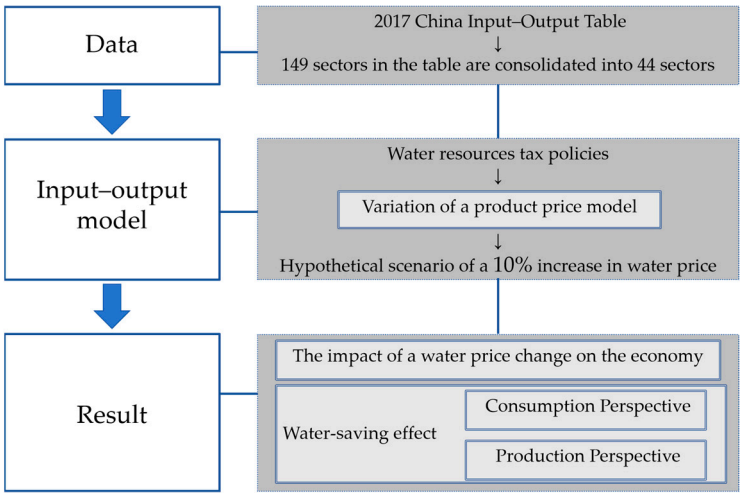


Figure 2. The flow chart of the study.

3. Results

3.1. The Impact of a Water Price Change on the Economy

In the case of a 10% increase in water prices, the overall impacts of the water pricing policy on various sectors are shown in Table 2. Among them, the effects of the water pricing policy on product prices and the total output value of each sector are shown in Figure 3.

Table 2. The impact of a 10% increase in water prices on the prices of various sectors.

Sector	ΔP	Rank	ΔTOP (ΔATOP)	Rank	ΔF	Rank	ΔVWF	Rank	ΔVWP	Rank
AFAHF	0.23%	24	−1.678	−18	−0.514	−20	−0.0429	−4	−0.07587	−10
MWC	0.08%	36	0.089	5	0.001	6	0.0000	4	0.00130	4
EPNG	0.06%	39	0.673	3	0.019	3	0.0000	3	0.00260	3
MPMO	0.05%	40	0.240	4	0.002	5	0.0000	6	0.00066	5
MPNMO	0.06%	38	0.023	7	0.000	8	0.0000	7	0.00009	6
MFT	0.99%	4	−6.068	−8	−4.122	−7	−0.0538	−2	−0.07487	−11
MTWAA	0.19%	29	−0.324	−30	−0.083	−30	−0.0012	−24	−0.02647	−20
MLFFRPF	0.22%	25	−2.209	−15	−1.512	−12	−0.0115	−8	−0.09857	−8
PTMWBRPSP	0.15%	32	−0.514	−26	−0.405	−21	−0.0144	−7	−0.04752	−14
MPPP	0.31%	18	−0.463	−27	−0.288	−26	−0.0037	−15	−0.00691	−29
PPCOF	0.19%	30	−0.336	−29	−0.044	−31	−0.0001	−33	−0.00350	−30
MCP	1.01%	3	−0.759	−25	−0.328	−24	−0.0063	−13	−0.01825	−21
MNMMP	0.48%	8	−0.181	−32	−0.020	−33	−0.0001	−32	−0.00120	−32
SPM	0.61%	6	−0.101	−33	−0.028	−32	−0.0001	−31	−0.00734	−27
MMP	0.25%	22	−1.841	−17	−0.355	−23	−0.0009	−27	−0.04653	−15
MGPM	0.29%	19	−0.915	−24	−0.396	−22	−0.0010	−25	−0.00707	−28
MSPM	0.22%	26	−1.204	−23	−0.793	−17	−0.0017	−22	−0.00842	−25
MTE	0.47%	9	−6.282	−7	−6.033	−6	−0.0377	−5	−0.16017	−4
MEMA	0.40%	12	−1.402	−22	−0.755	−18	−0.0026	−18	−0.00996	−24
MCOMP	0.13%	34	−1.433	−21	−0.989	−15	−0.0009	−26	−0.01363	−22
MCOMM	0.16%	31	−2.634	−12	−2.223	−11	−0.0025	−19	−0.03010	−19
MOEE	0.34%	17	3.178	2	0.617	2	0.0015	2	0.05988	2
MMIM	0.06%	37	0.007	8	0.003	4	0.0000	5	0.00003	8
OM	0.03%	42	−0.032	−35	−0.010	−35	0.0000	−34	−0.00024	−34
UWR	0.04%	41	0.051	6	0.001	7	0.0000	8	0.00009	7
RSMPME	0.01%	44	−0.003	−36	−0.001	−36	0.0000	−36	0.00000	−36
PSEPHP	0.60%	7	−2.073	−16	−0.129	−29	−0.0003	−30	−0.04510	−16

