Water Price Regulation Model Establishment &Influences on Urban Water Resource in Harbin, China

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Abstract. Water price regulation is an effective way to adjust the water imbalance. In the study, Harbin residents and industry water price regulation models are established to study the effects of water price on water supply and demand with society developing in the future. Water prices of Harbin are predicted by comprehensively considering the market factors and historic trend under the current water supply situation. The results show that the Harbin water contradiction between supply and demand will be alleviated in 2015 and 2020 under water price and society factors adjustment, which varies from 28.43% (2020) to 74.96% (2015) for Harbin.

Keywords: Water price regulation model; Water price forecasting; water resource management.

1. Introduction

In this study, elasticity of demand has been involved for establishing Harbin residential and industrial water price regulation models. Except price elasticity of demand, income elasticity of demand also is added as a society factor, which reflects the facts of society developing. The data on local residential actual water price, residential actual payments for water per month, actual industrial water price; actual total industrial output value, resident water consumption per capita monthly and industry water consumption per year in Harbin over ten years were used. Then, Harbin residential and industrial water price regulation models were built up. Besides, Comprehensive methods are used to forecast 2015 and 2020 Harbin residential and industrial water prices. Many factors were considered, such as the contradiction between water supply and demand, market factors and historic tend. In the end, based on the water price regulation models and used the forecasted water prices and forecasted other parameters (unary linear regression method), the effects of water price on water demand and supply balance of Harbin were analysed. And the results of water price adjustment were discussed and well explained.

2. Establishment of Harbin Water Price Regulation Models

Based on the elasticity of demand model (Monica, 2012), the residential water price regulation model is built to analyse the influence of residential water price on consumption of residents.

$$Y_r = \alpha X_1^{P_r} X_2^{I_r} \quad (1)$$

whereas α is a constant; X_1 is local residential actual water price and X_2 is residential actual payments for water per month. P_r and I_r represents price elasticity of demand and income elasticity of demand, respectively; $Y_r$is resident water consumption per capita monthly.

The industrial water price regulation mode is established with the same method,

$$Y_i = \beta Z_1^{P_i} Z_2^{I_i} \quad (2)$$

where β is a constant; Z_1 is actual industrial water price; Z_2 isthe actual total industrial output value; P_i and I_i represents price elasticity of demand and income elasticity of demand ,respectively; Y_i is industry water consumption per year.

According to the water regulation models,Harbin residential water price regulation modelhad been formulated(Ma T,2013).

$$y_r = -0.010x_1 - 0.876x_2 + 7.102 \quad (3)$$

R^2=0.94, which means that stepped water price model can make residents water price more reasonable and playa positive role inenhancingwater conservation. Both water price and disposable income per capita have negative impacts on water consumption.

The data on the Harbin industrial water price regulation model were in the Table.1 and used in the form of logarithm (y_i=lnY_i, z_1=lnZ_1, z_2=lnZ_2). The model is shown as followed.

$$y_i = -1.5z_1 + 1.18z_2 + 2.94 \quad (4)$$

R^2=0.623, it means the industrial water price accords with market supply and demand and has a regulated function. Water price has a negative impact on water consumption, while actual total industrial output value has the opposite effect. For industry the income elasticity of demand and price elasticity of demand is 1.18 and -1.5, respectively.

Table.1. Data on industrial water price regulation (Harbin ,1991-2011)

Year (1995 as the base year)	Industry water consumption per year (10^4m^3)	Actual Industrial water price (RMB/m^3)	Actual total industrial output value (Billion RMB)
1995	13455	53.1900	1.7500
1996	16975	59.8349	1.8993
1997	18902	67.0471	1.8658
1998	18842	70.0332	1.9077
1999	16801	78.1379	1.9688
2000	14705	90.5982	2.4908
2001	12598	97.6767	2.4662
2002	12280	103.9478	3.0136
2003	11348	115.6788	3.0472
2004	14685	115.2041	3.0200
2005	16464	143.7696	3.2473
2006	20168	162.2947	3.2376
2007	23654	175.3395	3.3172
2008	24707	190.2414	3.4282
2009	23522	223.5405	3.3863
2010	23490	254.2447	4.9848

