An Empirical Study Based on CGE Model in the Yellow River Irrigation District

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Abstract — To improve the agricultural water-saving technology in the Yellow River Irrigation District. Methods: Establishing the CGE model based on Yellow River Irrigation District. The article introduces the water shortage of the Yellow River area, describes the water saving technology in the relevant irrigation district in detail, and constructs the CGE model of the Yellow River irrigation district by using the set of module functions. This paper studies the data base of CGE model, analyzes the experimental data by Gragg method, and finds that the more the magnitude of irrigation water reduces, the more the water price increases. The CGE model based on the Yellow River Irrigation District in this paper can promote the development of water-saving technology of the irrigation district.

Keywords - CGE model; yellow river irrigation district; gragg method; water-saving technology

I. INTRODUCTION

With the scarcity of water resources has gradually been recognized, the commodity property of water has become increasingly prominent, as an important economic lever to promote water resources optimization allocation, improve water use efficiency, build water saving society and promote sustainable development, the research is concerned by domestic and international more and more attention. At present, according to the different theoretical background, the research method of the water price is a lot of methods, such as: shadow price method, cost pricing method, supply and demand pricing method, mathematical programming method, input (occupancy) output and social accounting matrix (SAM) method, fuzzy mathematics model method, conditional value evaluation method, characteristic price method, etc.. A review on the research methods of water price, Johansson, Dudu, etc.. In addition to the above methods, a common feature is the local equilibrium method, the behavior of economic agents, such as residents, is not considered, there is no research on the issue of water price in the unified social and economic framework. While the SAM method is based on the general equilibrium framework, but the disadvantage is that the price is exogenous, so as to adjust the internal.

Computable general equilibrium (CGE) model since the 1960's, after more than half a century, the development has become more and more mature. The CGE model is organically linked to the behavior of the factors of production, the commodity market and the economic entities (residents, enterprises, government, etc.),contains the constraints of the Department and the economic subject and mutual feedback, both reflect the role of market mechanisms, also highlight the link between departments. Because the CGE model has the characteristics of a strong micro foundation, general equilibrium and openness, its research in the field of resource and environment has become a bright spot, and more and more applications [1]. Figure 1 shows the irrigation situation in the Yellow River irrigation district.

Fig. 1 Irrigation situation in the yellow river irrigation district

(a) Distribution map of the yellow river irrigation district

(b) The construction of canals in the yellow river irrigation area
Most of the Yellow River basin is arid and semi-arid regions, and the solar thermal resource is abundant, but the rainfall is scarce, water resources are very poor, and the water resources of the river basin and the people's lives depend mainly on the development of the Yellow River water resources along with the development of industry and agriculture and the economic and social development, runoff consumption also by 12.2 billion m³ in the 1950s increased to 90's 300 billion m³/A, an increase of 1.6 times, which consumes the largest amount of water in 1989 reached 33.4 billion m³ [2]. The Yellow River basin water consumption in the river, such as Figure 2, in the Yellow River Basin, agricultural water is a major, the whole basin using streamflow in 92% for agricultural use, but at present, due to engineering, irrigation technology, irrigation management, and other aspects of the reasons, the utilization rate of agricultural irrigation water is lower, and the irrigation water use coefficient is only 0.45 a 0.30, among them, the coefficient of canal water conservancy is 0.50, and the coefficient of water use in the field is 0.90 0.80. Ningxia irrigation area is one of the oldest irrigation districts of the Yellow River basin, as many key projects for the construction of the gradual evolution of the building, the layout is unreasonable, no obvious classification, multi-channel, long line, in addition to the traditional irrigation practices and the need to suppress soil salinity, at present there are different degrees of gravity, flood irrigation, water with salt "phenomenon, the irrigation quantity is big, the irrigation quota is high, and the groundwater depth is shallow, the water evaporation is strong and the water resource is invalid. According to statistics, at present Ningxia the Yellow River irrigation area water gross irrigation quota of about 2.1 000 m³/hm². If the net irrigation return of the Yellow River water, the Yellow River water consumption quota of about 1 000 m³/hm², current situation of irrigation water use coefficient of about 0.40. Hetao irrigation area of Inner Mongolia is also a historical irrigation has a long history of the irrigation area, in the long-term production practice formed during the growth period of the crop irrigation and autumn irrigation reservoir water irrigation habits, except crop growth stage irrigation outside. After crop harvest again in autumn irrigation, to crop water conservation next year, the autumn water consumption accounted for 40% of the annual water. According to statistics, at present the Yellow River Hetao irrigation area of Inner Mongolia water gross irrigation quota of about 1.057 000 m³/hm², after deducting the total dry discharge and discharge of the Yellow River water, the Yellow River water consumption quota of about 0.912 000 m³/hm², irrigation water use coefficient of about 0.30 [3].

