Effect Simulation and Analysis of Water Price Policy to Promote Water Resources Rational Allocation in Tianjin

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Abstract: The water crisis has become a global fact. Relying on the price lever to promote water saving and rational distribution is inevitable trend and requirements for the development of economy. Considering water supply conditions and water use features in Tianjin, using 42 department input-output table of 2007 as the main data base, Based on the general equilibrium analysis model of price policy impact, this paper develops a water price policy impact analysis model that is suitable for Tianjin, with the module which takes into account certain substitutable elasticity of different kinds of water resources. By setting water price ratio between different kinds of water sources and price differentials between water users of the same source, the model can calculate water use amount of industries and residents, proportion of different kinds of water resources use and impact on the economy in Tianjin under multi-variant price policy. Through situational comparison and analysis between the different schemes, the recommended water scheme that can meet optimal utilization of water resources under constraints of water supply and priority sequence of different water use. It can provide a reference for water-price reform that can promote water conservation and reasonable allocation of water resources. The results show that Tianjin water ratio between different kinds of water in 2020 finally recommended is Water price of conservancy engineering: water price of tap: recycled water price: price of water-desalinize =1：27.35：3.41：4.40, price differentials between different user of city tap water is Residents water price: Water price of general industry: Water price of high water industry: water price of construction: water price of general tertiary industry: water price of high water tertiary industry = 1:1. 7:3. 4:1. 7:1. 7:5. 8.

Keywords：Water price, CGE simulation model of water price policy impact, Multi-water resource, Multi-scheme comparison, Reasonable allocation of water resources

1 Study background

China's water demand is increasing rapidly with economic development combined with waste and pollution which make the temporal and spatial water deficiency, and now water supply have more difficult to meet the needs of sustainable development. Water shortages are increasingly severe. Another, increasing change of extreme climate in recent years makes water risk and uncertainty increasing in China. The economic development’s need of expanding domestic demand in order to response to the financial crisis, as well as improving requirements for the

ecological environment pose a severe challenge to originally fragile water resources situation. Water with food and oil has become an important strategic resource of socio-economic sustainable development. The contradiction between supply and demand of water resources has become a major bottleneck for sustainable development of China.

The water-saving space from production and technological progress is limited, how to make full use of market mechanisms and price leverage in allocating water resources, adjusting water demand and preventing water pollution, to promote traditional water sources saving and non-traditional water sources use, to inhibit waste, to guide and optimize water consumption structure to coordinate to economic structure, and to promote the use of various types of water resources efficiently, ease the water crisis, those has become the important issues and tasks which can't be avoided in the current and future water management area. Study choose a typically severe water shortage city-Tianjin as a case, use CGE model to study reasonably relative price of various water sources and price difference of the different users getting the same water in order to promote full use of different water sources and optimal allocation of same water in the different users. The study project which can meet the requirements for total water resources is chose as the recommended project. the recommended project can provide a reference for other regions how to develop strategies of promote the optimal allocation of limited water, and how to take the market price to actively promoting China's most stringent water management system and implement total water control and optimize allocation, which have great practical significance.

2 Basic information of Tianjin

2.1 Economic Development and Water Use Situation in Tianjin

Tianjin as China's coastal municipalities is an important comprehensive industry base and trade center, which is a developed-city, which per capita GDP was third in the country, ranked only after Shanghai and Beijing. From 2006 to 2010, Tianjin's added value structure of three industry at current price change from 2.3:55.1:42.6 1.6:52.5:46.0 to 1.6∶52.5∶46.0, agricultural proportion annual fell by 0.14%, the industry proportion annual fell by 0.52%, the proportion of tertiary industry annual rose by 0.68%. At comparable price, added value structure of three industry change from 2.3∶55.1∶42. 6 to 1.4∶58.3∶40.3, agricultural proportion annual fell by 0.18% which is stable, the industry proportion annual rose by 0.64%, the proportion of tertiary industry annual rose by 0.46%. According to the "twelfth five-year" national economic development planning of Tianjin, the proportion of the tertiary industry will increase to 50% during the "twelfth five-year".

Tianjin's economic development needs adequate water. Tianjin is located in the river system downstream of the Hai River Basin, it said history known "the nine rivers tip", but due to pollution and climate change, Tianjin severely lack for water. The multi-year average surface water resources amount is 1.065 billion m^3, and groundwater amount is 590 million m^3, deducted from the double counting, the multi-year average total water resources amount is 1,569 million m^3. The per capita water resources amount is 160 m^3, only one over fifteen of the whole country, at the end of provinces and cities in China. Added immigration and transfer water (such as immigrate

Luan and Yellow River to Tianjin), But per capita water resources amount is only 370 m3, is the least city in China. Due to such as problems: conventional water source being single and groundwater serious overdraft etc. which makes the water shortage becoming most direct main urgent resource constraints to the Tianjin's socio-economic sustainable development.

Mainly by fully exploiting all kinds of water resources in Tianjin to meet the water needs of socio-economic development, the water use of urban production and life mainly rely on external water sources, also includes the part of local surface water, groundwater, and a small amount recycled water and sea water desalinated through exploration and technological exploitation.

