

Evaluating Economic Benefits of Water Diversion Project for Environment Improvement: A Case Study

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Abstract

The research in this paper was based on the project of water diversion from the Yangtze River to the Taihu Lake which significantly improves water environment of the lake and brings obvious economic benefits for surrounding areas. An analytical framework is developed on evaluating benefits of water supply to Huzhou city from project of water diversion from Yangtze River to Taihu Lake, including: (1) the value-added of water supply on the project are divided into four parts according to the characteristics of Hangzhou- Jiaxing-Huzhou Plain area. (2) The utilization ratio of water diversion is defined based on the features of water resources. (3) The water supply effects on industries and residents' living are explored using partition coefficient method in Huzhou city. Grey relation technique is used to examine the relationship between water use and industrial development in Huzhou, which aims to clarify the rationality of partition coefficient method. The results indicate that benefit of water diversion from Yangtze River to Taihu Lake to tertiary industry of Huzhou city is the highest, while that of industry is the lowest.

Keywords: Water Environment, Water Diversion, Economic Benefit, Grey Correlation

1. Introduction

With rapid economic development and great population increase, contradictions among population, resources, environment and development have become a serious challenge. There are extensive reports on this problem based on developed countries such as American, Britain, Holland and Australia. Gardiner advocated the integrated management of river basin aiming to realize river basin's sustainable development [1,2]. National Rivers Authority (NRA) (1995) in Britain published Thames Basin Agenda 21 and Sustainable Development Strategy [3]. The United States Environment Protection Agency (EPA) has addressed importance to governing river basin since 1990.

Since China's reform and opening policy in 1978, Taihu Lake Basin area has changed rapidly. According to the statistics supplied by Taihu Lake Basin Authority, Ministry of water Resources, P. R. China, in 2005, the area created GDP of 13% with its population of 3.2% and area of less than 0.4% in China; and in 2006, it created GDP of 11.1% with its population of 2.8% and area of less than 0.4% in China. However, poor water condi-

tions have been a factor restricting socio-economic development and causing environmental deterioration. Traditional water supply cannot help to provide more water to meet growing demands [4]. Water is often imported through inter-basin water transfers across national, regional and local boundaries to meet increasing off-stream demands in agriculture, industry, hydropower, and household sectors for economic and social development [5]. The project of water diversion from Yangtze River to Taihu Lake, to some extent, covers the shortage of water.

Diverting Yangtze River water into Taihu Lake is by the Wang Yu River project to introduce water from Yangtze River into Taihu Lake and its ambient plain river area, then by the Taipu River project to supply water for downstream area (e.g., Hangzhou-Jiaxing-Huzhou Plain area) (see Figure 1). It officially started in 2002. By the end of 2006, it has transferred 7.42 billion m³ water from Yangtze River into Taihu Lake Basin, of which 3.24 billion m³ into Taihu Lake; at the same time it has supplied 9.02 billion m³ for downstream area by way of Taipu brake, of which nearly half of water for Hangzhou-Jiaxing-Huzhou area [6].



Figure 1. Sketch map of water diversion from Yangtze River to Taihu Lake.

Huzhou city, a city of Zhejiang province and near south of Taihu Lake, is located in the mid-upriver of Taihu basin. Because of its especial geographic position, Huzhou city is always one of the important cities which greatly benefit from the project of water diversion from Yangtze River to Taihu Lake. In the area, water from Taihu Lake is introduced by using two channels. One is that water from Taihu Lake supplies water for basin lower reaches by way of Taipu River. While water from Taipu River directly enters Hangzhou-Jiaxing-Huzhou Plain area by way of Jing-Hang Grand Canal, You Pond, Da Zheng Pond and Wu Zi Pond. The other is that water from Taihu Lake supplies water for east parts of Hangzhou-Jiaxing-Huzhou Plain area by way of river diversion brakes of East Tiao Xi and Lou Harbor entrances of Taihu Lake.

Based on the practical measure and analysis for years by Taihu Lake Basin Authority, Ministry of water Resources, P. R. China, the results show that in Hangzhou-Jiaxing-Huzhou Plain area the range of influence from water flow are mainly east and west plains of Hangzhou-Jiaxing-Huzhou area with the area of about 3 thousand m^2 , of which Huzhou city is the core beneficial area.