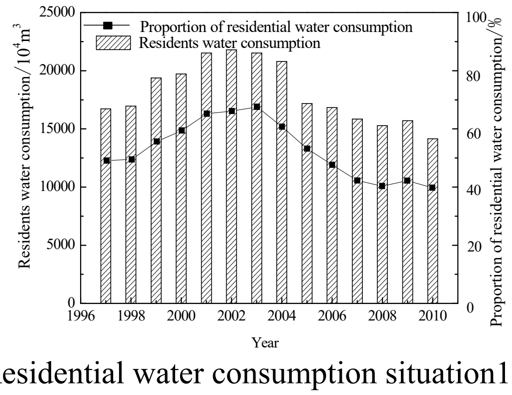

Fig. 1. Residential water consumption situation1997-2010

3. Water Price Forecasting in Harbin

In order to analyze the effects of water price regulation, Harbin water prices of 2015 and 2020 need to be predicted. Stepped water price model was used to forecast water price. As stepped water price model was determined by the water consumption, Harbin water supply and demand amount in 2015 and 2020 was calculated under the current mode of water supply in Harbin. At present, water supply in Harbin mainly comes from Mo Panshan reservoir and groundwater. Mo Panshan reservoir can supply 90 × 10^4 m^3/day after completion of the second phase, which 32850 × 10^4 m^3 / year. According to the Harbin city groundwater investigation report, the maximum groundwater supply in Harbinis 5253.354 × 10^4 m^3 / year.Therefore, based on the current water supply mode in Harbin, water supply is 38103.354 × 10^4 m^3 / year in 2015 and 2020. Referring to the average proportion of resident water consumption in Fig 1, the resident water consumption per month in 2015 and 2020 can be obtained as 9.699 and 8.8787 m^3/household, which belong to the 0-10 (m^3/household) in the Harbin resident water price schemes ofstepped water price model in Table.2.

Table.2. Harbin residents water price schemes of stepped water price model (Ma T,2013)

Water consumption monthly(m^3/household)		0-10	10-20	Above 20
Alternative water price (RMB/m^3)	scheme one	2.47	3.08	7.41
	scheme two	3.09	4.61	15.34
	scheme three	3.71	6.15	22.26

However, from the perspective of the residents demand water amount (Fan Y,2013), residents water consumption per month wascalculated as 11.1325 m^3/household and 11.873m^3/household in 2015 and 2020, both of which were among 10-20 m^3/household according to Table.2.

To sum up, there is a contradiction between supply and demand pricing. Therefore, the trend in Fig. 2 and water price in Fig. 3 are been considered. Because of water shortage being more prominent, water price based on water demand is preferred, which benefits water resource saving. Finally, the residential water prices in 2015 and 2020are forecasted as 3.5 RMB and 4.61 RMB. Industrial water prices in 2015 and 2020 are also forecasted based on the Harbin water price trend showing in Fig 2 and 3. Compared to other cities in China, Harbin industrial water price is relative higher. Therefore, 1% growth per year is preferred. Industrial water price in 2015 and 2020 will be 5.5 RMB and 5.78 RMB, respectively.