Table 1 Water supply quantity of four type water to different users from 2007 to 2010 in Tianjin (unit: million m^3)

		Agricultural	generally water use industry	high water use industry	construction	General water tertiary industry	high water use tertiary industry	Residents	Total
2007	Water supplied by water project	1406.00	13.10	185.63	3.99	12.91	18.10	145.00	1784.73
	Tap water	0.00	67.46	141.11	15.01	73.68	65.67	171.00	533.94
	Recycled water	0.00	0.00	10.70	0.00	2.82	0.00	0.00	13.52
	Sea water desalinated	0.00	1.80	0.20	0.00	0.00	0.00	0.00	2.00
	Total	1406.00	82.36	337.64	19.00	89.41	83.78	316.00	2334.18
2008	Water supplied by water project	1322.00	18.08	77.81	3.99	12.91	10.79	99.16	1544.73
	Tap water	0.00	82.15	150.85	14.29	49.51	39.93	211.84	548.56
	Recycled water	0.00	0.00	5.18	0.00	2.82	0.00	0.00	8.00
	Sea water desalinated	0.00	2.25	0.25	0.00	0.00	0.00	0.00	2.50
	Total	1322.00	102.48	234.09	18.28	65.23	50.72	311.00	2103.79
2009	Water supplied by water project	1306.60	18.99	176.01	3.99	12.91	9.46	106.91	1634.87
	Tap water	0.00	97.82	131.43	21.41	64.84	35.50	227.09	578.09
	Recycled water	0.00	0.00	7.77	0.00	4.23	0.00	0.00	12.00
	Sea water desalinated	0.00	2.70	0.30	0.00	0.00	0.00	0.00	3.00
	Total	1306.60	119.50	315.52	25.40	81.97	44.97	334.00	2227.96
2010	Water supplied by water project	1119.69	19.84	199.09	3.99	16.39	10.27	123.00	1492.27
	Tap water	0.00	127.16	125.47	20.61	87.53	32.25	226.00	619.03
	Recycled water	0.00	0.00	8.01	0.00	4.36	0.00	0.00	12.37
	Sea water desalinated	0.00	2.70	0.30	0.00	0.00	0.00	0.00	3.00
	Total	1119.69	149.70	332.87	24.60	108.28	42.53	349.00	2126.67

From 2007 to 2010, the water consumption proportion of agricultural, high water use tertiary industry were shown downward trend, while which of industry, general water use tertiary industry and residents were shown steady increase, which of construction is stability.

2.2 Water Price and Water Price Structure in Tianjin

Due to the lack of water, Tianjin walk in the top in using the market leverage to adjust contradiction between supply and demand of water, water price level is the highest standards. From 1997 to 2010, Tianjin's government has adjusted tap water price eight times according to the level of economic development. Resident water price adjusted from 0.68yuan to 4.4yuan per ton, industry water adjusted from 0.95yuan to 7.5yuan per ton, the portion of more than water index charge premium. Agriculture as water-saving priority breaking system of "certain price not limits number", has been charged by quantity. Tianjin's tap water comprehensive price is 5.95yuan/m^3 in 2010, which is made up of five parts, including water resource charge (1.59yuan/m3, South-to-North Water Transfer Project Funds), sewage treatment charge (1.05yuan/m^3), price of conservancy supply water (1.08yuan/m^3), basic tap water price (1.93yuan/m^3)and urban public utilities charge (0.30yuan/m^3). Since November 1, 2010, water price of conservancy for tap is 1.08yuan/m^3,the tap water price of resident's 4.40yuan/m^3, South-to-North Water Transfer Project Funds in the resident's water prices raised form 1.01yuan/m^3 to 1.39yuan/m^3, sewage treatment charge is 0.90yuan/m^3. Since April 1, 2010 non-resident tap water prices, water price of industry, administrative institutions, and business service has been 7.50yuan/m^3; water price of special industry has been 21.90yuan/m^3, sewage treatment charge has been 1.2yuan/m^3.

Table 2 Water price of different user and water resources from 2007 to 2010 (unit: yuan/m^3)

Years	component	Agricultural	generally water use industry	high water use industry	construction	General water use tertiary industry	high water use tertiary industry	Residents
2007	Water of conservancy	0.2	1.03	1.03	1.03	1.03	1.03	1.03
	Tap water	0	6.2	6.2	6.2	6.2	20.6	3.4
	Recycled water	0	1.2	1.2	0	1.5	1.8	
	water of desalination	0	4	4	0	0	0	
2008	Water of conservancy	0.2	1.03	1.03	1.03	1.03	1.03	1.03
	Tap water	0	6.2	6.2	6.2	6.2	20.6	3.4
	Recycled water	0	1.2	1.2	0	1.5	1.8	
	water of desalination	0	4	4	0	0	0	
2009	Water of conservancy	0.2	1.05	1.05	1.05	1.05	1.05	1.05
	Tap water	0	6.7	6.7	6.7	6.7	21.1	3.9
	Recycled water	0	3.1	3.1	0	3.1	4	
	water of desalination	0	4	4	0	0	0	
2010	Water of conservancy	0.2	1.08	1.08	1.08	1.08	1.08	1.08
	Tap water	0	7.5	7.5	7.5	7.5	21.9	4.4
	Recycled water	0	3.1	3.1	0	3.1	4	
	water of desalination	0	4	4	0	0	0	

Although Tianjin's water price are high in the country, but the overall level of water price is still low, the price leverage did not play a significant role, relative price and price difference are unreasonable. Further economic development requires more water, but water resources are limited, how to use the price leverage to promote establishing production way and structure of water-saving, clean and economy, and promote water resources rational allocation, is an important

measure of strengthening water resources management and ensuring the sustainable socio-economic development.

3 Design ideas of impact analysis model of different kinds of water price policy

3.1 The Overall Research Ideas

(1)The study analyzes Tianjin's basic condition of water price systems, water structure and the industrial structure from 2007 to 2010. Use CGE model to quantitative analyze the impact of water prices system on adjusting water structure and industrial structure, and reveal the impact and law of water price system on water structure and industrial structure adjustment, estimate whether current water price system in Tianjin is reasonable, and determine the adjusting direction of the reasonable water price system, lay the foundation for model parameters calibration and scenarios design.

(2)Consider water resource constraints, the paper use CGE model calculate water structure and industrial structure under the condition of optimized allocation of water resources, put forward reasonable water price system in the corresponding state (relative price of different water sources and users' price difference of the same water source).