II. MATERIALS AND METHODS

A. Water saving technology in irrigation district

Irrigation water saving technology block diagram is shown in Figure 2.

![Fig. 2 Block diagram of water saving in irrigation district](image)

(1) Channel seepage control. Mainly suitable for irrigation to irrigation and groundwater rich, such as NingMeng, irrigation district, and the lower reaches of the Yellow River river. The channel leakage can not only reduce the leakage loss, increase the water delivery efficiency, shorten the irrigation period, but also can improve the channel capacity of sediment transport, increase the proportion of the sediment to the lower reaches of the river and even to the field, to reduce the sediment caused by environmental pollution and occupy land. According to Chen Fen channel irrigation area seepage test, arterial lining after all, coefficient of irrigation water use is 0.80.

(2) Pipeline. Pipeline water transfer has obvious effect of water saving and water saving, under the same conditions than saving 5% a 15% channel lining of canal water, than save 40 to about 70%, and there is no water evaporation loss. But the water supply needs a certain water power consumption, the problem of sediment deposition in the pipeline is still in the lower reaches of the Yellow River, so the pipeline is used in the well irrigation area and the water area (Liu, 2016).

(3) Micro sprinkler irrigation. Compared with the traditional ground irrigation, micro irrigation can be based on crop water requirements, timely and appropriate irrigation, generally do not produce deep leakage and surface runoff, the ground moisture uniformity can reach 0.9, and the water loss is small, irrigation water use coefficient of up to 60%, more than 0.90 of water saving 30%, in the water permeability of sandy soil can reach more than 70%. However, due to the large investment and high management requirements, it is mainly suitable for small scale economic crops.
(4) Well canal combination. The combination of well and canal and the joint use of groundwater and groundwater, it can effectively control the groundwater level in the irrigation district, prevent soil salinization, reduce the invalid evaporation of groundwater, improve water resources reuse rate, reduce the demand for water in the irrigation district of the Yellow River, especially is suitable for the irrigation area is an important area of artesian water saving technology. According to statistics, irrigation area of well canal combined irrigation than the gross irrigation quota gross irrigation quota reduced by 30%.

(5) Water management technology. To strengthen water management is an effective measure of water saving in the Yellow River Irrigation District, which is not only invested less, but also effective. Mainly include: establish and improve the management system of irrigation district; water as a means of measuring the water, the implementation of "hierarchical management, classified water supply, water consumption measurement; modern information technology and optimization method based on microcomputer, strengthen water information management in irrigation areas; strengthen the plan for water use, the implementation of the declaration of water, the use of the system of water signed; The reform of fee collection system, formulate reasonable declaration of water, the use of the system of water signed; 

The calculation formula of the product price and the purchase price of the product in the irrigation district are respectively:

\[
PQ_i = \left( PD_i \times D_i + PE_i \times E_i \right) / Q_i
\]

\[
PX_i = \left( PD_i \times D_i + PM_i \times M_i \right) / X_i
\]

B. CGE model of irrigation district

The CGE model can calculate general equilibrium model, general equilibrium theory from Walrasian, this model is suitable for simulating the macro effects of various policies under the market economy system, compared with other commonly used methods in other economics, the most notable feature is that the whole economic system as a research object, relationship between supply and demand of various commodities and factors in the system. The model covers a number of optimization mechanisms, such as the minimization of the cost of the producer according to the principle, under the condition of resource constraints, the consumer is based on the principle of maximizing utility, under budget constraints, etc..