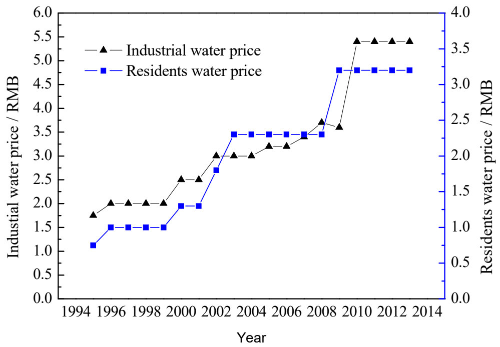

Fig. 2. Residents and industrial water price Harbin 1995-2013

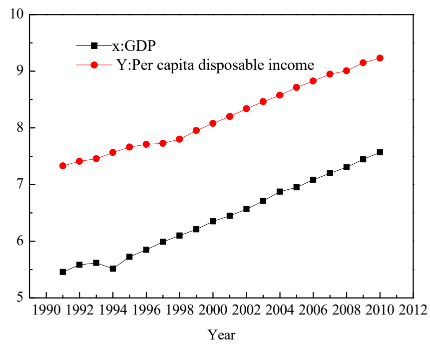

Fig. 3. Industrial water price 1995-2013 Y=0.899x +2.43 R2=0.989

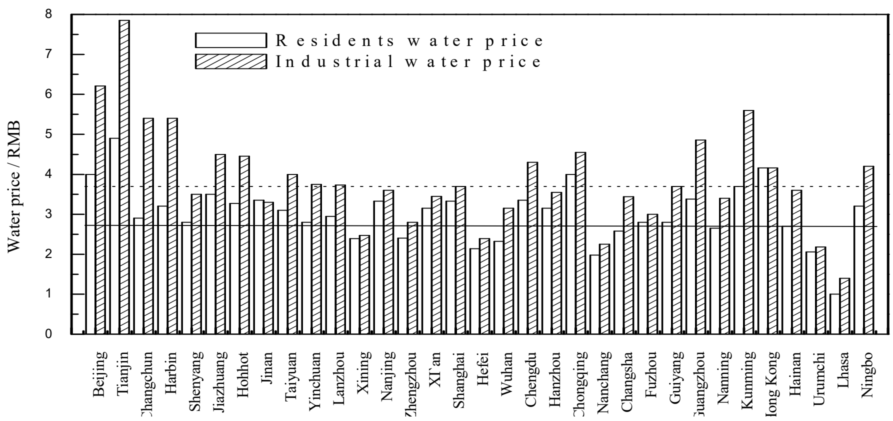

Fig. 4. China provincial cities residents and industrial water prices (March 2012)
Dash line: the average industrial water price is 3.75RMB
Full line: the average residents water price is 2.67 RMB

4. Effect of Water Prices on Water Consumption in 2015 and 2020

After model building and water pricing, the effects of water price regulation models were analyzed and explained. Model 3is used to study the impacts of residential water price. Disposable income per capita in 2015 and 2020 are calculated from the GDP (Harbin,2010) and the equation is formulated in Fig 4. As shown in Table 3, there is a huge difference between predicted (Fan Y,2013) and adjusted water consumption. Predicted household water consumption per month in 2015 and 2020 after regulation is 6.44 and 4.4 m^3/household, both of which are lower than China urban residents living water consumption standard (China, 2002). The phenomenon can be explained by setting three scenarios in Table 4. Higher water price and per capita disposable income will make residents in favour of bottled, branded water products. Furthermore, with water purification techniques becoming more and more mature, reused water will become another important part of water supply chain, which would definitely reshape the water use structure of urban city.

Model 4is used to study the impacts of industrial water price on water demand, and results are shown in Table 5. Industrial water price has an evident regulating effect on the industry water consumption, and significantly promote to save industrial water. This can be explained that factories would like to take positive measures to improve the water use efficiency to save water and meanwhile maintain their own interests.

Table.3. Residents water consumption under water price adjustment

Year	Predicted water consumption(10^4m^3)	Adjusted water consumption (10^4 m^3)
2015	17322.6153	10021.52
2020	19399.9325	7212.114

Table.4. Household water consumption under different scenarios

Unit: (m^3/household monthly)	Formality Type	Saving Type	General Type
Scenario one	5.126	6.744	8.894
Scenario two	5.748	7.47	9.569
Scenario three	3.012	4.282	5.921

Scenario one: reused water instead of toilet water;
Scenario two: commodity water instead of kitchen and drinking water;
Scenario three: The above two scenarios occur at the same time.

Table.5. Industrial water consumption under different scenarios

Unit:10^4m^3	Planned water consumption	Adjusted water consumption
2015	77638.428	36098.26
2020	91317.61	80177.64

Planned value: From the plan for water-saving construction,Harbin. (Harbin, 2010)
Adjusted value: water consumption under predicted water price adjustment.

