Simulation and Analysis on the Optimal Tax Rate of Water Resources in Yunnan Province

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Abstract. The shortage of water resources has become an increasingly common problem. One of the biggest challenges in China's current economic development is the prominent contradiction between water supply and demand in some densely populated areas. Although Yunnan Province has abundant water resources, due to factors such as precipitation timing, uneven distribution, regional geological conditions and low water-use efficiency, there are also contradictions in water supply and demand. In order to accelerate the transformation of extensive regional water resources utilization and achieve sustainable regional economy development, this paper establishes a Computable General Equilibrium Model (CGE) incorporating water resources elements of Yunnan Province, and simulates the water price changes. The conclusion is that the reasonable tax rate of water resources in Yunnan Province should be about 13%. Considering the corresponding average water price, the average specific tax rate of water resources should be 0.21 yuan/m³.

1. Introduction
Water is an important strategic social and economic resource. Yunnan has abundant water resources, whose total amount ranks third in China. However, its water resources distribution is uneven in space and time, and it does not match with densely populated areas and cultivated land. The plain area, which accounts for 6% of the province's land area, is concentrated two-thirds of the province's population. One-third of the cultivated land, however, only has 5% of Yunnan's total water resources. As the important economic zone in the province, the central Yunnan region has a per capita water resource of only 700m³, which is in a state of water shortage[1]. The residential water price in Kunming, which is a highest water resource price in Yunnan, has not changed since it was set at 2.45 yuan/m³ in 2009. The industrial water price has not changed since it was set at 4.35 yuan/m³ in 2010. At present, domestic water expenditure only accounts for 0.067% of the disposable income of residents, and industrial expenditure only accounts for 0.53% of the total industrial output value[2]. It can be seen that the water price in Yunnan Province is still low, which cannot truly reflect the scarcity of regional water resources and thus cannot present the pricing adjustment function. The market-oriented economic means better compensates for such defects and promotes the efficiency of water use. Among them, the tax policy can internalize the negative externalities of water resources into producers' production costs, regulate production and consumer behavior, reduce excessive water demand, and ease water stress[3-4].

At present, the research on water resources policy is mainly about the impact of water price
changes on industry, utilization efficiency and redistribution. The research methods are mainly CGE, and GIS. Smajgl used the CGE model to study the impact of water price reform on sugarcane cultivation and sugar industry in Australia\(^5\). Zhou Fang and Ma Zhong constructed a water price reform model for Chongqing, and analyzed the impact of water price increase on local high water consumption industry and construction industry\(^6\). In summary, the domestic use of CGE to study the impact of water tax on the economy mainly involves Chongqing and other regions, and Yunnan’s water resources policy simulation study has not been seen.

Based on the principle of maximizing consumer utility, this paper constructs a CGE model with water resources accounts, and focuses on simulating appropriate water resource tax rates to improve water use efficiency, alleviate water shortages, and adapt to the needs of Yunnan’s economic development.

2. CGE Model of Yunnan Province’s Water Resources

One of the characteristics of the CGE Model is to integrate all aspects of the national economy and economic systems into a unified scenario, and to study the impact of external changes on the various sectors of the economic system and the balance achieved after that\(^7\). The water resource tax policy directly affects the water price, which in turn affects market supply and demand, production and utility. This paper construct a basic model involving production, consumption and equilibrium modules. In the modeling process, the following basic assumptions are set: (1) assuming that, at a given technical level, the size of each production sector in the market for complete competition (commodities and factors of production) is constant, and the production water is determined according to the principle of cost minimization; (2) consumers and producers seek maximum utility and profit maximization respectively.

2.1 production module

For producers, given the technical constraints, the principle of cost minimization and profit maximization determines the level of output. In the production process, producers consume water resources, which will increase the producer's production costs and have an impact on the balanced output and final profit. The taxation of water resources is actually internalizing the external costs of the producers' production process.

The production function describes the company’s production profit by maximizing its production profit by choosing to invest in input factors. In the general equilibrium model, the constant elastic function (CES) is mainly used in complex multi-sectoral economic systems. The Cobb-Douglas production function (C-D) is a simplification and is a special case of the CES function. C-D’s simulation effect is not significantly different from the CES simulation result in analyzing the impact of taxation on production. According to the purpose of this paper and the characteristics of water tax, this paper uses C-D function as the production function.

