Price System for Water Supply and Its Economic Impact Analysis

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ABSTRACT

In light of the actual economic circumstances and water price level, the CGE model to simulate the price policy for multiple water sources is modified and expanded. A water price reform plan is proposed to meet water-saving requirements and water resources allocation. The affected scale and scope for implementing the water price policy is evaluated on a quantitative basis. Research results indicate that a reasonable water price system in Tianjin in 2020 should be set up as follows: the comprehensive tap water price stands at 4$/m³ , the tap water price for industrial, administrative and business service sectors is 2.4$/m³; and the tap water price for special industry and domestic use are 8.8$/m³ and 1.4$/m³ respectively. The adjusted water price will bring about tangible results to water resources allocation optimization and water conservation. Although most sectors are negatively affected to varying degrees after raising the water price, particularly the lodging and catering sectors, a 100% water price rising will produce only little impact on price index, and sectoral output and employment will not cause economic fluctuations or social instability. Water price adjustments, as long as it is reasonable, will be more positive than negative on the whole. Research outcomes will provide a scientific decision-making basis for formulating the local water price policy.

Key words: Price system for water supply; CGE model; multiple water source substitute module; economic impact; water conservation

1 INTRODUCTION

The Most Stringent Water Resources Management System was clearly proposed In the No. 1 Document in 2011, in which it was stipulated that water price reform should be vigorously advanced to bring the adjusting role of water price into full play. Important polices on water price reform have fully demonstrated the current water price reform is a challenging but crucial task. Tianjin is located in the Haihe River Basin, a seriously water-stressed area in North China. At present, being relatively low in its water price, its water use structure needs to be further optimized. Its unconventional water has far from been fully utilized and optimized, and its water resources still need further allocation. Tianjin has an unreasonable water price system, so the role of its water price fails neither in relieving water supply-demand conflict under the market force nor in promoting the reasonable allocation and highly efficient use of water resources. It has become a crux perplexing the government and water management decision makers about how to scientifically formulate a reasonable water price reform plan, solve water crisis and minimize the negative impact on social economy. Many scholars both at home and abroad have carried out in-depth research surrounding this issue. The most effective and widely applied technical analysis tool is CGE model. With a set of equations, CGE model can depict in detail how various water users, under the constraint of a series of optimal conditions, to choose best commodity combinations (including services, investment, leisure and water goods) for highest possible benefits. It can describe the function of systems related to all kinds of socio-economic activities, quantitatively analyze the interactive relationships between water price reform and socio-economy, and comprehensively evaluate the positive and negative impacts of water price reform. As a result, the rationality and feasibility of water price reform plan can be analyzed and the affected scale and scope of water policy can be precisely decided, thus helping decision makers to control the risk of water price reform, improve decision-making efficiency and benefits, as well as reduce or avoid faults （Dixon,1982, 2002, Horridge, 2001）.

Some existing literature stresses the economic impact of water price. Betck (1991) presented a computable general equilibrium model (CGE) for the Balearic Islands and specifically performed to analyze the welfare gains associated with an improvement in the allocation of water rights through voluntary water exchange. Becker (2002) dealt with a proposed price reform and its economic impact. The results showed that combining both demand and supply management can postpone desalinization projects by more than 20 years, increasing the marginal price of water to its real value damages the marginal users. Shen(2004) used CGE model to calculate water marginal price, but did not run the water as one of the production factors or a single department into CGE model, so it can't directly calculate water price. Calzadila (2007) used the new version of the GTAP-W model to analyze the economy-wide impacts of enhanced irrigation efficiency. The results indicated that a water policy directed to improvements in irrigation efficiency in water-stressed regions is not beneficial for all. For water-stressed regions the effects on welfare and demand for water are mostly positive. For non-water scarce regions, the results are more mixed and mostly negative. Maria (2007) ran five alternative simulation exercises, all dealing with the economic impacts of restricted water supply. There are regional winners and losers from water supply constraints. HASSAN R (2008) employed computable general equilibrium (CGE) to examine the economy-wide impacts of selected macro and water-related policy reforms on water use and allocation, rural livelihoods and economy at large. The concept of integration of a modified CGE model TERM-H2O, with a weekly/fortnightly stochastic model for water prices being introduced (Schreider, 2009). Increasing water price can produce both positive and negative economic impacts. By paying a relatively small up-front fee (option price), farmers are protected against adverse water price movements in the future and still allow themselves to benefit from potential water price advances. Qin (2014) used CGE model to simulate and analyze water price policy by setting up the water element as the basic element.