Table 2. *Cont.*

Sector	ΔP	Rank	ΔTOP (ΔATOP)	Rank	ΔF	Rank	ΔVWF	Rank	ΔVWP	Rank
PSG	0.03%	43	−0.053	−34	−0.018	−34	0.0000	−35	−0.00010	−35
PSW	10.00%	1	13.470	1	5.499	1	0.0257	1	0.62928	1
CONS	1.85%	2	−179.147	−1	−179.107	−1	−5.7489	−1	−31.78946	−1
WR	0.39%	13	−7.904	−5	−2.796	−9	−0.0062	−14	−0.08938	−9
TSP	0.44%	10	−2.463	−13	−0.721	−19	−0.0030	−16	−0.03292	−17
HCS	0.61%	5	−4.047	−9	−2.289	−10	−0.0101	−9	−0.13434	−6
ITSITS	0.21%	27	−1.608	−20	−1.235	−14	−0.0021	−20	−0.00841	−26
FS	0.42%	11	−3.373	−10	−0.927	−16	−0.0027	−17	−0.05706	−13
HOUS	0.25%	21	−11.519	−3	−6.775	−4	−0.0087	−10	−0.14770	−5
LBS	0.36%	15	−2.210	−14	−0.278	−27	−0.0013	−23	−0.10001	−7
SRTS	0.34%	16	−3.133	−11	−3.017	−8	−0.0078	−11	−0.03020	−18
WCEPFM	0.11%	35	−0.381	−28	−0.312	−25	−0.0004	−28	−0.00214	−31
RSROS	0.23%	23	−1.620	−19	−1.254	−13	−0.0018	−21	−0.01127	−23
EDU	0.19%	28	−6.679	−6	−6.377	−5	−0.0068	−12	−0.07073	−12
HSW	0.26%	20	−10.053	−4	−9.890	−3	−0.0199	−6	−0.18257	−3
CSE	0.14%	33	−0.240	−31	−0.194	−28	−0.0003	−29	−0.00072	−33
SO	0.38%	14	−19.546	−2	−18.866	−2	−0.0468	−3	−0.47668	−2
Total			−266.697		−246.942		−6.021		−33.121	