Setting of the CGE model of the irrigation district: The CGE model for calculating the shadow price of irrigation district is mainly composed of 6 modules, that is, the price module, production module, revenue module, consumer module, trade module and balanced module. CES function is used to describe the production behavior of the irrigation district, CES describes the producer under certain technical conditions, to achieve the lowest production cost by optimizing the allocation of intermediate inputs and the input of production factors [5]. Formula (1) – (11) is the main description equation, the type of \( i \) in the production of \( i \), the relevant parameters can be seen in Table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Parameter</th>
<th>Description</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mi</td>
<td>Import volume</td>
<td>Ai</td>
<td>Scale efficiency parameters of production function</td>
<td>PRI</td>
<td>Import commodity investment</td>
</tr>
<tr>
<td>Qi</td>
<td>Total output</td>
<td>Di</td>
<td>Quantity of goods sold in the domestic market</td>
<td>( \alpha_i )</td>
<td>Total increase in the value of capital investment</td>
</tr>
<tr>
<td>Xi</td>
<td>Total usage</td>
<td>Ci</td>
<td>Share of the total budget</td>
<td>YKi</td>
<td>Capital factor income</td>
</tr>
<tr>
<td>Ei</td>
<td>Export volume</td>
<td>PDi</td>
<td>Domestic prices of goods</td>
<td>WTi</td>
<td>Laborers' remuneration</td>
</tr>
<tr>
<td>Pi</td>
<td>Total investment</td>
<td>PEi</td>
<td>Domestic prices of export commodities</td>
<td>HE</td>
<td>Total expenditure of various departments</td>
</tr>
<tr>
<td>Ki</td>
<td>Capital investment</td>
<td>PMi</td>
<td>Domestic prices of imported goods</td>
<td>ME</td>
<td>Maximum profit</td>
</tr>
<tr>
<td>Li</td>
<td>Labor input</td>
<td>PQi</td>
<td>Product output price</td>
<td>FRi</td>
<td>Demand for imported goods</td>
</tr>
<tr>
<td>Vi</td>
<td>Added value</td>
<td>P Xi</td>
<td>Comprehensive use of commodity prices</td>
<td>YE</td>
<td>Enterprise income</td>
</tr>
<tr>
<td>Wi</td>
<td>Wage rate</td>
<td>PVi</td>
<td>Product added value price</td>
<td>W(i)</td>
<td>Actual use of water resources</td>
</tr>
<tr>
<td>Fi</td>
<td>Demand for goods</td>
<td>PKi</td>
<td>Average price of capital</td>
<td>B(i)</td>
<td>Incremental capital output coefficient</td>
</tr>
<tr>
<td>A(t)</td>
<td>Direct consumption coefficient</td>
<td>( A_\alpha(t) )</td>
<td>Water coefficient matrix</td>
<td>D(t)</td>
<td>Combined loss and output coefficient</td>
</tr>
<tr>
<td>X(t)</td>
<td>Total output</td>
<td>L(t)</td>
<td>Other constraints and parameters</td>
<td>AX(t)</td>
<td>Final consumption demand coefficient matrix</td>
</tr>
</tbody>
</table>

The calculation formula of the product price and the purchase price of the product in the irrigation district are respectively:

\[
PQ_i = \left( PD_i \times D_i + PE_i \times E_i \right) / Q_i
\]

\[
PX_i = \left( PD_i \times D_i + PM_i \times M_i \right) / X_i
\]

An important assumption in the price model is the assumption of small states”, that is, the study area is only a small part of the country and the world economy, its market price does not affect the price of the domestic market, in the trade can only be the market price of the recipient.

Production module:
Formula (3) defined the increase in the value of the product is the basic input elements of the Cobb-Douglas function; Formula (4) and (5) defined the labor input and capital input is the total output value of the new value and the ratio of the price of their own labor, capital use.

Income module:

\[ V_i = A_i \times K_i^{\alpha_i} \times L_i^{1-\alpha_i} \]  
(3)

\[ L_i = (1 - \alpha_i) \times PV_i \times Q_i / W_i \]  
(4)

\[ K_i = \alpha_i \times PV_i \times Q_i / PK_i \]  
(5)

Formula (6) defines the labor factor income of various departments is composed of the average wage rate of the Department and the number of inputs into the labor force; Formula (7) defines the capital factor income of each department is the difference between the new value of the Department and the income of the labor factor, it is also assumed that the production function is determined by the Cobb-Douglas function of the input of labor factor and capital factor; Formula (8) is defined as the total income of the irrigation district is the sum of the capital elements of the various departments [6].

Income module:

\[ WT_i = W_i \times L_i \]  
(6)

\[ YK_i = PV_i \times Q_i \times W_i \]  
(7)

\[ YE = \sum YK_i \]  
(8)

Formula (9) is the definition of the residents, irrigation and other economic entities for the Department of commodity consumption.

Consumption module:

\[ C_i \times HE / F_i = PX_i \]  
(9)

Formula (10) means the goods produced, producers also need to determine the region's share of sales and export sales, so that their profit maximization.