3.2 Model Design and Basic Principles

3.2.1 CGE model profile and Application research on water price

Tianjin dynamic CGE model in this study is developed jointly by State Information Center and China Institute of Water Resources and Hydropower Research. The core module are based on SICGE model of State Information Center, the model choose 42 sector input-output table of Tianjin 2007 as the main data base. In order to meet the content requirements of this research, according to the Investigation on the water problems of Tianjin, State Information Center and China Institute of Water Resources and Hydropower Research together developed the water price analysis model-WPSICGE on the basis of SICGE model, the model Subdivide water into four types: Water of conservancy engineering supply, tap water, recycled water and sea water desalinated. And simulate usage condition of Tianjin industry and resident different water resource use. While establish alternative relationship between the various water sources, in order to examine the adjustment of water price's impact on water structure and economy.

CGE model can analyze impact of adjusting water prices system on water use structure and industrial structure, which need to be divided into two steps:

The first step is to develop the baseline scenario. Assumed that water price system unchanged and maintain the existing level, simulate naturally socio-economic development situation to 2020 of Tianjin, which is called the baseline scenario. In this scenario, we first simulate future socio-economic development plan of Tianjin, including growth rate of economic development,

growth of population and workforce, economic and industrial structure adjustment, fluctuation of the social average price level, consumption, investment, import and export, product transferred into or brought out and so on. Then, Assuming water price system remain unchanged, the model estimates water consumption and water use structure of the baseline scenario.

The second step is the policy scenario simulation. CGE model introducing price changes into the baseline scenario, and get water price policy scenario results. In policy Scenario, CGE model raise the water price through the way of improve water charges (tax), change relative price relationship between other inputs and various industrial production and residents water use. One hand, stimulate industry and residents to carry out water-saving action and try hard to improve the efficiency of water use; on the other hand, the production cost of the high water use industries increase more relative to the general water use industry, which promote the transformation of economic structure towards the low water consumption industry.

Therefore, each variable results difference between the policy scenario and the baseline scenario reflects impacts from only water price adjusted while other variables held constant. Using this two-step method can more accurate strip out impact of water price adjusted on Tianjin's socio-economy to meet the needs of the research.

3.2.2 Water Replacement Module

The original model developed by State Information Center, water and other commodities as intermediate inputs similarly was used to production in zero alternative forms, as shown in Fig.1.

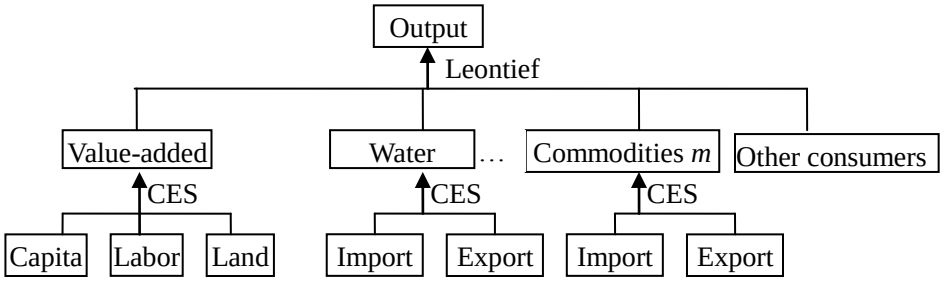

Fig.1 SICGE model structure of the original production module

In order to be able to analyze the economic impact of water price adjusted, this paper subdivide single commodity "water" into" conservancy project supply water ", "tap water", " recycled water and sea water desalinated." And consider four types of water have different alternatives, the logical structure shown in Fig.2. The improved model is able to simulate the progress that relative price change of different water sources will cause chances of water use structure.

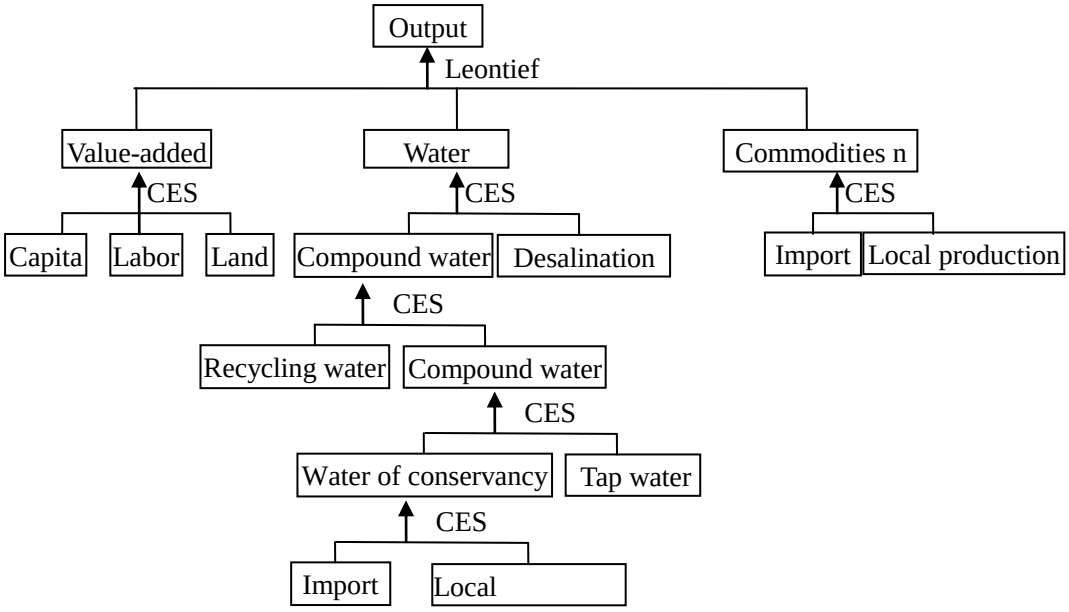

Fig.2 Production module structure of industries refined water use module

In the improved model, gross output of the industries is still decided by all sorts of intermediate input and added value in zero alternatives, and use the Leontief production function. Among them, water amount compounded by four kinds of water resources is no substitution relationship with other intermediate input.

