8-1-2014

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11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

WATER RESOURCES CONTRIBUTION TO ECONOMIC GROWTH IN ERDOS CITY: MODEL AND DEMONSTRATION

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Abstract: Erdos City has been one of the fastest growing economic regions in China in the past twenty years, whose average annual economic growth rate has exceeded 20%. However, water resources shortage is becoming increasingly significant in constraint on social development and has gradually developed to be one of primary weakest factors. Based on the analysis of main factors promoting economic growth in Erdos City with Cobb-Douglas production function in economics, the economic growth model involving water resources availability and coal output has been established and the data conversion method considering water consumption efficiency and water consumption structural change has been proposed. In this way, it has made up for the deficiency of failing to fully consider the contribution of water consumption efficiency improvement and water consumption structural change to economic growth in the past researches. What have been discovered in the simulation and analysis of water resources contribution to economic growth in Erdos City from 1980 to 2010 as follows: (1) Water resources average contribution rate to economic growth in Erdos City in the past 30 years is 8.26%; (2) Consumption efficiency and structural change of water resources have played an important role in promoting economic development; (3) Water resources contribution to economic growth has shown a gradually increasing trend that the average contribution rates in the three decades are 1.87%, 9.69% and 10.09% respectively. The trend is closely connected with constantly increased gross water consumption, obvious improvement of water consumption efficiency and gradual upgrading of water consumption structure in the local area. It also has reflected that water resources have played an increasingly significant role in constraint on regional economic social development..
Key words: Water resources, economic growth model, quantitative assessment, Erdos City

1. Introduction

Erdos City is located in south-western Inner Mongolia Autonomous Region with a total area of about 86,752 km^2. The average gross amount of water resources and the average water resources availability over the years are 2.99 billion m^3 and 1.46 billion m^3 respectively; in 2009, the gross amount of water consumption in Erdos was 1.946 billlion m^3; therefore, water resources shortage has been one of the weakest factors for constraint on rapid economic growth in Erdos. Erdos City was an area based on farming and animal husbandry in history. Since 2000, relying on the local rich mineral resources, economy in Erdos has developed rapidly; in 2010, its GDP was RMB 264.3 billion Yuan, with per capita GDP of RMB 138,000 Yuan and urbanization level of 69.5%. Economic growth achievements in Erdos City are remarkable, and then what is the source of such growth? Water resources as an irreplaceable production factor, how much water resources contribution is to its economic growth? It is significant to explore those questions for scientific understanding of economic growth mode in Erdos, and for the formulation of reasonable management policies on water resources by the local water administration.

Assessment on water resources contribution to economic growth is always a difficult issue in the research of water resources economics. The research methods mainly include two kinds, namely Cobb-Douglas production function method [1-2] in economics and emerge analysis method [3] in ecological economics. As the most commonly used method at present, Cobb-Douglas production function method can generalize the pattern of regional economic growth but has a defect that the impact on the contributions of water consumption efficiency improvement and water consumption structural change to water resources has not been taken into account. In the article, assessing water resources contribution to economic growth in the research area of Erdos with Cobb-Dougals production function method and proposing a data conversion thought considering water consumption efficiency and water consumption structural change have made up for deficiency in the current research, which expects to further improve analytical methods of water resources contribution to economic growth. Meanwhile, the analytical results may provide references for alleviating contradictions between water resources and economic growth in Erdos City.

2. Method

2.1. Cobb- Douglas production function

In 1928, economics professor Douglas (P. H. Douglas) in University of Chicago cooperated with mathematician Cobb (C. W. Cobb) and proposed the famous "Cobb-Douglas production function"[4] after research and analysis of large amounts of historical data. It holds that under constant technical and economic conditions, the relation between output-input capital and labor force is:

$$Y = AK^{\alpha\gamma}L^{\beta} \tag{1}$$

Its general form is:

$$Y = A\Pi_{n=1}^{N} X_{n}^{\alpha_n} \tag{2}$$

Y represents output; A represents efficiency factor (reflecting integrated technical level); K represents capital input; L represents labor input; α and β are output elastic coefficients of K and L. Generally, it is assumed that economies of scale remain constant, α+β=1.

Cobb-Douglas production function enables production theory to shift from abstract purely theoretical research to empirical analysis on actual production process. Its theoretical value and practicality have being accepted by more and more scholars. After continuously improved by Tinbergen, Solow and Dennison afterwards, it has hold a very important position in macro-economics.