However, the literature above used CGE model to describe the impact of water price changes on socio-economy, but not describe in detail the different effects of prices for various kinds of water sources. So it cannot reflect the impacts of various types of water price changes on optimal water resources allocation, water use structure adjustment as well as socio-economy. Therefore, it will be hard for decision makers to select the scientific scheme for making the right judgment. In the light of the characteristics of different water sources in Tianjin, a CGE model to simulate multiple water source price policy is modified and expanded by dividing water commodities into four types, namely raw water with substitute elasticity, tap water, reclaimed water and desalinated seawater. Positive and negative impacts of prices for various types of water sources and water price adjustments can be analyzed on a quantitative basis, the rationality and feasibility of water price adjustment degree are evaluated, the sensitivity degree of water policy implementation to socio-economy is revealed, and all constitute a basis for water resources economic policy formulation and water adjustment risk control.

2 STUDY METHOD AND THEORY

From the perspective of system theory, this paper studies the reform plan and impact of water supply price system as a whole, that is, a system of multiple water sources for different water users.

2.1 Theoretical Framework of Water Supply Price System

Water supply price system is also called water supply price structure. It is the total sum of comparison price and difference price of different water commodities based on the values formed from water commodity production and supply. (NI Hongzhen, 2014).

According to the available water supply in Tianjin, comparison relationship of water supply price in Tianjin refers to the ratio between four different types of water commodity prices of raw water, tap water, reclaimed water and desalinated seawater. Price comparison relationship in raw water relations includes the price comparison between local water and diverted water, and comparison between surface water and groundwater, etc.; Price comparison relationship in urban tap water include each link in price composition, such as ratio between water resources fees, raw water fees, water distribution fees by the tap water company and sewage water treatment fees. Formulating a reasonable price comparison relationship is instrumental in promoting unconventional water use and protecting the local groundwater.

The price difference relationship of water supply price system in Tianjin refers to the price difference relationship of the same water supply in the process of production for different users and regions in different seasons with different qualities and quantities. Currently, differentiated water prices are adopted in different industries in Tianjin. For example, the water price of special industry is higher than that in general industry and for domestic use. Progressive metering water price is adopted for domestic water use. Non-resident users shall pay for the water more than the rated amount or that beyond the water plan. High price will be charged for water in high quality and during the peak hours. A reasonable price difference can promote water-saving and reconcile the conflicts between supply and demand of water commodities.

2.2 Design of Multiple Water Source Substitute Module of CGE Model

To systematically illustrate the price difference relationship among diversified users of different water sources in water supply system, various types of water sources are analyzed in detail on a trial basis in this study. The water production and supply departments are divided into departments for raw water, tap water, reclaimed water and desalinated sea water based on conventional CGE model (Dixon,1982, 2002, Horridge, 2001, Khalid, 2014, Panida, 2013）. In terms of model design, CES functions are adopted to reflect the substitution relationship of various water types. Telescopic techniques for multi-scale analysis are also applied to achieve the substitution between various types of water sources.