Through multi-layer nested way to implement alternative among a variety of water sources, and reflects the substitution effect difference between different water sources. According to the analysis of strength and possibility of water alternative, the model set layer and the corresponding substitution elasticity of water resources.

3.2.3 Module of Water Resources Constraint Processing

The reasonable use of water can be seen as the optimal use of the total amount of water supplied by conservancy project. For sea water desalinated and recycled water, in theory, does not constrain the use, but supply limited by capacity growth, therefore constraint of recycled water and sea water desalinated isn't reflected in the module.

QHY represent water supplied by conservancy project, assuming a virtual tax rate (yuan /ton) to describe the shadow price called WTAX under the amount of water control. Water of conservancy water is used for intermediate inputs and final demand, the virtual tax rate need conversion from "amount tax called WTAX" to "price tax called TWAT", and incorporated into the commodity tax variable of the user's price.

Amount tax conversion process of intermediate inputs and consumer water supplied by conservancy engineering is as bellow:

$$WTAX \times QHY_{sj}^{(1)} = TWAT_{sj}^{(1)} \times \left(P_{HY,s,j}^{(1)} \times X_{HY,s,j}^{(1)} \right) \quad (s = 1,2;\ j = 1,...,44) \tag{1}$$

$$WTAX \times QHY_{s}^{(3)} = TWAT_{s}^{(3)} \times \left(P_{HY,s}^{(3)} \times X_{HY,s}^{(3)} \right) \quad (s = 1,2) \tag{2}$$

Converted into a linear equation:

$$100*\Delta WTAX\times QHY_{sj}^{(1)}=pwat_{s,j}^{(1)}*(V1BAS_{HY,j}+V1TAX_{HY,j})+V1TAX_{HY,j}*p_{HY,s,j}^{(1)} \quad (3)$$

$$100*\Delta WTAX\times QHY_{s}^{(3)}=pwat_{s}^{(3)}*(V3BAS_{HY}+V3TAX_{HY})+V3TAX_{HY}*p_{HY,s}^{(3)} \quad (4)$$

The sum of water consumption of resident and industry production is the total water quantity needed to control supplied by the conservancy project:

$$QHY=\sum_{s,j}QHY_{sj}^{(1)}+QHY_{s}^{(3)} \quad (5)$$

4 Effect simulation of water price policy to promote water resources rational allocation in Tianjin

4.1 Judging reform direction of water price system

By base scenario compared with others scenarios, the results of dynamically computable general equilibrium model based on water price system impact (WPSICGE) can reveal the unreasonable problems of relative price and price difference, and clearly indicate reform direction. The paper set water price of 2007~2009 as impact variables, and the simulation results are compared with "actual scenarios", which can analyze demand elasticity of water price, shown in tab.3.

Tab.3 Demand elasticity of water price from different water resources in 2007 ~ 2009

	generally water use industry	high water use industry	construction	General water use tertiary industry	high water use tertiary industry	Residents	Integrated water price
Water price of Conservancy project	0.286	a0.185	0.054	0.131	0.157	0.342	0.104
tap water price	0.562	0.262	0.077	0.152	0.188	0.304	0.125
Recycling water price	—	0.015	—	0.052	—	—	0.007

Tab.3 shows that price elasticity of tap water is relatively reasonable. However, it is within the scope of a lack of elasticity, which demonstrates not good water-saving effect under current water price. In general, the demand elasticity of conservancy project water price is far weaker than tap. Therefore, raising proportion of water price of conservancy project is the emphasis of the future reform. The demand elasticity of non-residential water price is less than residential, and price adjustment of the non-residential needs to be accelerated first obviously.

The present water price reform in Tianjin has certain impact in restraining water demand, saving water, improving water efficiency, and industries structural optimization, etc. However, the overall impact is not obvious. From the present experience of the water price reform, it can be found that it is good for reducing supply pressure of conventional water, promoting the water

resources optimal allocation and improving water use efficiency with establishing a reasonably relative price of different water sources and price difference among water users. It is the water price reform direction.

4.2 Predicting reasonable water price system of Tianjin in the future

In order to on the base of simulation results of water price system's impacts and law by WPSICGE model, and build a reasonable water price system of Tianjin, it needed to set two research scenarios respectively. First, based on accurate judgment of economic development trend to formulate basic parameters of the model, set up the baseline scenario and analyze. After that, design a series of different policy options scenarios of the water price system, simulate the law and impact of water price system choose a reasonable water price system adapt to expectations target of economic development and water planning objectives . Through comparison between policy scenario and no water price reform scenario (baseline scenario or inertial development state), the function and impact of the adjustment policy can be shown, which could provide the reference for establishing the reasonable water price system.

4.2.1 Set scenarios

(1) Set baseline scenario

Baseline is the basis of carrying out the policy analysis. Baseline in this article describes the socio-economic development of Tianjin from 2007 to 2020, dividing into two periods.

The first period from 2007 to 2010 is to assign the model variable according to the actual socio-economic development of Tianjin. The main economic indicators including GDP, residents' consumption, investment, three industrial structure, employment, price level, etc. Water data consist of water consumption and price of four categories water and six sectors.

The second period from 2011 to 2020 is to judge Tianjin's socio-economic development according to the "12th five-year" plan and 2020 outlook in Tab.4. In recent years, Tianjin entered the high-speed development period, and the GDP growth rate in 2011 reached 16.4%, which is the first in China. Tianjin is expected to maintain such a momentum of rapid growth at around 14.5% in the "12th five – year" period and at around 12% in the "13th five – year". One of them, investment is still the dominant force in the high-speed economic development, meanwhile resident consumption also present the fast growth, which is basically synchronous with GDP growth. According to the industry structure, the agriculture proportion continues to decline, from 1.5% of 2010 to 0.6%, secondary industry declines from 57.8% to 49.8%, while tertiary industry grows rapidly, that is expected to increase to 49.6% in 2020.