The paper aims in providing an analytical framework for evaluating benefits of water diversion projects.

2. Model Development

In order to analyze the benefits of supply water to the intake area, the method of partition coefficient was employed. That is, the benefits of supply water to the intake

area can be computed in creating value-added process according to contribution rate of water to primary industry, industry (included in secondary industry), tertiary industry and residential living.

The benefits of supply water for primary industry, industry, tertiary industry and residential living can be calculated as (1):

$$B_s = V_s \cdot (f_s \cdot q_s \cdot k_s) \quad (1)$$

where s represents the economic sector of interest (e.g., primary industry), B benefit of supply water, V benefit of each cubic water, f partition coefficient, q value-added of water supply and k utilization ratio of water diversion.

Individually, for primary industry, industry, tertiary industry, V can be calculated as (2):

$$V = I/W \quad (2)$$

However, for residential living, V has the form of (3):

$$V = r \cdot e / p \quad (3)$$

In (2) and (3), all the variables are explained as follows.

I –value-added of each industry

W –total volume of water use

r –disposable income of residents

e –Engel's coefficient

p –per capita water consumption of every year

Adopting the method of partition coefficient to calculate economic benefits of water supply is one of the methods according to the calculation norm of water resources economics. The method can show the correlation

among benefits, inputs and outputs. It has been proved suitable in theory and convenient in practice. The key to use the method is how to define the partition coefficient of benefits of water supply. When partition coefficient is appropriately chosen, the benefits of water supply can be concordant with practical results.

3. Description of Variables

In order to calculate the benefits of water supply B on the project of water diversion from Yangtze River to Taihu Lake, the eight variables, that is, value-added of water supply q , value-added of each industry I , total volume of water use W , partition coefficient f , disposable income of residents r , Engel's coefficient e , per capita water consumption of every year p and utilization ratio of water diversion k , must be given.

3.1. Value-Added of Water Supply

In Hangzhou-Jiaxing-Huzhou Plain area, there are multiple rivers and complex river nets with cross-piercing at the bottom as a big container. The water by diversion from Yangtze River to Taihu Lake can freely flow in the area. Thus allocating the value-added of water supply according to water use ratio can reflect the practical water utilization.

The lines of water diversion in the project of water diversion from Yangtze River to Taihu Lake are mainly two: one is supplying water to Hangzhou-Jiaxing-Huzhou Plain area by passing through the Lou harbors of the circle Taihu Lake; another is by passing through the Taipu River. The value-added of water supply are showed in Table 1. By the end of 2005, the total value-added of water supply to Hangzhou-Jiaxing-Huzhou Plain area has been up to 3.926 billion m^3 by the project.

Based on analyzing the water utilization of Hangzhou-Jiaxing-Huzhou Plain area in 2000, the value-added of water supply to every industry and residential living of Huzhou on the project of water diversion from Yangtze River to Taihu Lake were calculated respectively, as listed in Table 2.

Table 1. Value-added volumes of water supply to Hangzhou-Jiaxing-Huzhou plain area on project of water diversion from Yangtze river to Taihu Lake, 2002–2005 Unit: $10^8 m^3$.

Year	Taipu River	Circle Taihu Lake	Total Value-added of Water Supply
2002	2.65	1.06	3.71
2003	6.5	5.90	12.40
2004	2.66	6.61	9.27
2005	4.06	9.82	13.88
Total	15.87	23.39	39.26

Source: Taihu Lake Basin Authority, Ministry of Water Resources, P. R. China.

From Table 2, we can see that the value-added volume of water supply to Huzhou city on the project is steadily increasing. However, in 2003 the value-added of water supply added to 0.131 hundred million m^3 from the value-added of 0.039 hundred million m^3 in 2002 because the year of 2003 is especially on shortage of water. Thus the water height in Huzhou city in 2003 is above the normal water level so as to keep the water quality stable and alleviate water demand in Huzhou city.