2.2 Main factors of economic growth in Erdos

Factors of economic growth can be divided into two categories: one is increased inputs of tangible material elements; the other is intangible elements other than material elements, i.e. increase in productivity [5]. Material elements usually include capital and labor force. In oder to assess water resources contribution to economic growth in Erdos while taking into account coal resources important place in Erdos City, water resources and coal resources may be input as primary material elements; the output growth rate brought forth by all intangible elements other than material elements such as industrial structure, system innovation, research and training is called total factor productivity. Over the last 20 years, Erdos City has undertaken substantial adjustment of industrial structure and continuous system innovation, whose contribution to economically increased industries cannot be neglected. Therefore, industrial structure and system innovation among intangible elements are mainly considered and their contributions to economic growth from total factor productivity may be isolated.

2.3 Assessment methods of water resources contribution to economic growth in Erdos City

Bring water resources and coal resources into Cobb-Douglas production function and establish an economic growth model of Erdos City including water resources availability and coal output (assuming the return to scale is constant):

$$Y(t) = A(t)K(t)^{\alpha} W(t)^{\beta} C(t)^{\gamma} L(t)^{(1-\alpha-\beta-\gamma)} \quad \alpha > 0, \beta > 0, \gamma > 0, \alpha + \beta + \gamma < 1 \tag{3}$$

In the formula, Y represents economic gross output; A represents efficient coefficient; K represents capital input; W represents water resources availability; C represents coal output; L represents labor input; t represents time; α, β, γ respectively represent the elasticity of output to capital, water resources availability and coal output.

Take the logarithm of the both sides of the formula (3) and take the derivative of t:

$$g_Y(t) = g_A(t) + \alpha g_K(t) + \beta g_W(t) + \gamma g_C(t) + (1-\alpha-\beta-\gamma) g_L(t) \tag{4}$$

In the formula, $g_Y(t), g_K(t), g_L(t), g_C(t), g_A(t)$ represent growth rates of output, capital, labor force, water resources, coal resources and total factor productivity.

From the formula (4), we can see that when the gross output increases by $g_Y(t)$, water resources contribution rate (WCR) to economic growth is:

$$WCR = \beta g_W(t) / g_Y(t) \tag{5}$$

In the same way, we can find that the contribution rates of coal, capital and labor force to economic growth are $\gamma g_C(t) / g_Y(t)$, $\alpha g_K(t) / g_Y(t)$ and $(1-\alpha-\beta-\gamma) g_L(t) / g_Y(t)$; and the remaining part is the contribution rate of total factor productivity improvement to economic growth (recorded as EA), calculated as:

$$EA = \frac{\alpha g_A(t)}{g_Y(t)} = 1 - \frac{\alpha g_K(t)}{g_Y(t)} - \frac{\beta g_W(t)}{g_Y(t)} - \frac{\gamma g_C(t)}{g_Y(t)} - \frac{(1-\alpha-\beta-\gamma) g_L(t)}{g_Y(t)} \tag{6}$$

Continue to decompose total factor productivity and isolate the contributions of industrial structural adjustment and system innovation factor to economic growth; and the remaining part is remaining total factor productivity. The method is similar to the said method:

$$A(t) = A'(t) S(t)^{\delta} Z(t)^{1-\delta} \quad, \delta > 0 \tag{7}$$

In the formula, S represents industrial structure; Z represents system innovation; δ and $1-\delta$ represent elastic coefficients of industrial structural adjustment and system innovation; A' represents efficiency coefficient (reflecting technical levels of industrial structure and system innovation excluded).

In the same way, we can find that the contribution rates of industrial structure, system innovation and the remaining total factors to economic growth are $\delta g_S(t) / g_Y(t)$, $(1-\delta) g_Z(t) / g_Y(t)$ and $EA - \delta g_S(t) / g_Y(t) - (1-\delta) g_Z(t) / g_Y(t)$, among which, $g_S(t)$ and $g_Z(t)$ represent change rates of industrial structure and system factor.

2.4 Index quantization and elastic coefficient calculation

(1) Index quantization and data sources

Based on economic data, water resources availability and coal output data in Erdos City from 1980 to 2010, analyze water resources contribution in the economic growth process of Erdos, and various index quantization methods are as follows:

①Total output (Y). Adopt yearly GDP as the measurement index of the total output and convert as per the constant price in 1980.