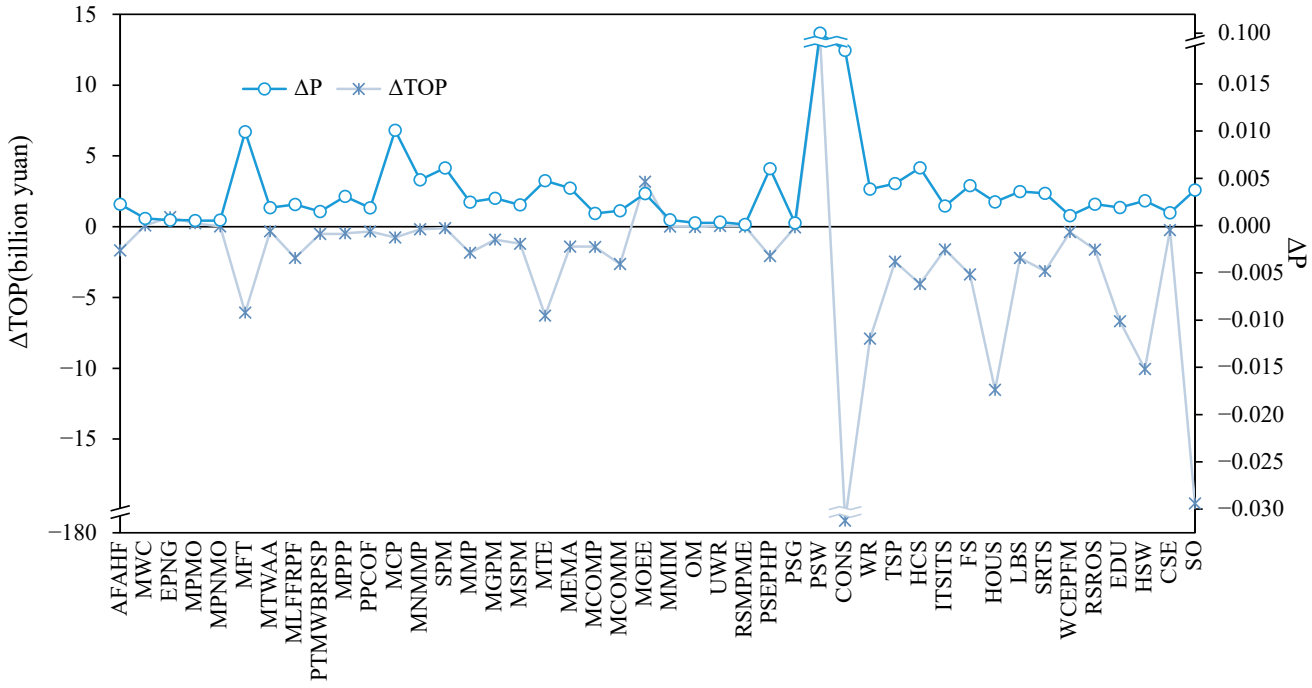


Figure 3. Product price and total output value change in each sector.

An increase in the water price increases the cost of using water, which has a significant impact on the production of water-intensive products. In Figure 1, it can be seen that the change in the output value and price of each sector is the opposite. It shows that implementing a water pricing policy generally increases the production costs for each sector. Under the influence of a water pricing policy, the price of products in some sectors significantly changes. However, the output values do not change much for the manufacture of non-metallic mineral products (MNMMP), the manufacture of metal products (MMP), and the smelting and pressing of metals (SPM). In terms of water resources utilization efficiency, the input–output structure of these sectors is relatively reasonable and remains relatively unaffected by the water pricing policy. On the contrary, the output value has a significant impact on other sectors when the prices of products change a little, such as

housing (HOUS), health and social work (HSW), and social organization (SO), which are mostly public service sectors, being significantly affected by water pricing policies.

Generally speaking, the increase in water price has little impact on the prices of various sectors. In Table 2, it can be observed that in addition to the water supply sector, the sector with the most significant price change is the construction (CONS) sector, with a price increase of 1.85%, followed by the manufacture of chemical products (MCP), the manufacture of foods and tobacco (MFT), and the hotels and catering services (HCS) sectors. Most of the products and services in these sectors are water-intensive, which are significantly impacted by a change in the price of water, indirectly bearing more costs caused by a water price increase. The prices of products in most other sectors rise by less than 0.5%.

A water resources tax policy is a tax policy that has a restraining effect on social and economic development. Only from the perspective of economic growth is an increase in water price not conducive to economic development. It can be seen from Table 2 that the water price increased by 10%, which reduced the total industrial output value by CNY 266.697 billion. The change in the total output value of each sector is different. The total output value of eight sectors increased, such as the production and supply of water (PSW), the manufacture of other electronic equipment (MOEE), and the extraction of petroleum and natural gas (EPNG). In contrast, the rest of the sectors decreased. The sector with the most significant reduction in total output value was the construction sector, which was CNY 179.147 billion, accounting for 67.2% of the decrease in total economic output value.

3.2. Water-Saving Effects Based on the Consumption Perspective

When the water price is increased by 10%, the production sector ultimately transfers the income change in products to consumers through the price. In this scenario, the expected expenditure change in consumers and the corresponding virtual water volume change are shown in Figure 4.