Equalization module:

\[ Q_i - E_i = (P_i - PR_i) + \sum (F_i - FR_i) \]  
(11)

Formula (11) means that, in general equilibrium conditions, the total supply and demand of the Department's products should be balanced.

C. Social accounting matrix

Irrigation water is attached to the land, if there is land but no water can be irrigated, or vice versa, these two cases have no concept of irrigation water. So, the land and water elements in the Agricultural Irrigation Department, with the Leontief function more practical. The production structure of the Irrigation department is shown in Figure 3, top total output is obtained by Leontief production function;

The second layer, the intermediate inputs from the import goods and the national product through the ordinary substitution elasticity (CES) function compound, but the production factor is the land and the water, the labor and the capital CES compound; Third layers, land and water are obtained by the Leontief function[7].

Social accounting matrix (SAM) is the data base of CGE model, balance of the SAM can be regarded as the base solution of CGE model. This study period is 2002, by reason of the data: This study focuses on agricultural irrigation water, the public release of the input-output table only for agriculture and other departments, no more detailed soybean and corn, wheat and other agricultural planting sector, while the Australian TERM model has this part of the data in 2002. Multi region CGE model takes into account the trade matrix between regions, which includes the amount of inflow and outflow of goods among different regions, as well as the volume and outflow of goods. Trade matrix of this article, for each commodity is a 9 x 9 square (Calderón, 2016). In view of the absence of such trade data available, the improved gravity model is used to estimate the model:

\[ \frac{V(r, d)}{V(*, d)} \propto \sqrt{V(r, *) \times D(r, d)} \]  
(12)

Among them, \( V(r, d) \) is the trade flow from regional \( r \) to regional \( d \), \( V(*, d) \) is the known production of \( r \), \( V(*, d) \) is the known demand of \( d \), \( D(r, d) \) said the distance between the two places, \( k \) is a parameter that is related to a specific commodity, and its value is between 0.5~2, for goods that are not trade, \( k \) value is higher.
D. Method to solve the water shortage in the yellow river irrigation district

The developed decision support system (DS) is a planning tool, the main purpose is to assist macro decision analysis, which can assist decision makers to compare and get the optimal decision. The whole frame is made up of two modules: the simulation model and the decision-making model. The simulation model is used to simulate the operation of irrigation district under the specific conditions, it includes a number of physical sub models, and can produce a series of quantitative indicators.

![Fig. 4 Structure and function of DSS](image)

This indicator provides for the next step in the decision making. Comprehensive formation and decision criteria of all kinds of indicators, these guidelines are based on a multi criteria analysis of the decision model of the input (Modi, 2016). Figure 4 shows the structure and function of the DSS.

![Table II Typical strategies relating to irrigation management](image)

The developed simulation model and DS have the following 2 basic uses:

1. Different planning design and management conditions (such as increasing the irrigated area, canal lining, change local water use rules) water systems. The water demand of irrigation district is the main basis for the water management of the Yellow River Basin. It will be for the Yellow River Basin in different provinces (autonomous regions) and provide valuable information for users of water project. Because the agricultural water demand is influenced by the weather conditions, so it is necessary, simulation and analysis must be carried out for different hydrological years. DS based on Simulation and decision model will provide an optimal set of strategies for saving water and improving crop yield and protection of soil and water resources in irrigation area [8].

2. The simulation model can be used to help understand the impact of the water supply system constraints on water management and to improve the impact of any programming design and management measures on these constraints and the corresponding water management. The role of DS is used to obtain the optimal strategy to meet all water supply constraints, this point is particularly important in the lower reaches of the Yellow River Basin, in these irrigation areas, effective strategies involve how to make full use of local water sources, to solve the problem and the lack of water diversion in the Yellow River. Delphi software development platform, has developed a framework for simulation model, this framework is based on water supply simulation, the water sub model, the water distribution model and the local water level model are respectively connected. In the irrigation area, the basic database management system uses GIS technology to meet the requirements of the management of spatial data. DSS tools menu driven, most of the physical or the management related parameters can be edited in a friendly graphical interface, the calculation results are also in the form of a chart, in order to facilitate the analysis of the test. Using the data in the irrigation district, the model rate is still in the middle of the work [9-14].