② Capital input (K). Refer to capital stock rather than capital flow and estimate with perpetual inventory method [8], involving three issues of base-period capital calculation, selection of depreciation rates and capital investment deflating. With the base period of the year 1980, base-period capital calculation adopts the method provided in literature [7]; because it is impossible to get price index of fixed capital in statistical materials, substitute price index of investment in fixed assets with GDP deflator to deflate the investment in fixed assets in Erdos; the depreciation rate refers to literature [6] to be 10%.

③ Labor input (L). Overall consider the labor force in terms of quantity and quality. Quantity of the labor force is expressed by the total number of practitioners; quality of the labor force is expressed by human capital, estimated with education stock method [7]; the labor force is the sum of years for practitioners' education in the year.

④ Water resources availability (W). Expressed by water resources availability each year. Based on difference unification of water consumption efficiency in different departments, convert water resources availability each year with the following methods and get the water resources availability considering water consumption efficiency and water consumption structural change:

⑤ Coal output (C). Expressed by coal output each year.

⑥ Industrial structure (S) Take the sum of proportion of the secondary and tertiary industries as the industrial structure index.

⑦ System factor (Z) It mainly works in the degree of denationalization and marketization. The degree of denationalization is expressed by the proportion of non-state industrial output value in the gross industrial output value; the degree of marketization is expressed by the proportion of practitioners number in non-state-owned enterprises in the total number of practitioners, and the proportion of investment in fixed assets of non-state-owned enterprises in investment in fixed assets of the entire society. System factor is expressed by the weighted average of these three proportions.

(2) Elastic coefficient calculation

Elastic coefficient of production factors refers to the percentage of the output increase brought by every 1% increase in production factor inputs. The commonly used methods for measurement are the distribution method (scaling method), empirical method and regression analysis method. The distribution method assumes that the distribution rate of factors in the national income equals to the output elasticity of factor inputs. As a factor input, water resources contribution has not been represented in the national income distribution, so the distribution method is not applicable; the regression analysis method is to make double logarithmic regression analysis with each economic data and water resources data and to each get elastic coefficient. For the specifications of statistical data are different, the results of elastic coefficient would always have big errors; the premise of empirical method is that under certain conditions, the output elasticity of factor inputs vary in certain range, which is roughly similar in different countries or regions. The capital elasticity shall be ranged from 0.2 to 0.45, and the labor elasticity shall be ranged from 0.55 to 0.8; Nordhaus supposes that elastic coefficient of all resources is about 0.2. Output elastic coefficients of capital, water resources, coal resources and labor force in Erdos shall be determined as 0.2, 0.1, 0.1 and 0.6 respectively in the light of empirical method. There is no existing empirical value used for elastic coefficients of industrial structural adjustment and system innovation in the further decomposition process of total factors now. The elastic coefficients calculated by regression analysis method are respectively 0.74 and 0.26.

3. Results and discussion

3.1 Results

Based on the original data and relevant parameters of Erdos City, we can find the average contribution rates of water resources and other production factors to economic growth from 1980 to 2010, as shown in Table 1. Assessment results at different time periods of the contribution rate of water resources and other production factors to economic growth rate are shown in Table 2.

Table 1 Assessment results of the contribution rate of water resources and other production factors to economic growth from 1980 to 2010 (%)

Project	Capital Contribution rate	Labor force Contribution rate	Water resources contribution rate	Coal Contribution rate	Contribution rate of total factor productivity			
					Subtotal	Industrial structure	System innovation	Remaining total factors Productivity
Without consideration of water consumption efficiency and structure	25.08	17.44	2.48	11.47	43.53	8.57	3.53	31.43
Taking into account water consumption efficiency and structure	25.08	17.44	8.26	11.47	37.75	8.57	3.53	25.65

Table 2 Assessment results at different time periods of the contribution rate of water resources and other production factors to economic growth (%)