In this paper, the basic elements of the production function are: capital K, labor L, and water resource element R. The respective share parameters are α, γ, and β respectively. A indicates the productivity of technical factors and is independent of other factor inputs. So the producer equation for this article is:

\[Q = F(K, L, W) = Ak^\alpha r^\beta \text{ and } \alpha + \beta + \gamma = 1 \quad (1)\]

Where Q is the total output, and both sides are divided by L to obtain per capita output q, per capita capital quantity k, and per capita water resource quantity r. Then the production function is converted to

\[Q/L = q(k, w) = Ak^\alpha r^\beta \quad (\alpha + \beta = 1) \quad (2)\]

The producer's pursuit of cost minimization, then the producer's per capita cost function is:

\[\text{Min}C(k, l) = (1+T_k)zk+(1+T_r)\theta r+(1+T_l)w \quad (3)\]

\(T_k\) is the applicable tax rate for capital, \(T_r\) is the water resource tax, \(T_l\) is the applicable tax rate for labor, and \(z, \theta, w\) are the price of capital, labor and water resources respectively.

Under optimal producer conditions, the per capita capital consumption k and the per capita water
use amount \( r \) (obtained by the Lagrangian multiplier method) are obtained:

\[
 k = \frac{q}{A} \left(1/(\alpha + \beta)\right)^{-1} \frac{\alpha(1 + T_r)\theta}{\beta(1 + T_k)z} \\
 r = \frac{q}{A} \left(1/(\alpha + \beta)\right)^{-1} \frac{\beta(1 + T_k)z}{\alpha(1 + T_r)\theta} 
\]

(4)

(5)

2.2 Consumer Module

For consumers, they choose a combination of different commodities under budget constraints to maximize utility. Through consumption, part of the resource cost of the producer will be passed on to the consumer, thereby the utility function of the consumer will be changed.

This paper divides consumer demand into government consumption \( C_g \) and household consumption \( C_p \). According to the hypothesis, consumers break even, and labor tax is required, and the cost of water consumption by producers is also transferred to consumers, as shown in (7). The various types of taxes (capital tax, labor tax, resource tax) constitute government revenue, and the government's balance of payments is shown in (8). Still use the C-D consumption function: \( m, n \) represent the consumption coefficient of residents and government respectively, and get the consumer utility function as:

\[
 U = U = C_p^m C_g^n \quad (m+n=1) 
\]

(6)

Household consumption \( C_p \) can be expressed as:

\[
 C_p = (1-T_l)w - T_lr \theta 
\]

(7)

Government consumption \( C_g \) can be expressed as:

\[
 C_g = \mu \left( T_l w + T_z k + T_r \theta \right) 
\]

(8)

Where \( \mu \) is the ratio of government public expenditure to fiscal revenue.

2.3 equilibrium conditions

In a perfectly competitive market, the equilibrium condition is the market clearing, that is, the total output is equal to the total consumption, as shown in (9):

\[
 q = C_p + C_g 
\]

(9)

At the same time, producers pursue profit maximization and minimize costs requiring marginal benefits equal to marginal costs. This leads to the capital prices:

\[
 z = \frac{\alpha q}{(1 + T_k)k} 
\]

(10)

The equilibrium output derived from the simultaneous equations are:

\[
 q^* = \frac{(1-T_r)w + \mu T_r w}{1 - \frac{\mu \alpha T_z}{(1+T_k)} + (1-\mu)\beta T_r} 
\]

(11)

Bring (11) into (10) and get the equilibrium capital price as:

\[
 z^* = \frac{\alpha q^* A}{(1+T_z)k} \left(1^{(1+\alpha)/(1+\alpha)} A^{-1} \right) \frac{\beta (1+T_r)}{\alpha(1+T_r)\theta}^{(\alpha+\beta)/(\alpha+\beta)} 
\]

(12)

2.4 Model parameter estimation

In order to obtain a complete equilibrium formula, the value of the model parameters needs to be determined. This paper uses the econometric method to determine the model parameters through statistical regression.