Table.6.The situation of supply and demand of water resources in Harbin

Unit: 10^4m^3	Under current water supply mode		Under water price regulating	
Year	2015	2020	2015	2020
Residents water demand	17322.6153	19399.9325	10021.52	7212.114
Industrial water demand	77638.428	91317.61	36098.26	80177.64
Ecological water demand	8295	9448	8295	9448
The total water demand	103256.04	120165.543	54414.78	96837.754
Available water supply	38103.354	38103.354	38103.354	38103.354
Imbalance between demand and supply	-65152.689	-82062.189	-16311.426	-58734.4

Ecological water is from the plan for water-saving construction,Harbin. (Harbin, 2010)

The total effects includingin both residential and industrial water price regulation range from 28.43% (2020) to 74.96% (2015) according to Table.6. Under current supply mode, water regulation models can reflect the impacts of water price and society development factors on water consumption. In addition, in light ofincreasing of per capita disposable income and pursuit of a higher life quality, the concept that water of different quality should be used differently will be widely accepted. When water becomes a commodity, the water adjustment mechanism is particularly important to balance the supply and demand of urban water resources.

5. Discussions

The water regulation models building up in the study, included in society factors, which can be used in different cities. For residential water price regulation model, it measured the effects of resident water price and resident income on water consumption, which considered the residents living standard .For industrial water price regulation model, it measured the effects of industrial water price and industrial output value, which considered the industry development situation. These models considered both water price and society factors, which conform to the actual development situation. These factors can be the reasons for water consumption changes. Besides, these models can also be used in other cities to discuss the effects of both water prices and society factors. There are some limitations in the model, first, the models are relative complex than the only water priceelasticity of demand, more data should be predicted, so error will be more. Second, the factors influencing water consumption may be more, but not all concluded in the model.

According the models, the effects on water consumption are from both water price and society factors. In order to decide which factors are more prominent,the data in model 3 and 4 were standardized. The results were as followed.

$$y_r = -0.064x_1 - 1.027x_2 \quad (5)$$

$$y_i = -2.05z_1 + 1.75z_2 \quad (6)$$

From model 5, same increasing in water price and disposable income per capita, the negative effects of disposable income per capita is over 16 times of water price. So the disposable income per capita is the main factor for the reduction in resident water consumption, while the effects of resident water price not distinctive. The results conform to the facts. Due to the pollution in the Songhua River, residents tend to consume morecommodity water, virtual water market is fast developing. From model 6, the industrial water price has 1.177 times impacts on industry water consumption than actual total industrial output value. It means the water price is an effective way for water saving in factories.

In the end, based on the water price regulation model, effects of water prices and society factors on waterconsumption in 2015 and 2020 are analyzed. The imbalance between water supply and demand is still negative, but highly reduced. Industry water saving contributes more to the results. Comparing 2015 and 2020 water imbalance, there is smaller gap to adjust in 2020 than 2015. The reasons may be the water consumption gradually close to the basicwater demand, with technology improving and water reuse.

6. Conclusion

Water price regulation model was proposed in the study. According to Harbin resident, industry water price, residents living standard (disposable income per capita) and industry developing situation (industrial output value), Harbin residents and industry water price regulation built up. The effects of resident's water price on water consumption are not distinctive, while water saving will be a tendency with the improvement of people's living standards. Because the commodity water will be more preferred for, reuse and recycled water will be widely used in future. The effects of industry water price can have significant impacts on factories water consumption. The reason is that the payment for industry water constitutes the production cost, which will decline the benefits. Meanwhile, with the expansion of factories, the water demand will be increased. So, the regulation models provide a method to measure the effects of both water price and society factors, can be used in other cities as well.

Besides, we come up with the Harbin resident and industry water prices in 2015 and 2020. For resident water price, from the demand and supply water condition to decide the water price schemes, but according to the stepped water price model, there is a contradiction. So, history water prices in Harbin and other cities` water prices are used as references. Finally, the residential water prices in 2015 and 2020are forecasted as 3.5 RMB and 4.61 RMB. Industrial water price in 2015 and 2020 will be 5.5 RMB and 5.78 RMB, respectively.

The effects of water price on water consumption also involving in society factors impacts. So in 2015 and 2020, if we conducted higher water price and economy situation as predicted, the water imbalance can be well reduced. For solving the water shortage, except of water price, new water resource and improving the reused water infrastructure constructionalso should be considered. From the resident and industry aspects, this studyprovides the specific instruction for Harbin to make water price and manage water demand and supply in the future.

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