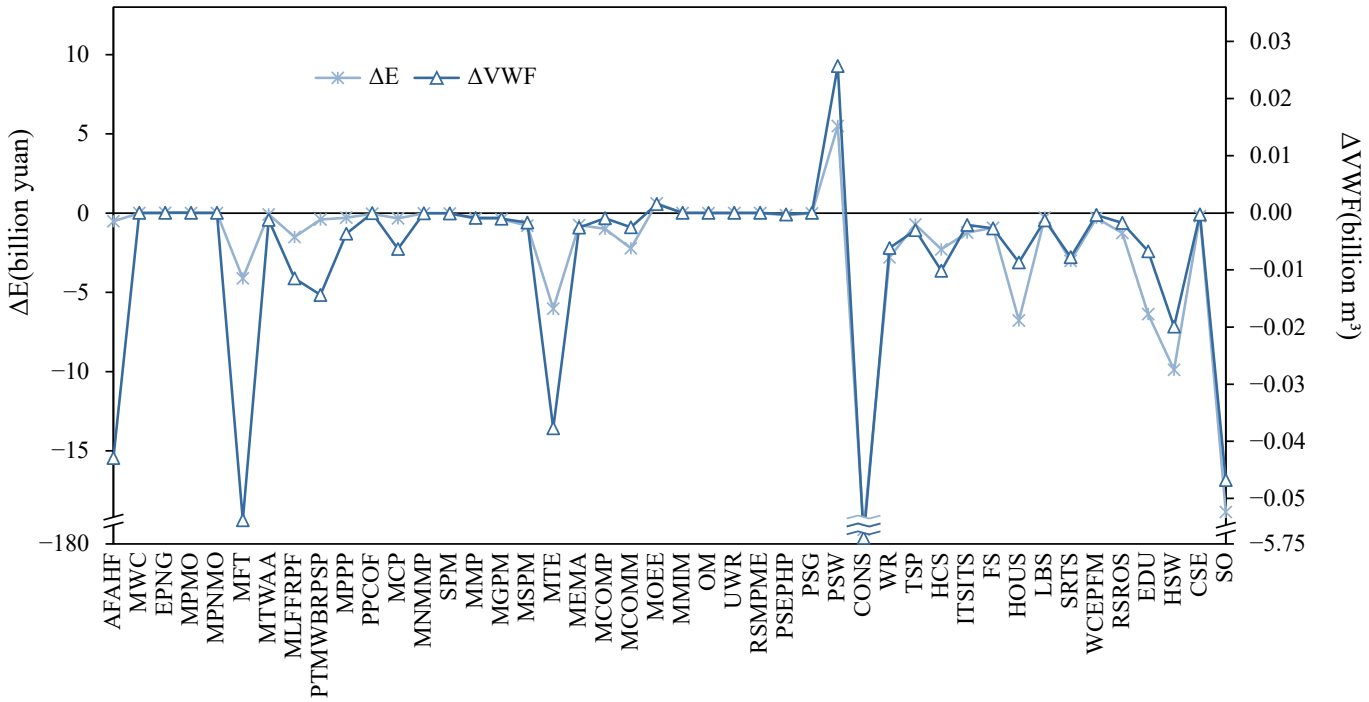


Figure 4. Changes in consumer expectations and virtual water volume.

It can be seen from Figure 4 that the changing trend in consumer's expected expenditure is the same as that of the virtual water volume. For products in some sectors, consumers expect to spend less, but the impact on virtual water saving is minimal, such as the education (EDU) and housing (HOUS) sectors. Reducing the consumption of products in these sectors has an insignificant effect on saving water. However, with the significant loss of economic benefits, from the perspective of comprehensive benefits, the effect of saving water is not ideal. For products in other sectors, consumers expect to spend less, but this has a significant impact on virtual water saving, such as on the manufacture of foods and tobacco (MFT) and agricultural, forestry, animal husbandry and fishery products and services (AFAHF) sectors. These sectors produce water-intensive products; thus, reducing the consumption of these sectors is conducive to water conservation.