3 CASE STUDY

3.1 Study Area

Rapid economic development, pollution and climate change are all responsible for the water scarcity in Tianjin. With per capita water resources amount as 160m³, Tianjin ranks the end of the country. Even adding inflow and diverted water, per capita water resources only stands at 370m³. Tianjin's conventional water sources are quite single with a serious groundwater overexploitation. Tianjin mainly relies on fully exploiting all kinds of water resources to meet its needs for socio-economic development. Water supply for urban production and domestic use depend mainly on diverted water sources, added by some local surface water, groundwater and a small part of reclaimed water and desalinated seawater through tapping water use potentials and technological innovation. Tianjin's current water price level is still relatively low without giving a prominent role to water price leverage and the structure of comparison price, and its difference price is far from being reasonable.

3.2 Parameters Processing

Production functional parameters, the CES parameter estimate (factor for substituting the elasticity), CET elasticity, resident demand expenditure elasticity, all adopt the parameters of China Version of ORANIG — model involving 122 departments and developed by MONASH University.

Some parameters are adjusted as follows: Labor demand elastic SLAB: this paper adopts the estimated data of 0.243 by the Chinese Academy of Social Sciences (CASS) (Pang ,2005); The elasticity of consumption price: the model in this paper takes CASS's PRCGEM model data 4(Zhao ,2009); Arminton elasticity refers to substitute elasticity of commodity consumption between imports and domestic goods, parameters in SICGE model(zhang, 2010; Li, 2012) are adopted and weighted average values of some departments are taken.

3.3 Simulation Analysis

(1) Scheme Design

The first step is to set a baseline scenario by assuming the water price system maintains at the current level and the natural socio-economic development trend by 2020. From 2007 to 2010, it mainly aims to assign the variables of the model on the basis of the actual socio-economic development in Tianjin. From 2011 to 2020, it aims to predict the socio-economic development in Tianjin according to the 12th Five-Year Period Plan and 2020 Outlook. Assuming that water price stays unchanged with the level in 2010 during the 12th Five-Year Period, and water use grows at an average rate of 5.1% with the total water use up to 2.726 billion m³in 2015 (not considering water use for ecological purposes). During the 13th Five-Year Period, water use grows at an average rate of 4.7%, with the total water use up to 3.44 billion m³in 2020. It will be hard for Tianjin to satisfy such high water demand by 2020. Therefore, it is particularly important to build a reasonable water price system and bring the role of market mechanism into play.

Second, a policy scenario is simulated. Based on the baseline scenario, the water price is enhanced by raising the water use fees. A policy-oriented scenario is thus established. The gap of the simulated results between the policy scenario and baseline scenario is the impact of water price adjustment on water resources allocation and its socio-economy.

After comparing various schemes, water price policy schemes can meet the targets for the redline of total water use quantity control and for optimal water resources allocation, with the most approximation to regional economic development objectives, as indicated in Table 1.This scheme assumes that the prices for reclaimed water and desalinated sea water will stay unchanged in various industries by 2020, the tap water price of special industries will grow by 150%, water prices in industrial, administrative and economic service sectors will increase by 100%. Calculations conclude that the total water use in Tianjin will drop to 2.87 billion m ³.

Major impact indicators on socio-economy, including water-saving amount, water use structure, GDP, consumer price index and sectoral output are evaluated for the rationality and risk by building upon information of the impact of selected water price scheme.

Table 1 Water price policy simulation scenarios of different water sources and users in Tianjin (unit: $/m ³)[1]

Scenario	User Resource	Agriculture	Industry	Administration	Business service	Special industry	Resident
Status	Raw water	0.032	0.173	0.173	0.173	0.173	0.173
	Tap water		1.202	1.202	1.202	3.510	0.705
	Recycled water		0.497	0.497	0.497	0.497	
	Desalinated water		0.641	0.641	0.641	0.641	
Policy	Raw water	0.064	0.346	0.346	0.346	0.443	0.346
	Tap water		2.404	2.404	2.404	8.775	1.410
	Recycled water		0.497		0.497	0.497	
	Desalinated water		0.641		0.641	0.641	

(2) Water-saving and Water Resources Allocation Effects

As shown in figure 1, by adopting the selected water price reform scheme, 560 million m ³ of water can be saved with salient water saving effects up to a 19% saving rate. The price difference between the special industry and other industries is further expanded, which is more conducive to promoting the reform of production and use modes of water intensive industries, and to saving more water and reducing emissions from the demand side. Water saving rate of special industry reaches 24% and the proportion of water use is down by 0.7%; water saving rate in service sector reaches 16% and the proportion of water use is up by 0.4%; the proportion of domestic water use is also on the rise. Rising prices have positive implication to improve the structure of water use.