Time period		Capital Contribution rate	Labor force contribution rate	Water resources contribution rate	Coal Contribution rate	Contribution rate of total factor productivity: Subtotal	Industrial structure	System innovation	Remaining total factor productivity
Five years	1980~1985	41.57	28.66	0.38	8.46	20.93	3.33	9.29	8.31
	1985~1990	22.91	21.23	1.75	10.12	44.00	2.90	0.92	40.18
	1990~1995	38.39	19.93	8.79	15.57	17.31	11.19	1.10	5.03
	1995~2000	7.08	13.61	10.48	3.13	65.70	17.81	7.23	40.66
	2000~2005	18.63	12.20	9.16	16.79	43.21	6.50	2.48	34.23
	2005~2010	26.37	10.08	11.30	9.02	43.23	3.22	1.72	38.30
Ten years	1980~1990	40.44	33.20	1.87	13.45	11.04	4.29	4.90	1.85
	1990~2000	20.62	16.49	9.69	8.56	44.63	14.78	4.40	25.45
	2000~2010	21.98	11.26	10.09	13.21	43.44	5.05	2.14	36.25

3.2 Discussion

(1) Comparison of water resources contribution rate before and after considering water consumption efficiency and structure

From Table 1, we can see that, from 1980 to 2010, before and after considering the impact of water consumption efficiency and structure, the average annual contribution rate of water resources to economic growth in Erdos City is 2.48% (the increase rate hereinafter refers to average annual increase rate), and the capital contribution rate at the same period is 25.08%, and the labor input contribution rate is 17.44%, and the coal resources contribution rate is 11.47%, and the increased contribution rate of total factor productivity is 43.53%. Among the total factor productivity, the contribution rates of industrial structural adjustment and system innovation are respectively 8.57% and 3.53%. Water resources contribution rate to economic growth is relatively low, mainly because of without considering the impact of water resources use efficiency and water resources use structural change to water resources contribution rate. Agriculture in Erdos City consumes the most water resources of more than 80% of the total water consumption, while the proportion of value added in agriculture in GDP is less than 3%. Since water resources use efficiency is low and water consumption in industry and tertiary industry occupies low proportion with high water consumption efficiency, water resources contribution rate to economic growth varies with economic efficiency produced by essential water in agriculture, industry and tertiary industry. As total water consumption increases, water consumption structure also continues to change. Calculating water resources contribution rate merely on a basis of gross amount of water resources but ignoring changes of water consumption efficiency and structure will weaken water resources contribution to the entire national economy.

As water resources availability in Erdos City continues to increase, water consumption structure has shown a trend of shifting from agriculture to industry, construction industry and tertiary industry. For water consumption efficiency in each industry have a big difference, minor adjustments of water consumption structure will bring a great improvement in water resources use efficiency, and water resources contribution rate to economic growth will be obviously affected as well. After considering water consumption efficiency and water consumption structural change, the average contribution rate of water resources to economic growth from 1980 to 2010 is 8.26%, which has been much enhanced than that before considering water consumption efficiency and water consumption structure (as shown in Table 1). The contributions of capital, labor force and coal resources to economic growth have not changed and the contributions of total factor productivity and remaining total factor productivity to economic growth have decreased. In fact, the increased part of water resources contribution to economic growth is hidden in total factor productivity; when this part of the contribution is figured out, the contributions of total factor productivity and remaining total factor productivity to economic growth would reduce, and the reduced degree equals to the increased part of water resources contribution rate.

Comparison of assessment results at different time periods (five years on average) of water resources contribution rate to economic growth before and after considering water consumption efficiency and water consumption structure can be seen in Figure 1. We can see that, water resources contribution rate after considering water consumption efficiency and structural change has been obviously enhanced; water resources contribution rate from 1980 to 1985 is lower than that before considering water consumption efficiency and water consumption structure. It is mainly because that agriculture water occupied more than 95% of gross water consumption at that time, and difference of water consumption efficiency in each department is lower. After unification of the difference, water resources availability growth tends to be moderate and water consumption growth rate reduces. As agricultural water shifts to industry and tertiary industry departments, the difference of water consumption efficiency in each industry becomes bigger, and water resources contribution rate increases significantly. Therefore, when water resources are constrained, water resources contribution to economic growth may be improved through water consumption structural adjustment and water consumption efficiency improvement.