2.4.1 Production function parameter estimation

First, linearize the nonlinear production function by taking the logarithm of both sides of (2):
\[ \ln(q) = \ln(A) + \alpha \ln(k) + \beta \ln(r) \]

Where \( \alpha, \beta \) and \( \ln(A) \) are parameters to be estimated. Organize the required data, as shown in Table 1.

| Years | GDP (100 million yuan) | Employment population (ten thousand people) | Per capita output (yuan) | Capital stock (100 million yuan) | Per capita capital stock (yuan) | Total water use (billion m³) | Per capita water consumption (m³) |
|-------|------------------------|---------------------------------------------|--------------------------|---------------------------------|-------------------------------|-----------------------------|---------------------------------|
| 2007  | 4741.31                | 2573.80                                     | 18421.439                | 2798.89                         | 10874.543                     | 150.03                      | 582.9124                        |
| 2008  | 5692.12                | 2638.40                                     | 21574.135                | 3526.60                         | 13366.432                     | 153.13                      | 580.3896                        |
| 2009  | 6169.75                | 2684.80                                     | 22980.296                | 4527.02                         | 16861.6656                    | 152.64                      | 568.5339                        |
| 2010  | 7224.18                | 2765.85                                     | 26119.203                | 5528.71                         | 19989.1895                    | 147.47                      | 533.1815                        |
| 2011  | 8893.12                | 2857.24                                     | 31124.861                | 6185.30                         | 21647.8139                    | 146.79                      | 513.7475                        |
| 2012  | 10309.47               | 2991.90                                     | 35399.023                | 7831.10                         | 26174.3373                    | 151.83                      | 507.4702                        |
| 2013  | 11832.31               | 3216.32                                     | 40651.203                | 9968.30                         | 34227.5680                    | 149.71                      | 514.0505                        |
| 2014  | 12814.59               | 2962.25                                     | 43259.651                | 11498.6                         | 38817.0478                    | 149.40                      | 504.3464                        |
| 2015  | 13619.17               | 2942.49                                     | 46284.507                | 13500.6                         | 45881.6172                    | 150.10                      | 510.1122                        |
| 2016  | 14719.95               | 2998.89                                     | 49084.661                | 16119.4                         | 53751.2212                    | 150.20                      | 500.8519                        |

Data source: 2007-2016 Yunnan Statistical Yearbook

Using Eviews software analysis, \( A=5.51, \alpha=0.85, \beta=0.13 \), the simulation results show that the adjusted \( R^2 \) reaches 0.988, and the fitting degree is good. And the \( \alpha \) and \( \beta \) parameter estimates were statistically significant at the significant 0.05 level, which in line with the model's expected requirements. Among them, the output elasticity of water consumption (\( \beta \)) is 0.13, and the elasticity coefficient is small, indicating that the impact of water resources consumption on Yunnan's economic development is relatively small.

In summary, the production function is: \( q(k,r)=5.51k^{0.85}r^{0.13} \).

2.4.2 Estimation of consumption function parameters

Estimation of consumer utility function: Looking at the total consumption of the Yunnan provincial government and the total consumption of residents in 2007-2016, the consumption ratio of residents and the government is about 2.54, and the government consumption coefficient and the household consumption coefficient is 0.22 and 0.78 respectively. Looking for the sum of government tax revenue, the average ratio of the Yunnan provincial government's revenue and expenditure ratio is 0.614. The specific data is shown in the following table:

| Years | Government consumption (100 million yuan) | Household consumption (100 million yuan) | Ratio(household/government) | Total government tax revenue (100 million yuan) | Government consumption ratio (%) |
|-------|------------------------------------------|------------------------------------------|----------------------------|-----------------------------------------------|---------------------------------|
| 2007  | 859.72                                   | 2095.31                                  | 2.437200484               | 973.43                                        | 0.88318626                     |
| 2008  | 935.85                                   | 2474.62                                  | 2.644248544               | 916.12                                        | 1.02153648                     |
| 2009  | 1045.31                                  | 2723.45                                  | 2.605399355               | 1036.86                                       | 1.00814961                     |
| 2010  | 1208.95                                  | 3123.69                                  | 2.583804128               | 1303.51                                       | 0.9274574                      |
| 2011  | 1452.18                                  | 3821.44                                  | 2.63159509                | 1636.12                                       | 0.88757548                     |
| 2012  | 1763.22                                  | 4543.53                                  | 2.576836696               | 1962.51                                       | 0.89845147                     |
| 2013  | 2119.60                                  | 5244.58                                  | 2.474325344               | 2335.01                                       | 0.90774772                     |
| 2014  | 2456.63                                  | 5750.89                                  | 2.340967097               | 2440.11                                       | 1.00677019                     |
| 2015  | 2501.08                                  | 6354.25                                  | 2.54060246                | 2513.52                                       | 0.99505077                     |
In summary, the utility function is: \( U = C_p^{0.78} + C_g^{0.22} \).