III. RESULTS AND ANALYSIS

The CGE model based on GEMPACK is constructed, and the Gragg method is used to solve the model. Generally speaking, in the same step, the Gragg method can get more accurate results than the Euler method. Because the
GEMPACK software is used to solve the nonlinear equations, the method of solving linear equations is used, so should pay attention to the accuracy of its solution. Irrigation water volume in each province was reduced by 10%, 15%, 20% and 30% respectively, the simulation results were accurate; but in the case of a decrease of 50%, the results were less precise and even errors, such as the amount of irrigation water in Qinghai Province, were reduced by 112.42%, which is clearly incorrect. In the case of the initial price of water price in the provinces increased by 10%, 15%, 20%, 30% and 50% respectively, solving accuracy is more accurate, which is different from the 5 kinds of simulation calculation accuracy of irrigation water quantity, may be the reason for the absolute change in the smaller[9]. Different agricultural irrigation water price: Although the irrigation water price can be calculated from the different crop types in different provinces, the actual situation is considered, each province to implement a price of water is relatively reasonable, therefore, the model can only calculate the single irrigation water price in different provinces. In the case of 5 kinds of irrigation water, the result of water price change is shown in Table 3. It can be seen that the change of water price increases with the increase of irrigation water quantity. Under the condition of reducing water consumption by 10%, the largest change in the price of water Inner Mongolia rose 0.86 yuan /m³, the smallest change in Ningxia has increased by 0.01 yuan /m³; the ultimate price of water Inner Mongolia is the highest, for 0.907 yuan /m³, Ningxia minimum, 0.056 yuan /m³.5 cases: the biggest change in the price of water is Inner Mongolia, increase respectively 0.86, 1.36, 1.92, 3.29 and 7.65 yuan /m³; The smallest change in the price of water is Ningxia, increase respectively 0.01, 0.02, 0.03, 0.06 and 0.24 yuan /m³ [15]. As can be seen from Table III, the irrigation water quantity is different, the price of the water price and the final price is reduced.

<table>
<thead>
<tr>
<th>Province</th>
<th>Reduce 10%</th>
<th>Reduce 15%</th>
<th>Reduce 20%</th>
<th>Reduce 30%</th>
<th>Reduce 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qinghai</td>
<td>0.46(0.10)</td>
<td>0.72(0.13)</td>
<td>1.02(0.17)</td>
<td>1.22(0.28)</td>
<td>5.60(0.62)</td>
</tr>
<tr>
<td>Gansu</td>
<td>0.30(0.21)</td>
<td>0.47(0.28)</td>
<td>0.60(0.37)</td>
<td>0.50(0.47)</td>
<td>1.13(0.20)</td>
</tr>
<tr>
<td>Ningxia</td>
<td>0.31(0.08)</td>
<td>0.52(0.08)</td>
<td>0.63(0.08)</td>
<td>0.60(0.11)</td>
<td>1.24(0.09)</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>0.86(0.91)</td>
<td>1.36(1.41)</td>
<td>1.92(1.97)</td>
<td>3.29(3.34)</td>
<td>7.65(7.70)</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>0.30(0.42)</td>
<td>0.47(0.59)</td>
<td>0.67(0.79)</td>
<td>1.14(1.26)</td>
<td>2.67(2.79)</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>0.37(0.57)</td>
<td>0.60(0.80)</td>
<td>0.85(1.05)</td>
<td>1.49(1.69)</td>
<td>3.85(4.05)</td>
</tr>
<tr>
<td>Henan</td>
<td>0.58(0.64)</td>
<td>0.91(0.97)</td>
<td>1.27(1.33)</td>
<td>2.13(2.19)</td>
<td>4.71(4.77)</td>
</tr>
<tr>
<td>Shandong</td>
<td>0.46(0.51)</td>
<td>0.72(0.77)</td>
<td>1.02(1.07)</td>
<td>1.75(1.78)</td>
<td>4.06(4.11)</td>
</tr>
<tr>
<td>Average</td>
<td>0.35(0.43)</td>
<td>0.55(0.63)</td>
<td>0.70(0.83)</td>
<td>1.32(1.40)</td>
<td>3.10(3.13)</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

The Yellow River irrigation district is a major agricultural production base in China, it has important significance for the research of irrigation technology. This paper describes the technology of water saving in Irrigation District, and establishes the CGE model of the Yellow River Irrigation District, and through the analysis we know that the change of water consumption in irrigation district has a direct impact on the change of water price. To strengthen water management is an effective measure of water saving in the Yellow River Irrigation District, which is not only invested little, but also effective. Farmers are the most direct users and direct participants of water in the Yellow River, mobilizing the initiative and enthusiasm of farmers' participation in management, so as to promote the healthy development of water-saving irrigation.

REFERENCES