The rise in water prices reduced the expected consumer spending. It can be seen from Table 2 that consumers reduced their expenditure by a total of CNY 246.94 billion. The construction product sector was expected to exhibit the greatest reduction, decreasing by CNY 179.11 billion, accounting for 72.5% of the total expected reduction in expenditure. Moreover, consumers' expected spending on social service products also reduced in sectors such as social organizations (SO) and health and social work (HSW).

Increasing water prices helps guide consumers to save virtual water. It can be seen from Table 2 that the total amount of virtual water saved by reducing consumption is 6.02 billion m^3. Moreover, the sector that saves the most virtual water is the construction sector, at 5.75 billion m^3, accounting for 95.5% of the total virtual water saved. In addition, consumers' expected consumption reductions in products in the manufacture of foods and tobacco (MFT) and agricultural, forestry, animal husbandry and fishery products and services (AFAHF) sectors can also lead to more savings in virtual water.

From the perspective of consumers, the measures of increasing water prices by 10% reduce the expected expenditure of residents affecting the total output value, which is not conducive to economic development. At the same time, through reducing the consumption of products, the consumption of water resources is indirectly saved, and the purpose of water saving is achieved. In addition, the reduction in the consumption of construction products saves more virtual water but greatly affects economic development. Moreover, reductions in the consumption of food, tobacco, and agricultural products have little impact on the economy but save more virtual water. From the perspective of economic benefits, we should improve the efficiency of water resources utilization in these sectors and improve the value of water resources utilization.

3.3. Water-Saving Effects Based on the Production Perspective

Under the condition that the water price is increased by 10% and the production sectors adjust their production structure to ensure their current income remains unchanged, the expected changes in the output value of each sector and the resulting virtual water volume changes are shown in Figure 5.

In Figure 5, the expected change in the output value of each sector is roughly the same as the changing trend of the virtual water volume. The production sectors were expected to reduce the output value by a total of CNY 266.697 billion. The sector with the most considerable expected reduction in output value is the construction sector, which is CNY 179.147 billion, accounting for 67.2% of the total expected reduction in output value. The construction sector is also the sector with the most considerable reduction in virtual water consumption. The adjustment of the production structure needs to bear the cost of output reduction. In some production sectors, the expected output value decreases more, while the virtual water saved is lower, such as in the manufacture of foods and tobacco (MFT), housing (HOUS), and social organization (SO). These sectors need to pay a relatively high cost to change their production structure.