Tab.4 Judgment of socio-economic trends in Tianjin

options		2010	2015	2020	Average annual growth rate (%)	
					2011~2015	2016-2020
GDP(100 million price in 2007)		8369.7	16471.6	29028.6	14.5	12
Total Employment(10000 persons)		728.7	966	1175.3	5.8	4
GDP sub-item by	Household consumption	2104.2	4051.5	7140.2	14	12
	Government consumption	1186.9	1911.5	2681.0	10	7

expenditure approach(100 million, price in 2007)	Gross capital formation	6044.7	13214.1	23501.8	16.9	12.2
	import	10999.3	17079.5	24360.7	9.2	7.36
	export	9559.3	14373.9	20066.2	8.5	6.9
Three industries structure	Agriculture industry	1.5	0.9	0.6		
	Secondary industry	57.8	54.7	49.8		
	Tertiary industry	40.7	44.4	49.6		

According to research goal, water price is assumed to remain at 2010 level, and total water consumption and water structure is predicted on the basis of the economic and social development trend in Tab.5. Total water in 2015 will reach 2.726 billion m^3 (not considering ecological water), with the average growth of 5.1% during the "12th five – year", and total water will reach 3.44 billion m^3 in 2020, with the average growth of 4.7%. Considering the agriculture development of mechanization, refinement, and high value added, the water consumption of unit product decreases obviously, resulting in a marked decline in the growth rate of agricultural water. Considering the investment growth in the future ten years will continue to keep the high level, the water growth rate of the construction will keep at 8% basically until "13th five – year" period. Similarly, residents' living standards improve gradually, along with lots of the labor immigrates, domestic water also retain at a relatively stable growth rate. By contrast, the water growth rate of industrial and service basically vary with added values, but the decline is not obvious if there is no additional water saving measure.

Tab.5 Tianjin's water consumption prediction when water price remain 2010 level

Water consumption （10000 m^3）	2010	2015	2020	Average annual growth rate (%)	
				2011~2015	2016-2020
agriculture	111969	131386	144634	3.2	1.9
General water industry	14970	24849	40331	10.7	10.2
High water industry	33287	42253	52416	4.9	4.4
construction	2460	3613	5306	8.0	7.9
general water tertiary industry	10828	22257	41892	15.5	13.5
high water tertiary industry	4252	6000	8242	7.1	6.6
residents water	34900	42191	50896	3.9	3.8
total	212666	272550	343718	5.1	4.7

According to survey in Tianjin, the current water situation couldn't bear such a high water demand by 2020. Therefore the implementation of water-saving policy is inevitable. Adjusting water price and building reasonable water price system is expected to play the role of market mechanisms to save water effectively from the consumer side.

(2) Policy scenario

The policy objective is to estimate reasonable price system in the future. Two parts are used to judging whether the main indicators of water price system are reasonable. Firstly, whether water price system induce total water in a reasonable level in the future, secondly whether water price system induce water structure optimized in the future.

In the baseline, total water consumption will increase to 3.4 billion m3 if water price remain at 2010 level in Tianjin, it is difficult to guarantee supply. According to experts' judgment, water supply in Tianjin is between 2.8 billion and 3.1 billion m^3 by 2020. So we achieve the goals by setting the policy scenarios.

Through the comparison between a series of policy scenarios and the baseline, price elasticity coefficient of water demand of different water and different user in 2011 ~ 2020 are calculated in Tianjin in Tab.6, the reform trend of water supply price is judged and the reform project is set.

Tab.6 Price elasticity coefficient of water demand of different water and different user in Tianjin from 2011 to 2020

Water price（relative to 2007）		40%	50%	60%	70%	80%	90%	100%
different water	Water supply of conservancy	0.338	0.382	0.408	0.452	0.469	0.512	0.562
	Tap water	0.590	0.594	0.609	0.620	0.676	0.745	0.765
	Recycled water	0.038	0.058	0.061	0.073	0.106	0.125	0.147
different user	agricultural	0.118	0.140	0.163	0.187	0.201	0.225	0.243
	general water industry	0.391	0.411	0.435	0.453	0.488	0.520	0.578
	high water industry	0.413	0.443	0.474	0.507	0.541	0.574	0.607
	construction	0.080	0.120	0.131	0.157	0.167	0.189	0.200
	general water tertiary industry	0.334	0.379	0.379	0.398	0.407	0.409	0.413
	high water tertiary industry	0.390	0.404	0.418	0.426	0.439	0.447	0.461
	residents water	0.455	0.482	0.505	0.549	0.583	0.634	0.692

The simulation results show that water-saving elasticity grows with the growth of water price. the rising water price will promote water-saving directly, as well as promote water-saving technological progress, which promote water – saving under the double impulse. The more water price rises, the more the technological advance and water-saving elasticity of water price is bigger while the rate of water-saving is more. However, the demand elasticity of water price is still less than one even if water price is twice as much as the original price, which belongs to a lack of flexibility. It indicates that water price still has great space to improve.

According to the comparison between a series of the policy scenario simulations, we get the following two preferred reasonable water price projects, shown in Tab.7.

Tab.7 Water price level of different water and different water user in Tianjin (unit: yuan/m^3)

Scenarios	level year	users / water resource	Agricultural	generally water industry	high water industry	construction	General water tertiary industry	high water tertiary industry	Residents water
Status	2010	Water of conservancy	0.20	1.08	1.08	1.08	1.08	1.08	1.08
		Tap water		7.50	7.50	7.50	7.50	21.90	4.40
		Recycled water		3.10	3.10		3.10	4.00	
		Water of desalination		4.00	4.00				
Scenario 01	2015	Water of conservancy	0.28	1.53	1.53	1.53	1.53	1.53	1.53
		Tap water		10.61	15.00	10.61	10.61	43.80	6.22
		Recycled water		3.10	3.10		3.10	4.00	
		Water of desalination		4.00	4.00				
	2020	Water of conservancy	0.28	2.16	2.16	2.16	2.16	2.16	2.16
		Tap water		15.00	30.00	15.00	15.00	87.60	8.80
		Recycled water		3.10	3.10		3.10	4.00	
		Water of desalination		4.00	4.00				
Scenario 02	2015	Water of conservancy	0.28	1.53	1.53	1.53	1.53	1.53	1.53
		Tap water		12.99	16.77	12.99	12.99	48.97	7.62
		Recycled water		3.10	3.10		3.10	4.00	
		Water of		4.00	4.00				

		desalination							
	2020	Water of conservancy	0.40	2.16	2.16	2.16	2.16	2.16	2.16
		Tap water		22.50	37.50	22.50	22.50	109.50	13.20
		Recycled water		3.10	3.10		3.10	4.00	
		Water of desalination		4.00	4.00				