3.2. Utilization Ratio of Water Diversion

The total volume of value-added of water supply by the project of water diversion from Yangtze River to Taihu Lake is not possible to be completely used, of which they are discharged without being used. Thus when the direct economic benefits of water diversion are calculated, the parts of water transmission losses should not be computed. In the paper, the utilization ration of water diversion k is defined as (4):

$$k = q_0 / q \quad (4)$$

where q_0 represents the practical use volume of water diversion and q describes the total volume of water diversion. The value of k is decided by the shortage degree and the use capability of water resources in the researched area. According to the total planning of water resources protection and use capability in Zhejiang province, the utilization ration of water diversion is approximately 0.6 in recent years. Thus the utilization ratio of water diversion in Huzhou city is chosen as 0.6.

3.3. Partition Coefficient

The option of the partition coefficient of benefits of water supply is quite important. The benefits of water supply are not concordant with practical results until the partition coefficient is appropriately chosen.

Table 2. Value-added volumes of water supply to three industries and residential living of Huzhou city on project of water diversion from Yangtze River to Taihu Lake, 2002–2005 Unit: $10^8 m^3$.

Year	Total Value-added of Water Supply	Value-added of Water Supply to Primary Industry	Value-added of Water Supply to Industry	Value-added of Water Supply to Tertiary Industry	Value-added of Water Supply to Residential Living
2002	0.362	0.176	0.072	0.014	0.039
2003	1.210	0.588	0.240	0.046	0.131
2004	0.905	0.439	0.180	0.034	0.098
2005	1.355	0.658	0.269	0.051	0.147

1) Partition coefficient of primary industry

Generally, the increasing of production of farm crop results from the synthetical effects of water, fertilizer, seed, soil improvement and technical measures in primary industry (e.g. prevention from disease and insect pest). Thus, allocating the total value-added of production should be scientifically transacted. According to the computation results of benefits of irrigation for many years in Jiangsu, Zhejiang and Shanghai, the average partition coefficients of primary industry in Taihu Lake are individually shown as follows: it is 0.4 in level water year, 0.53 in low water year or slightly low water year. Thus, according to the situation of rain water in Huzhou city in 2002–2005, we can define the average partition coefficients of primary industry (Table 3).

2) Partition coefficient of industry

By the use of the data in Huzhou Statistical Yearbook (1989–2005) [7], an industrial production function can be showed as (5). The equation can be gained by the regression analysis with total production of industry Y as dependent variable, and fixed assets K , populations of labour force L and total volume of water use of industry W as independent variables.

$$Y = 0.997K^{0.493}L^{0.534}W^{0.242} \quad (5)$$

In (5), it indicates that the contribution coefficient of water to industry is about 0.2. That is to say that the total production will increase by 0.2% with the increase of water use of 1%. In recent years, the average value-added rate of industry is near 0.25 in Huzhou city. It shows that the total production of industry will increase by 0.05% with the increase of water use of 1% in Huzhou city. Thus, the partition coefficient of industry in Huzhou city is about 0.05.

3) Other partition coefficient

The contribution rate of water to restore labour force is defined as the partition coefficient of tertiary industry. The value is 0.3 according to Chen [8]. The partition coefficient of residential living is calculated by the contribution rate of all kinds of the living materials to restore labour force. According the viewpoint of the Chen [8], the value is thought as 0.3 in this paper.

3.4. Other Variables

The value-added of each industry I and disposable income of residents r can be attained from Huzhou

Table 3. Average partition coefficients of primary industry in 2002–2005.

Year	2002	2003	2004	2005
Rain Water	Lever water	Low water	Slightly low water	Slightly low water
Average Partition Coefficient	0.4	0.53	0.53	0.53

Statistical Yearbook (2002–2005) [7,9–11]. Total volume of water use W can be obtained from Huzhou Water Resources Bulletin. Engel's coefficient e can be calculated by (5). Per capita water consumption of every year p can be demonstrated by (6).

$$e = e_1 / e_2 \quad (6)$$

$$p = W / Pop \quad (7)$$

where e_1 describes the food expenditure, e_2 shows the total expenditure and Pop defines the population in cities and towns. The value of the three variables can be obtained from Huzhou Statistical Years (2002–2005) [7, 9–11].

4. Results

Using (1) and (2), the economic benefits of water supply to the three industries of Huzhou city on the project of water diversion from Yangtze River to Taihu Lake were calculated in the years of 2002–2005, as listed in Table 4.

By (1) and (3), the economic benefits of water supply to the resident living of Huzhou city on the project of water diversion from Yangtze River to Taihu Lake were calculated in the years of 2002–2005, as listed in Table 5.