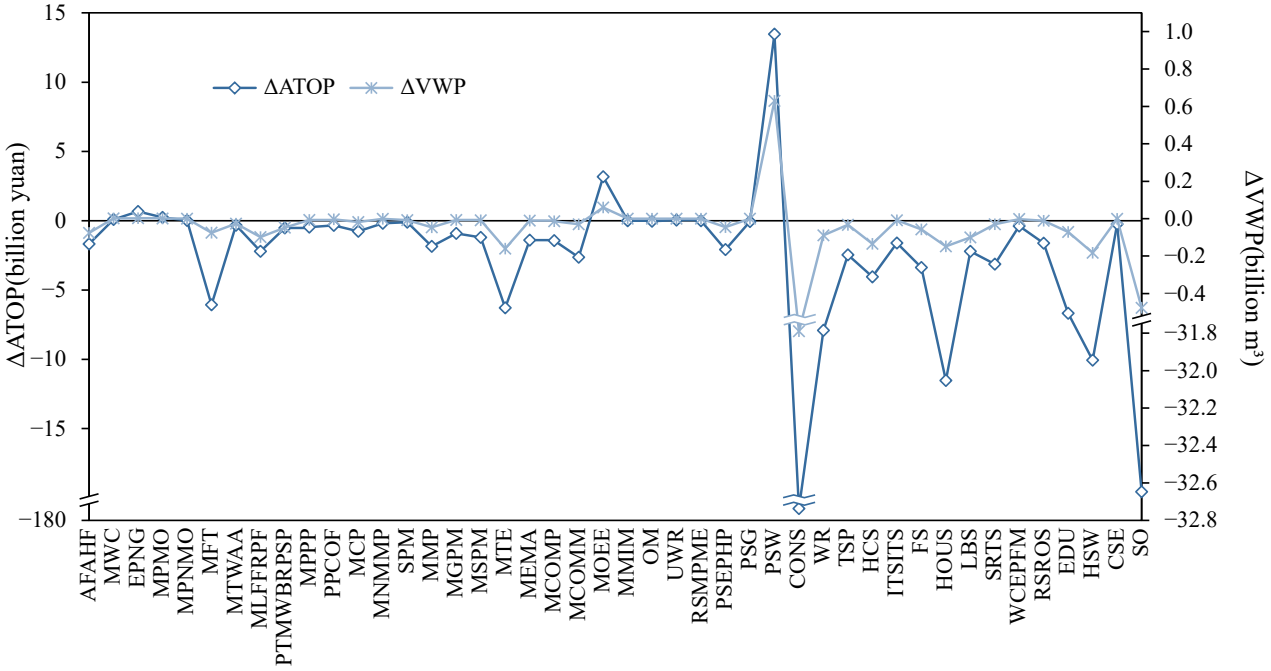


Figure 5. Changes in the value of production and virtual water.

The construction sector is critical to virtual water conservation. As shown in Table 2, the construction industry saves 31.79 billion m^3 of virtual water, accounting for 96% of the total virtual water savings, which is roughly the same as the proportion of virtual water saved by the construction industry from the perspective of production. As shown in Figure 6, the 15 sectors with the highest input ratios account for 95% of the cumulative input in the construction sector. Moreover, the products in these sectors contain relatively large amounts of virtual water, especially agricultural, forestry, animal husbandry and fishery products and services (AFAHF), processing of timber, manufacture of wood, bamboo, rattan, palm and straw products (PTMWBRPSP), and manufacture of chemical products (MCP). This led to the fact that the products produced by the construction sector contain a high amount of virtual water, and are significantly affected by its price. Moreover, in terms of the output value structure, the output value of the construction sector is the largest of all sectors, accounting for 10.13% of the total output value. Therefore, when upstream industries are affected by the price of water, the construction sector is significantly affected by this price change, which makes the construction sector's total output value change more significantly, and the construction sector output decline accounts for 67.2% of the decline in total output value. Furthermore, because of the larger amount of virtual water contained in the products of the construction sector, this further expands the water-saving effect, making the virtual water savings of the construction sector account for 96% of the total savings in virtual water.

From the perspective of producers, an increase in the standard of water resources tax driven by market forces will lead to an increase in production costs, resulting in higher product prices and consequently a decrease in market demand. In the long run, in order to pursue profits, production sectors will cater to changes in market demand, thereby forcing production enterprises to transform their production structure, accompanied by the cost of reduced output, which is detrimental to economic development. At the same time, the water-saving effect of the water resources tax policy is also significant. If we comprehensively consider water-saving and economic benefits, compared with consumers changing their consumption structure, the way producers change their production structure is more in line with the comprehensive economic benefits. Since the production sectors paid CNY 266.697 billion in costs, which can save 33.12 billion m^3 of virtual water, consumers

reduced their expenditure to CNY 246.942 billion, which only saved 6.02 billion m^3 of virtual water.