Scenario 1: the price of recycling water and water of desalination for various industries is assumed to remain unchanged. Prices of tap water and water of conservancy are the main parts to adjust. Except agriculture, price water of conservancy in other industries is double in 2020 than in 2010. Tap water price of resident, general water industries, construction and general water tertiary industry is double in 2020 than 2010. Tap water price of high water industry and high water tertiary industry is four times as much as the original price. The price of agricultural water of conservancy is 0.2¥/m^3 higher than 2010. Based on this scenario, total water consumption of Tianjin will drop to 3.01billion m^3 in 2020.

Scenario 2: except agriculture, water price of conservancy in other industries is assumed to remain unchanged. The price of recycling water and water of desalination for various industries is assumed to remain unchanged. Price of tap water and agricultural water of conservancy is further improved. Tap water prices of residents, general water industry, construction, general water tertiary industry rise 150% of 2020 than 2010. Tap water prices of high water industry and high water tertiary industry rise 250%. Price of agricultural water of conservancy is double in 2020 than 2010. Based on this scenario, total water consumption of Tianjin will drop to 2.88 billion m^3 in 2020.

4.2.2 Scenario selection and impact analysis of water price policy

Scenario selection. Comparing scenario 1 with scenario 2, the total water consumption has obvious decline for tap water price increase further improves. There is 2.873 billion ton in scenario 2, which are 0.14 billion ton less than scenario 1. Although water-saving rate increases to 16.3% of scenario 2 from 12.1% of scenario 1, the water-saving rate increase of high water industry and high water service is much lower than water price increase, which indicates that the water-saving effect of water price has diminishing marginal returns. In addition, within full use of limited water, GDP of scenario 1 is higher than scenario 2. Scenario 1 is the recommended one in general.

Impact on the main macro-economy. The government rise water price, which is seen to decrease the cost of the completely economic and social production and living, and increase users' cost. The completely economic system will get negative impact. In tab.8 and fig.3, annual water price amplification increases gradually, and the impact of GDP in any year is the superposition of annual price increases before, it continues to aggravate from -0.01% in 2011 to -0.18% in 2020. Similarly, the negative losses of total investment and resident consumption also increase gradually, the former from -0.01% in 2011 to -0.48% in 2020 and the latter from -0.02% in 2011 to -0.17% in 2020. At the same time, the consumer price level rises significantly, from 0.07% in 2011 to 2.49% in 2020 because of the price linkage effect from water price increase, while the price rises 2% for agricultural products, 2.65% for food, and 2.56% for textiles. However, the negative influence of export decreases gradually, and the export increases slightly in 2020, mainly from the positive influence of agricultural export and brought out (increasing 1.8%

in 2020 than baseline scenario). This is because the price increase of agricultural water of conservancy is relatively small (41%), causing the small increase of agricultural production (2%), which is smaller than the average increase of other productions (2.5%), indicating that agricultural productions in Tianjin is relatively cheaper and the export and brought out has positive impact.

Tab.8 Impact on the macroeconomic development of scenario 1 in Tianjin (%)

index	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP	-0.01	-0.02	-0.04	-0.06	-0.08	-0.10	-0.11	-0.13	-0.15	-0.18
aggregate investment	-0.01	-0.02	-0.07	-0.12	-0.16	-0.23	-0.28	-0.33	-0.40	-0.48
household consumption	-0.02	-0.04	-0.06	-0.09	-0.10	-0.11	-0.12	-0.13	-0.15	-0.17
Exports and brought out	-0.02	-0.04	-0.04	-0.04	-0.04	-0.03	-0.02	-0.01	0.01	0.04
Import and transferred to	-0.02	-0.03	-0.07	-0.10	-0.13	-0.17	-0.21	-0.24	-0.29	-0.34
CPI	0.07	0.19	0.37	0.59	0.85	1.13	1.43	1.76	2.11	2.49