In Table 4 and Table 5, it indicates that in the years of 2002–2005, economic benefits of water supply for primary industry, industry (included in secondary industry), tertiary industry and the residential living of Huzhou city on the project of water diversion from Yangtze River to Taihu Lake are respectively 1.726 hundred million Yuan, 1.309 hundred million Yuan, 12 hundred million Yuan and 0.415 hundred million Yuan. Among them, economic benefit of water supply for tertiary industry is the highest. And the next is primary industry.

5. Evaluating of Economic Benefits of Water Diversion

Although using the method of partition coefficient to calculate economic benefits of water supply is useful, there are some limitations. For example, more investment in the project of water supply, more economic benefits which is unreasonable in practice. Thus, in order to validate the rationality of adopting the method applied in the Huzhou area, the grey relation analysis method is chosen.

Compared with traditional statistical methods which require more data and time, the grey relation analysis (GRA) only needs minimal data to get reasonable and good results. The technique of grey relation analysis has been applied in many fields. For example, Morita *et al.* [12] applied GRA to examine the annual load demand of the power system in Japan, and drew a conclusion that the grey system for the long-term load forecasting problem

Table 4. Economic benefits of water supply to three industries of Huzhou city on project of water diversion from Yangtze River to Taihu Lake, 2002–2005 Unit: 10⁸ Yuan³.

Year	2002	2003	2004	2005	Total
Primary Industry	0.100	0.492	0.493	0.641	1.726
Industry (belong to secondary industry)	0.115	0.389	0.303	0.502	1.309
Tertiary Industry	2.850	3.180	2.380	3.590	12

Table 5. Economic benefits of water supply to residential living of Huzhou city on project of water diversion from Yangtze River to Taihu Lake, 2002–2005 Unit: 10⁸ Yuan³.

Year	2002	2003	2004	2005	Total
Residential Living	0.039	0.131	0.098	0.147	0.415

Table 6. Statistical results on total volume of water use and structure of gross domestic product in Huzhou city.

Year	Total volume of water (billion m ³)	Value-added of Primary Industry (%)	Value-added of Industry (%)	Value-added of Tertiary Industry (%)
2002	1.804	12.2	46.6	34.2
2003	1.764	11.3	46.7	35.4
2004	1.841	11	47.8	34.2
2005	1.776	9.8	48.8	35.25

Source: 2005 Huzhou Statistical Yearbook, P. R. China [7] and Huzhou Water Resources Bulletin, P. R. China (2002–2005) [14].

Table 7. Results of grey relation analysis method.

Item	Grey Relation Degree of Structure of Gross Domestic Product		
	Primary Industry	Industry	Tertiary Industry
Grey relation degree	0.7372	0.5697	0.8068
Weight	0.3488	0.2695	0.3817

had a higher accuracy than the linear single regression model. Lin *et al.* [13] used GRA to analyse the productivity, aggregate energy consumption, and the use of fuel mix in relation to CO₂ emission changes and thus the suggestions are given.

According to the grey relation analysis method, the total volume of water use were considered as main element sequence, and the structure of gross domestic product was thought as sub-element sequences (see Table 6). The computational results are listed in Table 7.

From Table 7, the grey relation degree of value-added of tertiary industry is the highest, reaching the value of 0.8068, while that of industry is the lowest with the value of 0.5697. Thus, adding the water supply can greatly improve the value-added of tertiary industry.

6. Conclusions

The paper has developed an analytical research framework on benefits of water supply to Huzhou city on the project of water diversion from Yangtze River to Taihu Lake. The result is perfectly coincident with that of the grey relation degree analysis method. It also showed that the project of water diversion from Yangtze River to Taihu Lake plays an important role in improving economic benefits to Huzhou city. It also proves significant and necessary to continuously implement water diversion from Yangtze River to Taihu Lake.

However, in the paper, only direct economic benefits of water supply to Huzhou city on the project of water diversion from Yangtze River to Taihu Lake were calculated by analyzing the value-added of water supply. It is insufficient in researching ecological and social benefits, such as zoology, environment, health and physiology etc., with water improvement and water flow changes resulting from the increase of value-added of water supply. The future research will focus on the ecological and social benefits of the project.

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