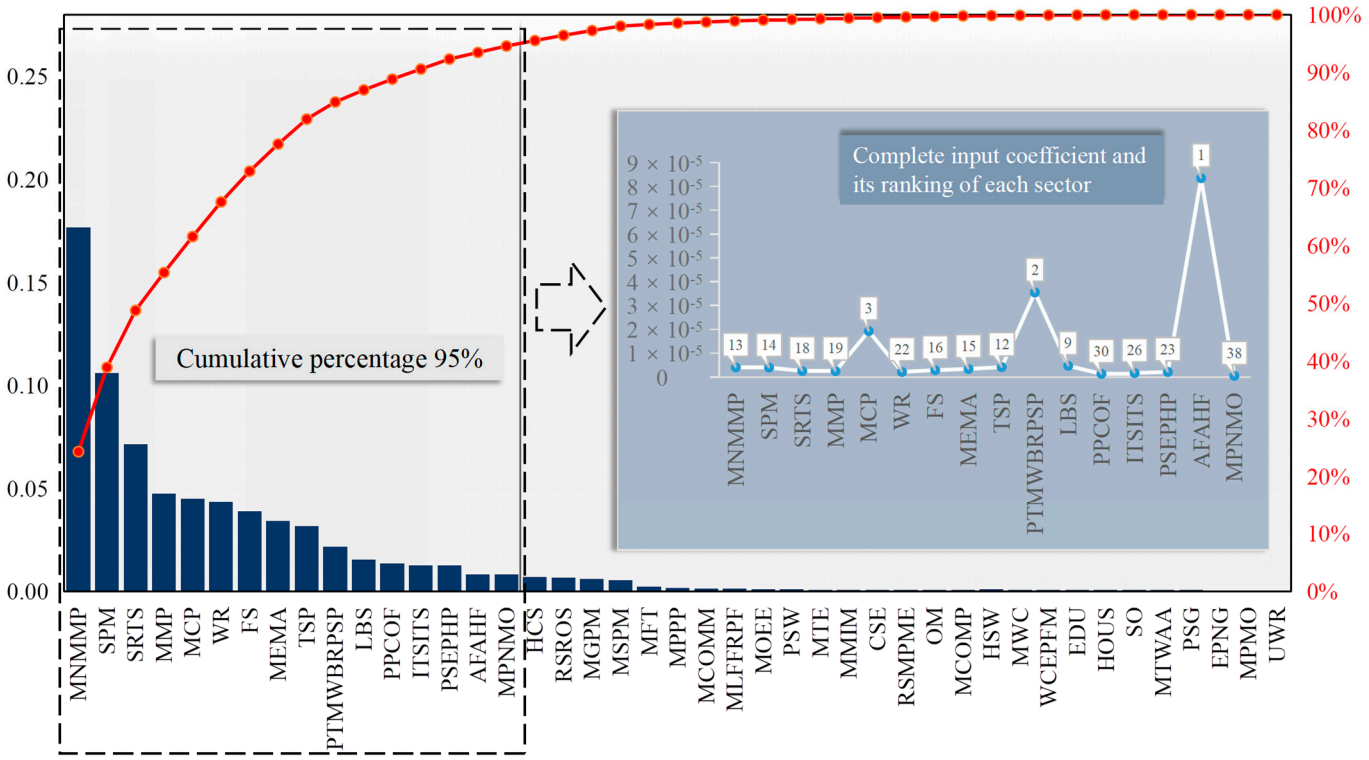


Figure 6. Input structure of the construction sector.

4. Discussion

By introducing the theory of virtual water, in this paper, we linked changes in economic benefits and water consumption in the production sector and conducted a detailed study on the effect of a water resources tax. The results show that the collection of a water resources tax can promote water conservation in various sectors, but this has a certain negative impact on economic development in the short term.

Generally speaking, under the leading role of the market, an increase in water resources tax will increase the production costs of enterprises, reduce the demand of consumers, cause a loss of output in the production sector, and have a negative impact on the economy. However, the collection of water resources taxes effectively saves virtual water in the process of consumption, thus achieving the goal of water saving [36]. However, Liu et al. (2022) found that water resources taxation reform can achieve a double dividend effect [37]. That is, the collection of a water resources tax can not only achieve the goal of water saving but also achieve economic effects. This is because the collection of water resources taxes is a government behavior. The government needs to adopt some macro-controls in the process of policy implementation. It can improve the investment structure through public policy, adjusting factor input, and driving investment and consumption, thereby improving social welfare and creating conditions for sustainable economic development. Due to the differing dependencies of different industries on water resources, after the water resources tax system is fully implemented and the tax burden level is raised, each sector needs to promote the rationalization of industrial structure according to its own actual situation; urge enterprises to carry out technological innovation to reduce emission reduction costs; improve water use efficiency; and optimize water use structure, in order to achieve the dual dividend effect of water savings and economic impact.