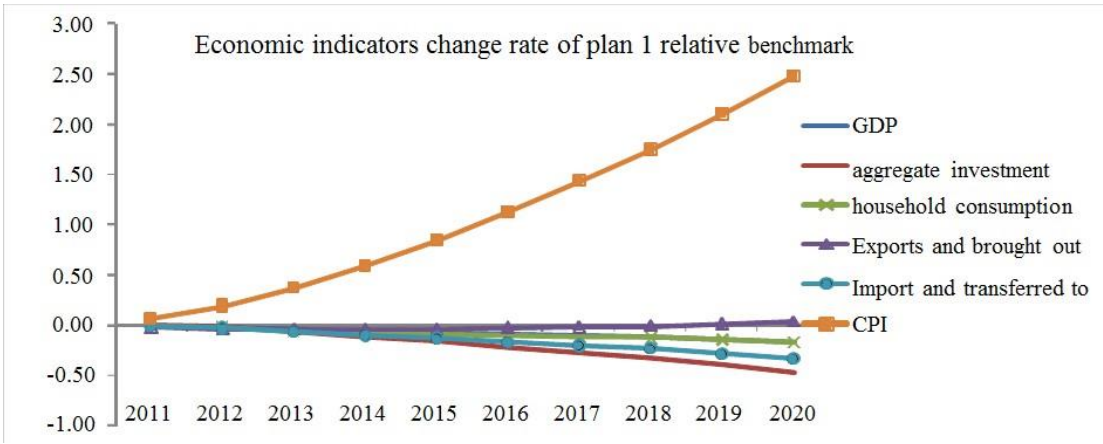

Fig3 Raising water prices impact on macroeconomic of Tianjin

Impact on water consumption and water structure. Improving price of tap water and agricultural water of conservancy leads to the obvious decline of total water consumption and water supply. Total water consumption decreases from 3.4 billion ton to 3.013 billion in 2020, and the water-saving rate reaches 12.2%. The demand of various users decreases with the increase of price of tap water and water of conservancy. In tab.9, water consumption of high water industries and services decreases the most which caused by the increase of tap water price. Meanwhile, the demand of tap water results in the decline of water of general water industries, which contain tap water industries. Water of general water service and constructions has fewer declines. Tab.9 shows that the price of water of conservancy increases while agricultural water consumption decreases. From supply structure different water, the demand of tap water decreases 11.84% in 2020 than baseline scenario when increasing the price of tap water. The decrease demand of water of conservancy mainly contains two parts. One is that all tap water is from water of conservancy. The other is that the direct increase of agricultural water of conservancy. In scenario 1 the price of recycling water and water of desalination is assumed to remain unchanged. Instead, the price of water of conservancy and tap water is increasing cheaper, which greatly stimulates the utilization of these two types, the former increases 10.43% in 2020 than baseline scenario and the latter increases 12.65% in 2020 than baseline scenario in tab.10.

Tab.9 Comparison of water consumption from 2010 to 2020 scenario in Tianjin

(Unit: millions of m^3)

industry	2010	benchmark		Scenario 01		water-saving rate of ten years
		2015	2020	2015	2020	Scenario 01
agricultural	1120	1312	1445	1248	1311	9.3%
general water industry	150	248	402	227	337	16.2%
high water industry	333	422	524	382	438	16.4%
construction	25	36	53	34	48	9.4%
general water tertiary industry	108	222	418	210	375	10.3%
high water tertiary industry	43	60	82	52	62	24.4%
subtotal	1779	2300	2924	2153	2571	12.1%
residents water	349	422	509	401	442	13.2%
Total	2128	2722	3433	2554	3013	12.2%

Tab.10 water supply and structure of different water resource from 2010 to 2020 in Tianjin (units: millions of m^3, %)

Water resource		2010	benchmark		Scenario 01	
			2015 年	2020 年	2015 年	2020 年
Water supply	Water of conservancy	1493.5	1789.1	2053.0	1698.1	1855.0
	Tap water	631.3	905.2	1331.2	824.9	1095.1
	Recycled water	12.4	21.7	34.6	23.8	41.7
	water of desalination	3.0	7.0	14.1	8.4	20.6
	Total	2140.2	2723.0	3432.9	2555.2	3012.5
Water structure	Water of conservancy	69.8%	65.7%	59.8%	66.5%	61.5%
	Tap water	29.5%	33.2%	38.8%	32.3%	36.4%
	Recycled water	0.6%	0.8%	1.0%	0.9%	1.4%
	water of desalination	0.1%	0.3%	0.4%	0.3%	0.7%
	Total	100.0 %	100.0%	100.0%	100.0%	100.0 %

Impact on industrial structure. Tab.11 shows that the water price adjustment promote to optimize industrial structure, the proportion of tertiary industry increases and the proportion of agricultural and secondary industries decrease which coincide with China's future adjustment trend of industrial structure. It is conducive to promote the coordinated development of industrial structure through improving water price, developing users' price difference and increasing relative price of conventional and unconventional water.

Tab.11 the added value (benefit?) and structure from 2010 to 2020 in Tianjin

industry /year		2010	benchmark		Scenario 01	
			2015	2020	2015	2020
value-added（One hundred million）	agriculture	121	147	182	148	180
	secondary industry	4705	8549	13612	8540	13580
	industry	4145	7354	11548	7347	11526
	tertiary industry	3079	6635	13419	6627	13397
	total	7906	15331	27214	15315	27158
Structure of	agriculture	1.54%	0.96%	0.67%	0.96%	0.66%

value-added	secondary industry	59.5%	55.76%	50.02%	55.76%	50.01 %
	industry	38.94%	43.28%	49.31%	43.28%	49.33 %

Analysis of the water use efficiency of the main departments. Raising water price leads to gradual decline of water consumption of ten thousand GDP, and increase water efficiency. Water charges proportion of gross income are synchronized with the growth of water price. In the same economic background, water charges rates are higher when water price increases more. However, long series of simulation results show that resident water charges rates in the two policy scenarios present a declining trend, which indicates the income of residents in Tianjin increases rapidly in the future, and the increase of water price is less than the increase of income in our setting scenario. Both of the two water price scenarios that receive the objectives of water supply and consumption do not result in the substantial increase of water charges rates, indicating that water price has some space to growth.

Tab.12 Efficiency of water use from 2010 to 2020 in Tianjin (unit m^3 /ten thousand, L /person, d, m^3)

行业		2010	benchmark		Scenario 01	
			2015	2020	2015	2020 年
production	agricultural	921.68	888.90	804.29	845.42	727.62
	general water industry	5.92	5.74	6.19	5.27	5.19
	high water industry	20.61	13.93	10.39	12.63	8.70
	construction	4.39	3.01	2.57	2.87	2.33
	general water tertiary industry	3.88	3.70	3.43	3.50	3.08
	high water tertiary industry	14.84	9.53	6.64	8.28	5.04
	subtotal	22.48	15.01	10.74	14.07	9.47
live	residents water	74.31	71.37	72.51	67.83	62.94
water consumption of ten thousand added value		26.92	17.75	12.62	16.68	11.09