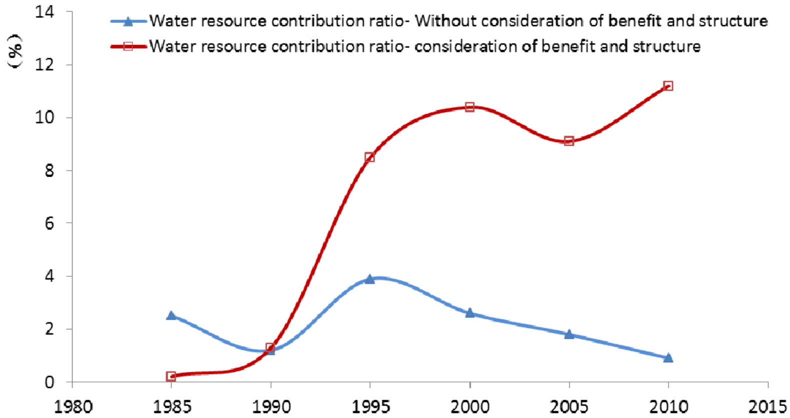

Figure 1 Assessment results at different time periods of water resources contribution rate to economic growth before and after considering efficiency and structure

(2) Variation trend of water resources contribution rate to economic growth

The changing process at five-year statistical time periods of production factors contribution rate to economic growth as shown in Table 2 and Table 3. We can see that, water resources contribution rate roughly shows an increasing trend, from 0.38% of 1980~1985 to 8.79% of 1990~1995 and to 11.3% of 2005~2010. The changing trend is closely connected with the constant increased growth rate of water resources availability after considering water consumption efficiency and water consumption structure. It also has something to do with relative changes of the growth rates of water resources availability and economy.

The variation trends of the contribution rates of coal and capital are similar; peaks appeared during 1990~1995 and 2000~2005 twice, and a valley appeared during 1995~2000. It is closely connected with the growth rate of coal exploitation. Prosperity of coal industry gives rise to material capital contribution to economic growth. Decrease of labor force contribution rate is obvious; one of the main reasons is that large non-native population has not been considered in calculation. The contribution rate of total factor productivity improvement to economic growth increased from 18.63% of 1980~1985 to 53.35% of 2005~2010, among which, structural change contribution to economic growth is relatively great. But after the year 2000, the contribution rates of industrial structural adjustment and system innovation to economic growth had been reduced significantly. This illustrates that in recent years, roles of those factors have not been fully played, and the driving effect of remaining total factor productivity inclusive of technical progress has been increased significantly.

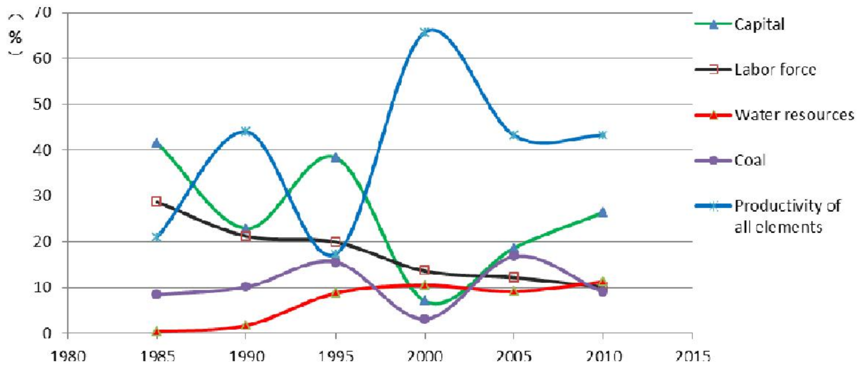

Figure 2 The variation trend of the contribution rate of water resources and other production factors to economic growth

4. Conclusions

Based on the analysis of main factors of economic growth in Erdos City with Cobb-Douglas production function in economics, the economic growth model involving water resources availability and coal output has been established and the data conversion method considering water consumption efficiency and water consumption structural change has been proposed. It has made up for the deficiency of failing to fully consider the contribution rates of water consumption efficiency improvement and water consumption structural change contribution to economic growth in the past researches. Main conclusions include:

(1) Water resources contribution rate to economic growth is significantly affected by water consumption efficiency and water consumption structural change. The average contribution rate of water resources during 1980~2010 to economic growth in Erdos City is 8.26%, greatly enhanced than 2.48% before considering water consumption efficiency and water consumption structural change.

(2) Water resources contribution to economic growth in Erdos roughly shows an increasing trend. The changing trend is closely connected with water consumption efficiency and water consumption structure, the growth rate of water resources availability, and the relative change of water resources availability's growth rate and output growth rate.

In the article, elastic coefficients of tangible material elements are determined with an empirical method, and to find a more objective method of parameter measurement still needs further research.

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