Estimation of the applicable tax rate and the applicable tax rate of capital: In the consumption function, the labor applicable tax rate \( T_l \) and the capital applicable tax rate \( T_k \) cannot be accurately replaced by the statutory tax rate, because the latter cannot reflect the actual tax burden level and needs to be converted into an effective tax rate. Due to the large difference in effective tax rates in the eastern, central and western regions of China, this paper mainly draws on the research results of Wang Dalin, Cheng Xuezhen.\(^8\). Wang Dalin calculated that the average effective tax rate of capital in western China is 28.74% and the average effective tax rate of labor is 6.35%.

Labor price and resource price: According to the annual average salary of the employed people in the Yunnan Statistical Yearbook, the labor price is obtained. Considering the factors such as inflation, the average wage in the five years from 2012 to 2016 is calculated to be 49,860 yuan/person.

Since the water resources market doesn’t have a national unified price, and the residents and industrial water prices also have certain differences. This paper selects the weighted average of residents and industrial water in 14 representative cities of Yunnan Province to calculate water resources. The average price is 1.588 yuan /m³. In summary:

\[
\text{Household consumption: } C_p = (1-0.0635) \times 49860 \times 1.588r
\]
\[
\text{Government consumption: } C_g = 0.614(0.0635 \times 49860 + 0.2874zk + T_r \times 1.588r)
\]

According to the market clearing assumption, build the model equilibrium condition \( Q = C_p + C_g \).

### 3. Water resource tax rate simulation

The different water resource tax rates (1%-19%) set by the model are brought into the equilibrium equation to simulate the impact of water resource tax rate changes on balanced output, water consumption reduction ratio and consumer utility, and zero tax on water resources scenario is compared. The simulation results are shown in Table 3.

| Water resource tax rate (%), Balanced output change rate (%) | Water consumption reduction ratio (%) | Consumer utility(U) |
|-------------------------------------------------------------|--------------------------------------|---------------------|
| 1                                                           | -0.03                                | -1.01               | 17908.35 |
| 3                                                           | -0.71                                | -2.07               | 17914.97 |
| 5                                                           | -0.16                                | -4.48               | 17928.23 |
| 7                                                           | -0.27                                | -5.35               | 17936.76 |
| 9                                                           | -0.35                                | -6.84               | 17950.21 |
| 11                                                          | -0.38                                | -8.79               | 17959.87 |
| 13                                                          | -0.40                                | -10.76              | 17968.79 |
| 15                                                          | -0.47                                | -11.78              | 17963.02 |
| 17                                                          | -0.52                                | -13.46              | 17957.37 |
| 19                                                          | -0.59                                | -15.76              | 17949.04 |

As can be seen from the above table, as the water resource tax rate increases, the equilibrium output decreases, that is, the increase in the water resource tax will have a certain degree of adverse impact on the economy. At the same time, water consumption will also decline, but due to the low elasticity of water consumption, the impact of water tax on the economy is small. And the consumer utility increases first and then decreases, reaching the highest at 13%. It is estimated that the reasonable tax rate of water resources in Yunnan Province should be around 13%, calculated from the average price of water resources in Yunnan Province of 1.588 yuan / m³, the corresponding average specific tax rate is 0.21 yuan /m³.
4. Conclusion

Although Yunnan Province is located in the southern China, due to the uneven distribution of precipitation time, the small amount of surface water storage, low water efficiency, coupled with its rapidly increasing population, water resources demand will further increased, which will lead to more prominent contradiction between supply and demand of water resources.

By simulating the CGE model incorporating water resources accounts, the ideal average water resource tax rate for Yunnan Province should be 0.21 yuan/m³. As a result, the price of water will increase, and producers will have to bear some of the water tax burden, and part of the tax burden will be passed on to consumers through price. Relatively rising costs have led producers to switch to intensive using of water resources, and residents will also reduce water wasting. The result of the above-mentioned effects is the reduction of water consumption, which is conducive to promote the efficient use of water resources, and achieve the goal of saving water resources.

In summary, Yunnan Province should improve its water resource tax system, advocate water conservation, and promote intensive use of water resources. Of course, the complexity of the real economy and the use of water resources itself is not fully explained by mathematical models. It also need to take the tax rate based on the actual water supply and demand situation in Yunnan Province and the unique characteristics of water resources into account.

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