Water price rising will result in a bigger proportion of reclaimed water and desalinated seawater. Among various water sources, the proportion of reclaimed water, desalinated water and raw water is respectively up from 1.0% to 1.6%, from 0.4% to 0.7% and from 59.8% to 61.1%, while the tap water is down from 38.8% to 36.6%. Water price adjustment reflects the price advantage of the unconventional water, thus meeting the target of promoting the use of unconventional water, including the reclaimed water and desalinated water.

[1] Note: special industries refer to water intensive ones, including non-metallic mineral ore industry and other mining industries, food production and tobacco processing industry, textile industry, paper-making industry, chemical industry, non-metallic mineral product industry, electric power and heat production and supply industry, lodging and catering industry, resident services and other services . Administrative sector\industry refers to public administration and social organization. Business service industry refers to the tertiary industry.

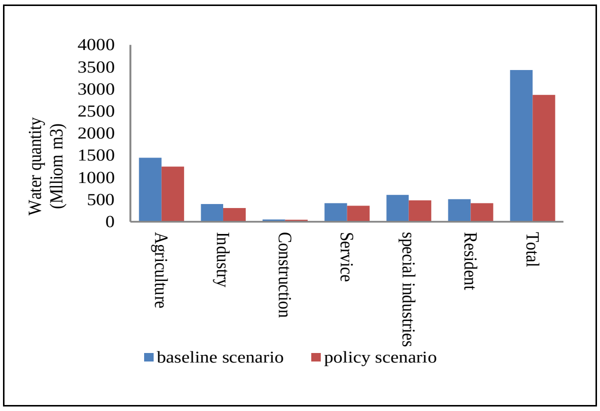

Figure 1 Water use quantities of different users under various schemes in 2020

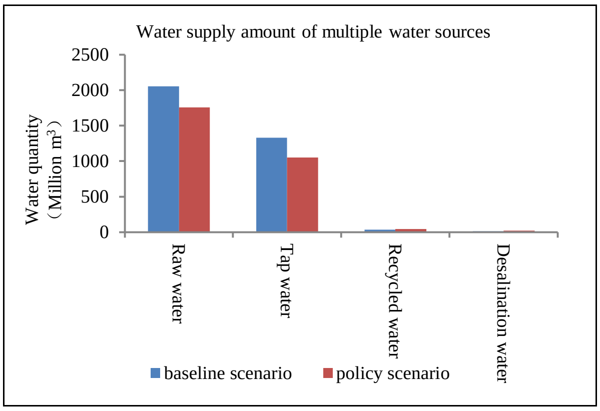

Figure 2 Water use quantities of different water sources under various schemes in 2020

(3) Impact on GDP and CPI

From the perspective of GDP in income method, Y = f (K, L), land and technology improvement are exogenous factors and investment has not yet produced capital in short term. Economic growth mainly depends on the employment level. If the government raises the water price, the production cost of the water user increases, the relative price between the average wage to the comprehensive factor rises, thus causing less employment. In the first year, the employment level declines by 0.04%, resulting in a 0.01% fall in GDP. From the viewpoint of GDP in spending method, GDP = C + I + G + X - M, the water price adjustment leads to a rise in output price and the consumer price index (CPI), equivalent to reduction of residents' income with the residents' consumption falling by 0.02%. Tianjin, as an open major economy in China, the prices for import and the inbound products will not change too much. Rather, if prices for its export and the outbound products increase by 0.05%, its trading conditions will exacerbate with a decrease of 0.02%. Due to the impact of shrinking demand within Tianjin, its import and the inbound products fall by 0.03%.

