Water marginal benefit analysis in the recipient area of Water Transfer Project from South to North

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Abstract

Huang-Huai-Hai River Basin, the recipient area of Water Transfer Project, is one of the most water-scarce territories in the world. Water resources already became the key factor to tie up the socioeconomic development. Therefore, to quantitatively analyze its contribution to national economy will be an important reference for the huge water diverting project evaluation. This paper calculates the output elasticity and marginal benefit of water by establishing Cobb-Dauglas production function for Huang-Huang-Hai and whole nation. The result shows the marginal benefit of Huang-Huai-Hai including agriculture is around 2.9yuan/m^3, excluding agriculture is around 13.2 yuan/m^3, which is higher than national average value. It can be predicted that the water marginal benefit will increases as scarcity of water, correspondently the GDP losses by water shortage will be intensified. Thus, implementing the diverting project will be a wise way to diminish the loss.

Key words: marginal benefit, national economy, water transfer project from South-North, Huang-Huai-Hai, China

1. Background

Huang-Huai-Hai region of North China (further called 3-H region), served by three major rivers (The Yellow) Huang River, Huai River and Hai River), with per capita supplies of about 6 percent of the world average (500m^3 per capita), is the home of more than 30% of China's population, produced about 30% of national GDP. Alongside the good economic performance and agricultural growth, water-related problems such as water shortages, pollution, groundwater tables falling and drought damages are becoming more frequent and severe in this region. The research (World Bank, 2001) shows all the severely water-deficient cities and 55 percent of the other water-deficient cities in China are located in Huang-Huai-Hai River Basin.

Facing such a serious water crisis the huge water transfer project from South to North is regarded as a fundamental way to release the water shortage of the area. However, when the huge project was drafted, many people will has doubt from economic aspect that how much losses can be redeemed by building the water diverting project? Is it worthy of spending huge money with a investment more than 30 billion US$? The aim of this paper attempts to quantitatively identify the water marginal benefit and output elasticity in 3-H region to assess the losses which can be redeemed by the project.

2. Methodology

2.1 Cobb-Dauglas production function

The Cobb-Douglas functional form of production functions is widely used to represent the relationship of an output to inputs in economics (Vargas et.al.). It was proposed by Knut Wicksell, and tested against statistical evidence by Paul Douglas and Richard Cobb in 1928.In this production function, the elasticity of factor substitution is constant and equal to unity. In general, this function has the form as follows:

$$Q = AK^{\alpha} L^{\beta} M^{\gamma} \quad (0 < \alpha, \beta, \gamma < 1) \tag{1}$$

where Q is product, A is an efficiency parameter, K is the input of capital, L is the input of labor, M is the input (or utility) of other materials and supplies and α, β, γ, are the input coefficients (which, for this function, are equal to constant elasticity of substitution).

If $\alpha+\beta+\gamma > 1$,it is in line with the law of increasing return to scale. If $\alpha+\beta+\gamma = 1$, it is in line with the law of constant return to scale. And if $\alpha+\beta+\gamma < 1$, it is in line with the law of diminish return to scale (Wiens, 2005).

2.2 Application-establishing water utility function

The Cobb-Dauglas production function is frequently used to analyze productivity and efficiency of resource. The water withdrawal can be incorporated in the production function as a dummy variable to estimate the efficiency effect of water withdrawal to the national economy. Therefore, the function can be rewritten by the following form:

$$Y = AK^{\alpha} L^{\beta} W^{\gamma} \quad (2)$$

where Y is GDP in a specific year, W is the input of water withdrawal for producing GDP in a specific year. Since various data are used to estimate the function, one expects the amount of different inputs used to be highly correlated with the amount of GDP. This creates the well-known problem of multi-collinearity in estimating the parameters of the function. No doubt, labors and investment are consumed during water withdrawal and supply process. Nonetheless the overlapping effects among water, labor and capital can be ignored as the input proportions of labor and investment of water supply among whole economic sector are too small, 0.06% and 0.2% only in Huang-Huai-Hai River Basin, for instance.

The function's logarithm form to a linear relation will be convenient for the calculation (Wang, Ruan & Shen, 2003), i.e.

$$Ln(Y) = Ln(A) + \alpha * Ln(K) + \beta * Ln(L) + \gamma * Ln(W) \quad (3)$$

The derivative of Y is

$$\Delta Y / Y = \alpha \Delta K / K + \beta \Delta L / L + \gamma \Delta W / W \quad (4)$$

The partial derivative of Y to W is

$$\partial Y / Y = \gamma \partial W / W \quad (5)$$

The γ i.e. the elasticity of substitution of water for the GDP will be

$$\gamma = \frac{\partial Y / Y}{\partial W / W} = \frac{\partial Y \times W}{\partial W \times Y} \quad (6)$$

Therefore the marginal benefit of water for national economy is equal to the multiplier by the value added elasticity of water and output produced by per unit water usage.

$$V_w = \partial Y / \partial W = \gamma \times \frac{Y}{W} = \frac{\partial LnY}{\partial LnW} \times \frac{Y}{W} = \gamma g \quad (7)$$

Where g is output produced by per unit water usage.