Tab.13 Water charge rate from 2010 to 2020 in Tianjin (units: %)

index		2010	benchmark		Scenario 01	
			2015	2020	2015	2020
Integrated water charge rate (%)		0.20%	0.17%	0.15%	0.24%	0.34%
water charge rate Of industry (%)	agricultural	0.84%	0.92%	0.90%	1.04%	1.15%
	general water industry	0.11%	0.12%	0.14%	0.15%	0.22%
	high water industry	0.16%	0.11%	0.09%	0.13%	0.12%
	construction	0.05%	0.03%	0.03%	0.03%	0.03%
	general water tertiary industry	0.13%	0.15%	0.15%	0.27%	0.54%
	high water tertiary industry	1.14%	0.83%	0.62%	1.41%	1.81%
Water charge rate of resident (%)		0.50%	0.28%	0.17%	0.36%	0.28%

5 Conclusions

According to water supply plan of Tianjin, Total water supply of 2020 is constrained to 3.1 billion m^3. According to comparison and feasibility analysis, scenario 1 is recommended as water price adjustment scenario of 2020 in Tianjin. Various types of users' relative price relationship of different water resource are shown in Tab.14.

Tab.14 various types of users' relative price relationship of different water resource are recommended in 2020 in Tianjin

subentry	general water industry	high water industry	construction	general water tertiary industry	High water tertiary industry	resident
Water of conservancy	1	1	1	1	1	1
Tap water	6.9	13.9	6.9	6.9	40.6	4.1
Recycled water	1.4	1.4	0.0	1.4	1.9	0.0
water of desalination	1.9	1.9	0.0	0.0	0.0	0.0

User's price difference of tap water price is shown in Tab.15.

Tab.15 User's price difference of tap water price of are recommended in 2020 in Tianjin

user	general water industry	high water industry	construction	general water tertiary industry	High water tertiary industry	resident
price difference（times）	1.7	3.4	1.7	1.7	5.8	1.0

Note: residents of water is benchmark

Price difference relationship of 2020 between agricultural and urban water from conservancy is that agricultural water price 0.4¥/m^3, only 20% of the city users that is 2.16¥/m^3.

Scenario 1 can get water consumption of distinguishing different user and water resource, and further get integrated water price of Tianjin recommended scenario, as shown in Tab.16.

Tab.16 integrated water price of Tianjin in 2020 recommended (unit: ¥/m^3)

Water resource	Water of conservancy	Tap water	Recycled water	Water of desalination
Integrated water price	0.91	24.89	3.10	4.00

The simulation results show that the recommended scenario does not have a greater adverse impact on economy, and have positive significance of promoting water-saving and optimizing industrial structure. The future water price adjustment of Tianjin is put forward as followed:

1) Continue to improve integrated water price gradually and promote water-saving

Overall, production and living water of Tianjin is relatively sensitive to price, and have high water-saving potential. Therefore, Tianjin should make full use of price leverage, and use economic instruments to promote water-saving.

2) Respectively improve water price of industry-specific and water-specific

In accordance with various sensitivity of different industries to water price, it is recommended that water prices from tap of the high water service should be improved in prior, and followed by high water industry. Improving residential water price belongs to the third level, and agricultural water prices are belongs to the fourth level.

3) Raise water price mainly by improving water resource charge

In order to reflect ease contradiction of water shortage by raising water price, water price are raised through improving water resource charge. Water resource charge owns by the government,

and is not taken as the income of the water company, which is conductive to rational allocation of the proceeds. For example, water resource charge can use as subsidies for poor families, or support water-saving technology research. Meanwhile it can avoid monopoly enterprises gain the benefit from improving price effectively.

4) Encourage to use unconventional water through financial subsidies

Since conventional water is limited, unconventional water including recycled water and water of desalination should be encouraged to use. This is one of the important strategic for cities of serious water shortage including Tianjin. It helps to ease supply pressure of conventional water, as well as establish economic production of clean recycled.

Based on currently technological level, the cost of recycled water and desalinated are relatively high. Low-cost policies should be taken in order to promote the use of unconventional water. However, the cost of water supply cannot compensate. Financial subsidies or refund can compensate water supply enterprise of unconventional water source, and encourage unconventional water utilization.

Reference

[1] Liu zhaohui，Hu hua，Review and exploration of price system partition method[J]. Science and technology economy market，2006,09,150-151

[2] Hu changai. The source price system, price formation mechanism and price form [J].Economic Issues in China，1992,04,1-7

[3] Tang libin, Mao zhifeng. Studies on water pricing system of Beijing Municipality[J]. ,China Water Resource，2009，（10）:47-52

[4] Sun guosheng，Sun fenghua. Recommendations on establishing reasonable water price system in Beijing [J]. 2003 Annual Conference Proceedings，2003:827-831

[5] Ariel Dinar. The Political Economy of Water Pricing Reform, 2000.

[6] LIN CRASE,SUE O'KEEFE and BRIAN DOLLERY. Water Pricing: Practical Perspectives And Customer Preferences. Economic Papers Vol. 27 No. 2 June 2008:200

[7] Tianjin Municipal Water Affairs Bureau. Tianjin city water resources bulletin，2007~2010

[8] National Bureau of Statistics of China. Tianjin Statistical yearbook [M].Beijing: China Statistics Press，2008~2011

[9] Zhang Yaxiong, Li Jifeng. Correlation of Oil prices, trade subsidies and China's economic development. Reform. No.8:49-57. 2010.

[10] Anna Hurlimann, Jennifer McKay. Urban Australians use recycled water for domestic non-potable use—An evaluation of the attributes price, saltiness, color and odor using conjoint analysis. Journal of Environmental Management 83 (2007):94，96

[11] Dixon, P.B. and Maureen T. Rammer. Dynamic General Equilibrium Modeling for Forecasting and Policy. North-Holland. P88, 243. 2002.

[12] Dixon, P.B., Parmenter, B.R., Sutton, J., and Vincent, D.P.. ORANI: A Multi-sectoral Model of the Australian Economy, North-Holland, Amsterdam. 1982.