Since the government takes a water price reform approach featuring small but quick steps, the water price registers a year-on-year growth than the previous year. So the impact on macroeconomic indicators of any year will be an accumulated impact of water price during all the previous years. On the whole, the impact will be subject to lasting influence. The long-term employment level falls to a certain value with fixed returns of the capital rate, and the economic growth mainly relies on the change of the capital stock. Being more expensive than the labor force, the capital is required less and causes a 0.17% decrease in real GDP. For GDP in spending method, residents' consumption (-0.13%) decreases under the influence of residents' income and CPI. The CPI (0.36%) increases under the influence of a rise in output price. A decline in capital marginal output and investment returns causes a decrease of 0.47% in investment. But the negative impact of export and the outbound products is gradually becoming smaller standing only at 0.1% in 2020. Export of agricultural products and the outbound products constitute a major contributor (a 1.6% of increase relative to the baseline scenario in 2020). Compared to other products (2%), the price of agricultural products export (1.6%) increases by a small margin, thus showing that agricultural products in Tianjin are relatively cheap. Import and the inbound products decrease by 0.12% owing to the shrinkage in regional demand.

Short-term labor and real wages are rigid and change slightly. Compared to the comprehensive factor price, the average wage rises with a declining employment. Long-term labor market adjustment mechanism assumes that a decline in real wages will force the employment level back to the baseline. The impact of the employment level and real wages in any year is subject to the accumulated effects of water price rise during all the previous years. By 2020, Tianjin's employment level and real wages, relative to the baseline scenario, will register - 0.24% and -0.42% changes respectively. The number of employee will reduce by about 28,000.

Generally speaking, a small degree in water price rising will not cause economic fluctuations or social instability.

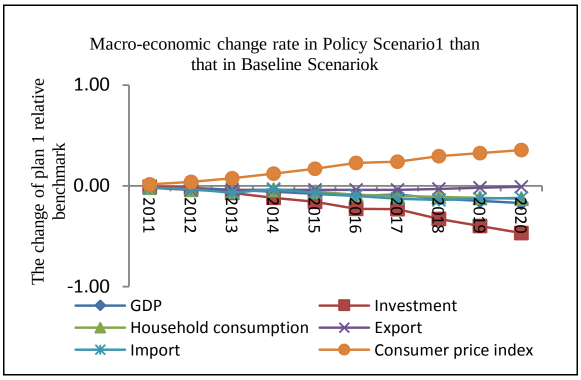

Figure 3 Macro-economic change rate in Policy Scenario1 than that in Baseline Scenario（%）

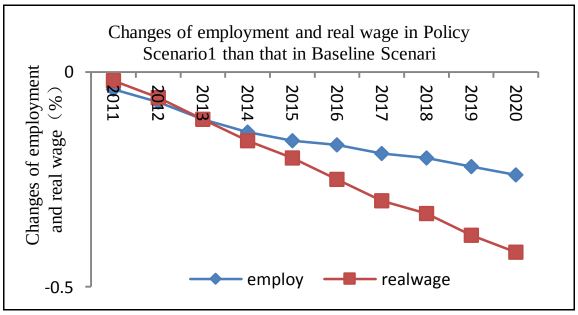

Figure 4 Changes of employment and real wage in Policy Scenario1 than that in Baseline Scenario（%）

(4) Impact on Sectoral Output

Prices of reclaimed water and desalinated seawater of water maintain the 2010 levels, lower than the raw water price and tap water price, so the demand and the output increase. The total output in reclaimed water and desalinated seawater sector increases by 10.42% and 10.42% respectively, while the total output in raw water and tap water sectors decreases by 13.66% and 12.16%, respectively. Water price adjustment has played an important role in optimizing the structure of water sources.