However, this paper simplifies the real situation, and its analysis of the effect of water resources taxation is not comprehensive enough. First of all, the transmission efficiency of water resources is lost in reality, and this research defaulted the transmission efficiency

of water resources to be 100%, in order to simplify the model. Secondly, the collection of a water resources tax not only affects a single sector but also has a direct impact on all sectors as well as residents' lives. Finally, the impact of water resources taxation should be continuous and dynamic, and this research only considered the impact of a water resources tax under static conditions. Therefore, this paper only provides a simple perspective to quantify the transmission path of water pricing policy, economic benefits, and water-saving effects. In subsequent research, based on the ideas of this research, the following three aspects can be further expanded. Firstly, by expanding a single region to multiple regions through the guidance of water pricing policy and virtual water theory, a reasonable water resources allocation model can be constructed. Secondly, the impact of one product change can be extended to the impact of multiple product linkages. Thirdly, the influence of water pricing policy is a continuous long-term process, and the choice of producers and consumers is also dynamic, water pricing policies promote change in industrial structure and consumption structure; therefore, the analysis of the effects of water resources taxation policies should be changed from static analyses to dynamic analyses.

5. Conclusions

In this study, the virtual water theory and a price input–output model were used to simulate and analyze the impacts of water resources taxation on the economy and the effect of water saving, simplifying the implementation process of water pricing policy. This study found the following:

(1) Under the scenario of a 10% increase in water price, both from the perspective of consumers and producers, a negative impact on economic development is expected; even if the impact is small, it plays a role in water conservation. An increase in water price had little effect on the product price of each sector, but it generally caused the unit output value cost of each sector to increase, which, in turn, reduced the output value and affected economic development. It was found that the adjustments in production structure by producers were more in line with the comprehensive benefits of water-saving objectives.

(2) The impacts of a water pricing policy on various sectors differ. The construction industry was the sector most affected by the water pricing policy. The imposed increase in water prices reduced its total output value by 67.2% compared to the total expected output value. At the same time, the construction industry also saved the most virtual water, accounting for 96% of the total virtual water savings. Agriculture, food, and tobacco manufacturing are greatly affected by consumer choice. With changes in consumption structure, water resources can be effectively saved. There is a large space for water resource optimization in service sectors such as social organizations, health and social work, real estate, and accommodation and catering. Through adjustments to industrial structure in these production sectors, the goal of water conservation can be effectively achieved.

(3) The water pricing policy plays a role in guiding consumer behaviors. If the impact of rising water prices is transferred to consumers, increases in the prices of purchased products will reduce the expected cost of such products under the premise that consumers' purchasing power remains unchanged. The water pricing policy encourages consumers to reduce their consumption of water-intensive products, thus changing consumer consumption patterns to achieve the goal of water conservation.

It can be seen that when implementing a water resources tax reform policy, its impact on the economy should be comprehensively compared from the perspective of both producers and consumers. This approach aids in selecting an adjustment method that is more in line with the goals of water conservation and reducing economic effects. Due to the relatively inefficient use of water by the construction industry, its water-saving potential is significant, and it is necessary to accelerate technical improvements to achieve efficient water use. At the same time, it is necessary to consider the government's leading role in the following: policy implementation, setting up supporting policies, coordinating the

production structures of various sectors, and maximizing water conservation efforts while considering their effects on economic development. The government must coordinate the allocation of tax revenue for the implementation of water-saving measures, such as the construction of water conservancy facilities and water source protection. In addition, it should provide financial support to industries that consume large amounts of water to improve their technology and promote their shift to cleaner production methods. This ensures that the tax revenue from the water resources tax system is truly utilized to "take from water and use it for water".

Author Contributions: T.L. wrote the original manuscript and performed the statistical analysis. J.L. and X.H. collected important background information and designed the figures. G.T. carried out the concepts and definition of the study, analyzed the data, and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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