3. Water marginal benefit of Huang-Huai-Hai River Basin

3.1 Average marginal benefit

The 40 industries iuput-output table of 3-H region in 2000 (Wang, Qin et al, 2005) listed in Table 1 indicates 253 million employees among 40 industries produced a value added of 2.7 trillion Yuan which is equivalent to 338 billion US$ with a investment input of around 18 trillion Yuan and a water withdrawal of the amount of employee among was around 253 million and water withdrawal 132 billion m^3 in the year of 2000.

Table 1 Investment, labor and water withdrawal by industries in 2000

	Industries	Value added	Invest-ment	Employee	Water withdrawal
		10^9 Yuan	10^9 Yuan	10^6 person	10^6 m^3
1	Agriculture	511	620	125.15	107830
2	Coal mining and processing	75	448	4.47	484
3	Crude petroleum and natural gas production	35	239	0.41	227
4	Metal ore mining	23	105	1.21	339
5	Non-ferrous ore mining	20	89	1.27	208
6	Manufacture of food and tobacco processing	124	519	1.92	2277
7	Textile goods	70	393	3.57	977
8	Wearing apparel, leather, and related products	39	182	3.51	470
9	Saumills and furniture	17	83	1.27	185
10	Paper and products, printing	44	224	2.37	2940
11	Petroleum processing and coking	28	151	0.37	426
12	Chemicals	129	834	3.65	3507
13	Nonmetal mineral products	106	552	5.59	1060
14	Metal smelting and pressing	61	433	3.26	1423
15	Metal products	43	218	2.47	595
16	Machinery and equipment	101	642	4.58	1382
17	Transport equipment	31	205	1.56	262
18	Electric equipment and machinery	34	164	2.08	366
19	Electric and telecommunication equipment	32	301	0.9	152
20	Instruments, cultural and office machinery	5	32	0.59	37
21	Maintenance and repair of machine	9	44	0.63	43
22	Other manufacturing products	23	57	0.95	142
23	Scrap and waste	33	204	3.04	98
24	Electricity, steam and hot water supply	62	582	0.77	4839
25	Gas Production and supply	1	5	0.07	24
26	Water production and supply	6	34	0.14	33
27	Construction	194	354	13.96	505
28	Transport and warehousing	76	1030	8.04	204
29	Post and telecommunication	46	657	1.67	32

	Industries	Value added	Invest-ment	Employee	Water withdrawal
		10^9 Yuan	10^9 Yuan	10^6 person	10^6 m^3
30	Commerce	169	559	21.96	397
31	Restaurants	30	37	3.31	463
32	Passenger transport	26	316	3.34	24
33	Finance and insurance	107	3628	2.38	41
34	Real estate	40	650	0.31	13
35	Social service	100	671	5.21	214
36	Health service, sport and social welfare	26	94	2.24	29
37	Education, culture and arts, broadcast	78	363	7.63	59
38	Scientific research	5	36	0.64	2
39	General technical services	37	813	1.49	126
40	Public administration and other sectors	104	1159	5	55
	Subtotal	2700	17727	253.00	132490

According to previous information, the logarithm form relation based on Cobb-Dauglas Production function can be derived by a multi-linear regression in Table 2 and Table 3 where R square is 0.94, F value is 191 with a significance of 3.77 $\times 10^{-23}$ and variances pass T-test, which implies that the regression has a good precision and variances are stable.

Table 2 Regression statistics

	R^2	Adjusted R^2	F	Significance F
Regression	0.9699	0..9408	190.7559	3.77E-22

Table 3 Average elasticity of substitution in 2000

	Coefficients	Standard Eroor	t Stat	P-value	Lower 95%	Upper 95%
Intercept (Ln (A))	3.6664	0.6717	5.4587	4.64E-06	2.3042	5.0286
Investment (α)	0.4939	0.0449	10.9999	3.45E-12	0.4029	0.5850
Labor (β)	0.3215	0.0476	6.7593	2.46E-07	0.2251	0.4180
Water withdrawal (γ)	0.1427	0.0286	4.9860	2.85E-05	0.0847	0.2008

The formula 2 which incorporate water input of 3-H region in 2000 can be expressed as:

$$Y = 39.1 \times K^{0.4939} \times L^{0.3215} \times W^{0.1427} \tag{7}$$

The average valued added produced by per cubic meter in 2000 was 20.4 Yuan/m^3, thus the average marginal benefit of water in 2000 was 2.9Yuan/ m^3, namely the value added would increase 20.4 Yuan by adding one cubic meter water withdrawal, of which the contribution of water is 2.9 Yuan.