Water price increase leads to changes in the relative competitiveness of various industries. The lodging and catering industry witnesses the biggest drop in total output among various industries (0.59%), with its major products mainly for intermediate input (60%) and residents' consumption (37%). Due to the shrinkage in its demand and the decrease in the output of its partial industries, Tianjin's demand decreases, so the total output decreases. What followed is the food production and tobacco processing industries. Consumption demand decrease in Tianjin results in a decline by 0.47% in the output. The third are resident service industry and other service industries, whose products are mainly used for government consumption (77%). In the model, government consumption and residents' consumption change along the same direction, so the consumer demand shrinkage causes the sectoral output to fall by 0.43%.

Agriculture is water intensive, but its total output increases by 0.24%, mainly because of a relatively small increase in the raw water price for the agricultural use. The price rising degree of agricultural industry output is smaller than that of other products (2.5%). It shows that agricultural products in Tianjin are relatively cheap, and the increase in the demand of agricultural products produces a positive impact.

It is because water price rising has little impact on production cost that the output grows in non-water intensive industries such as electrical machinery and equipment manufacturing, handicrafts and other manufacturing industries. These two industries are relatively capital-intensive industries, elements such as capital and labor flow to these two industries when the other industries received adverse impacts, leading to an increase in output. Electrical machinery and equipment manufacturing industry registers relatively large variations in output (0.11%), mainly because approximately 50% of their products are aimed for export. The export price variation (1.9%) is smaller compared to the average rising degree of other products (2%). So the export demand becomes bigger, thus increasing the total output.

Water price rising causes the decrease in water demand in water intensive industries. So the total output decreases and water resources flow to industries for highly efficient water use. It will be beneficial for supporting the national strategic adjustment of industrial structure. Figure 3 shows an increase in the proportion of the tertiary industry and a decrease in the proportion of primary industry and secondary industry, which is consistent with China's planning for adjusting its industrial structure.

Table 2 Industrial structural indicators under various schemes in 2020

Industrial structure	Baseline scenario	Policy scenario
Agriculture	0.67%	0.66%
Industry	50.02%	50.00%
Tertiary	49.31%	49.34%

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Positive and negative effects caused by water price changes have been simulated and quantitative calculation results are obtained.

Positive aspects of raising water prices are mainly embodied in the following: (1) Constraint of water demand and water savings (up to 560 million m^3) will promote highly efficient use of water resources and rationalization of water use structure; (2) Proportion of service industry increases while the proportion of agriculture and industry decreases, which are conducive to optimizing the industrial structure and a shift to a production structure for highly efficient water use.

Negative aspects of raising water prices mainly include: (1) The total output in most of the industries decline with lodging and catering industry, food production and tobacco processing, residents service and other services falling among the most. (2) The social economy is negatively affected, with GDP falling by 0.17%, employers decreasing by around 28,000 people, CPI rising by 0.37%. But a small degree in water price rising will not influence macro-economy too much, and will not cause economic fluctuations or social instability.

4.2 Recommendations

To reduce and avoid the negative impact of water price reform, recommendations are proposed on the basis of this study: (1) Short-term fall in GDP is mainly caused by falling employment, employment levels should be raised in the short term. Long-term decline in GDP is mainly caused by the falling capital. So it is conducive to stabilizing GDP growth speed by increasing investment. In the long run, the development of water-saving industry should be accelerated to realize the product structural upgrading, optimize the industrial structural adjustment and sustainable economic development. (2) The tap water price of the special industry should be a focus for price rising. (3) For those disadvantageous industries or sectors with higher water use cost and lower input-output ratio, measures such as reduction in or exemption of relative taxes as well as water-saving subsidies can be taken to make up for the taxpayer's cost, maintain normal production activities, reduce the adverse effects caused by the reform of water price and bring the risk of water price reform under control.

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