3.2 Marginal benefit of non-agricultural industries

The average marginal benefit sometimes will hide the contribution of water to value add of non-agriculture due to agriculture incorporated as agriculture always ranks the first for labor and water consumption with relatively lower benefit in comparison with the second and tertiary industries. The elasticity of substitution of investment, labor and water withdrawal for non-agricultural industries are computed by the same method and listed in table 4.

Table 4 Water elasticity of substitution of non-agriculture in 2000

	Coefficients	Standard Eroor	t Stat	P-value	Lower 95%	Upper 95%
Intercept (Ln (A))	3.6696	0.6784	5.4094	4.64E-06	2.2924	5.0468
Investment (α)	0.4871	0.0471	10.3471	3.45E-12	0.3915	0.5827
Labor (β)	0.3325	0.0521	6.3777	2.46E-07	0.2267	0.4383
Water withdrawal (γ)	0.1487	0.0309	4.8088	2.85E-05	0.0859	0.2114

$$Y = 39.2 \times K^{0.4871} \times L^{0.3325} \times W^{0.1487} \qquad (7)$$

The average valued added produced by per cubic meter water withdrawal of non-agricultural industries in 2000 was 88.8 Yuan/m^3, thus the average marginal benefit of water in 2000 was 13.2Yuan/ m^3.

It is difficult to compute the water elasticity of agriculture by the same method due to lacking of variance amount. Wang et.al. (2005) calculated the water agriculture is around 0.2541 by a regression with the sample series from 10 river basins. Then, the water marginal benefit of agriculture in 2000 was 1.19 Yuan/ m^3 corresponding to a valued added produced by per cubic meter of 4.7 Yuan/m^3.

3.3 Marginal benefit by regions

The marginal benefit varies in different region with different industrial structure, development standard and water withdrawal by sectors. 3-H region, for instance, is a fluvial plain with a territory of 1.44 million km^2 where Beijing, Tianjin, two metropolises are located, whereas the least developing region of China is also involved. The calculation result indicates (table 5) three individual regions whose average water marginal benefit is higher than national average level, as well as that of non-agricultural industries. Huanghe (Yellow River), producing 22 % GDP by using 29% water withdrawal of subtotal of 3-H region, has the lower marginal benefit among the three regions, i.e. 2.2 yuan/m^3 for the average and 12 yuan/m^3 for nor-agricultural industries, 14% and 9 % lower than regional level respectively.

Table 5 Water marginal benefit three river basin

	Average			Non-agriculture		
	g	γ	V_w	g	γ	V_w
	Yuan/m^3		Yuan/m^3	Yuan/m^3		Yuan/m^3
Huanghe(Yellow River)	16.1	0.1387	2.2	81.0	0.1483	12.0
Huaihe	22.1	0.1971	4.4	83.91	0.1832	15.4
Haihe	24.4	0.1481	3.6	108.4	0.1602	17.4
Whole country	15.9	0.1275	2.0	54.2	0.1365	7.4

The indicator can reflect the water use efficiency. The average marginal benefit of water is lower in Haihe than Huaihe, moreover he value is higher than Huanh if excluding the agriculture. The water use efficiency of agriculture is obviously higher in Huaihe than Haihe. The water use efficiency of non-agriculture industries has the contra result.

4 The losses redeemed by the water transfer project

World Bank estimated (2001) that current 3-H shortages for "priority sectors" (urban, industry, and rural domestic) total about 6.35 billion m^3/yr (despite very large groundwater mining). Shortages are much higher for irrigation, fluctuating between 12 billion to 32 billion m^3 when the region experiences wet, normal and dry year, averaging about 19 billion m^3 when the probability of flow is 50%. The loss induced by water shortage can estimated by the marginal benefit, about 98~123 billion Yuan, of which the loss caused by "priority sectors" i.e. non-agricultural industries is 84 billion Yuan.

The final plan of the Water Transfer Project from South to North is already drafted, as Qian et al. (2002) elaborates, which will divert water from the upper, middle, and lower reaches of the Yangtze River respectively, with a maximum transfer amount of 38~43 billion m^3/yr by three water diverting routes. In other words, when the huge project is finished the deficit of 3-H region will be almost filled in even if it encounters a dry year. Therefore, the loss redeemed by the projected is equal to the loss induced by the water shortage in this region.

5 Conclusion

Incorporating water into Cobb-Dauglas production function receive a good result has a high precision for the regression. The calculation shows, currently, the water marginal benefit of average, agriculture and non-agricultural industries is 2.9 Yuan/m^3, 1.19 Yuan/m^3 and 13.2 Yuan/m^3 respectively. The loss induced by water shortage is around 98~123 billion Yuan, which can be regarded as the loss redeemed by the S-N Water Transfer Project at the current status.

It can be predicted that the water marginal benefit will increases as scarcity of water, correspondently the GDP losses by water shortage will be intensified. Therefore, implementing the diverting project will be a wise way to diminish the loss.

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