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Shanxi Water Resource Input-Occupancy-Output Table and Its Application In Shanxi Province of China*

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ABSTRACT

Shanxi Province of China is extremely poor in water resource. We constructed water resource input-occupancy-output table for 1995. In this paper we introduce characteristics of the table and propose some new methods to calculate total water input coefficients, total waste water emission coefficients and total water imports. On the basis of the table we use translog production function method and linear programming model to estimate the economic value of the water. In the last part we introduce our suggestion for creating a water resource saving national economy to the local government.

Keywords: Input-occupancy-output techniques, Total water input coefficient and total waste water emission coefficient, Total water import, Translog production function.

1. Introduction

China is poor in water resource with the average annual water resource of 2812.4 billion m^3. Per capita annual water resource of China in 1999 was 2230 m^3, which is equal to 1/3.5 of the per capita water resource in the world. Regional distribution of water resource in China is unbalanced. The most water resource is located in the south part. The land area of north part accounts for 64.4% of total land area of China, but water resource in north part only accounts for 19% of national water resource. Particularly Shanxi Province is extremely poor in water resource. The average annual water resource of Shanxi is about 12.9 billion m^3 and per capita water resource is only 407 m^3, which is equal to 1/18 of the per capita water resource of the world.

Shortage of water resource produces a great impact on people's health and economic development. In recent years average annual city life water consumption in Shanxi is 131 L/person·day, of which city household water consumption is 72 L/person·day. Particularly in rural areas rural household water consumption is only 29 L/person·day. In Taiyuan, capital of the province, the tap plants carry out the systems of interval water supply and part time water supply. If there is not additional pump, people lived in the third floor of building often cannot get water. Most residents can only get water in 12 hours a day and often take water after 11 p.m. Some people only got 5-7 liters water per day. In Datong, the biggest Coal City in Shanxi, usually there is only 30 liters water for household use every person day. The tap plants supplied water three times per day, i.e. 7:00-8:00, 11:00-12:00 and 17:00-19:00. In the mining area of Datong, the water price of private seller was about 8 yuan per ton. Because of water shortage in the coal mining area of Datong the man bathhouses changed fresh water in big pools every 7 days, and the woman bathhouses every 3 days. It has caused serious dermatopathy.

In order to relax the situation of severe water shortage there is a special project, namely Wanjiazhai Yellow River-Shanxi Diversion Project (WYSDP). The project takes water from Wanjiazhai Reservoir

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on Yellow River, and provides water for three energy bases Taiyuan, Datong and Pingshuo respectively thus relaxes the situation. The total annual water supply amount provided by WYSDP will be 1.2 billion m^3. The total length of transmission line from Wanjiazhai to the water supply places is about 314 km. In order to do the economic evaluation of the project we constructed Shanxi water resource input-occupancy-output table.

Application of input-output techniques to the study of resource and environment problems began in the 1970s. W. Leontief and D. Ford (1972) use input-output model to study the air pollution. Carter, H. O. and D. Ireri (1970) use interregional input-output model to study water problem between California and Arizona. R.Thoss and K. Wiik (1974) use input-output techniques to study the water management. D.W. Hendricks (1982) uses input-output model to study supply and demand balance of water resource. Xie Mei and others (1991) use the model to the Beijing urban water systems. H. Bouhia (1998) incorporates water sector into the input-output table. Chen Xikang (1990, 1992) proposed input-occupancy-output model and used the model in agriculture and energy of China. In this paper we construct water economy input-occupancy-output model and study economic value of water for Shanxi.

2. The Model

The framework of water resource input-occupancy-output model is as follows (table 1)

Table 1 Water resource input-occupancy-output model

			Intermediate Demands				Final Demands	Total Output and Total Water
			Production Sectors	Water				
				Fresh water	Recycle water	Waste water treatment		
			1,2,⋯ n	1, 2,⋯ k	k+1,⋯m	1,⋯,h	1,2,⋯,t	
INPUT	Production …… Sectors		1 : n	X_{ij}	T_{ij}		T^{w}_{ij}	Y_{ij}	X_i
	WATER	Fresh Water	1⋯ k	F_{ij}				Z_{ij}	W_i
		Recycle Water	k+1⋯ m						
		Waste water. Emission	1⋯ h	P_{ij}				R_{ij}	W^{W}_{i}
	Primary Input		1⋯ S	V_j	V^{R}_{j}		V^{W}_{j}		
	Total Input, etc.			X_j					
OCCUPANCY	Fixed Assets		1⋯ n	D_{ij}	D^{R}_{ij}		D^{W}_{ij}		
	Circulating Assets		1,⋯ n						
	Labour Force		1⋯ g						

There are two characteristics in the model:

(1). The model includes three types of water sectors: fresh water sectors (1,2, ⋯ ,k), recycle water sectors (k+1,⋯,m) and waste water sectors (1, ⋯ ,h). Fresh water resource can be classified into surface water and ground water, etc.. Concerning waste water sectors vertically there are waste water emission sectors and horizontally waste water treatment sectors. In reality, in the model we regard water sectors as common production sectors

(2). In the common input-output model vertically there is only input section. The model includes not only input section, but also occupancy section. Occupancy section includes fixed assets, circulating assets, labour force and natural resource, etc. In the model sector classification of fixed assets is the same with the classification of production sectors. Then D is a n×n square matrix.

In table 1 horizontally there are three classes of equations:

(1). The equations of output use in production sectors

$$\sum_{j=1}^{n} X_{ij} + \sum_{j=1}^{m} T_{ij} + \sum_{j=1}^{h} T_{ij}^{W} + Y_i = X_i \qquad \text{(i=1,2,…,n)}$$

The intermediate demands are divided into three parts: consumption by production sectors (first item in the above equations), consumption by water sectors (second item) and consumption by waster water treatment sectors (third item). Where X_{ij} , T_{ij} , T^{w}_{ij} represent interindustry flows, the consumption of the ith product by the jth water sector, and consumption of ith product by the jth waste water treatment sector, respectively. Y_i represents final demand in ith sector $(Y_i = \sum_{j=1}^{n} Y_{ij})$ and X_i indicates total output of ith industry sector. In above equations, we introduce direct input coefficients of production sectors a_{ij} , direct input coefficients of water resource sectors t_{ij} , and direct input coefficient coefficients of waste water treatment sector t^{W}_{ij} as follows:

$$a_{ij} = \frac{X_{ij}}{X_j} \qquad \text{(i, j = 1,2,…, n)}$$

$$t_{ij} = \frac{T_{ij}}{W_j} \qquad \text{(i= 1,2, …,n; j =1,2, …, m)}$$

$$t_{ij}^{W} = \frac{T_{ij}^{W}}{S_j^{W}} \qquad \text{(i= 1,2, …,n; j =1,2, …, h)}$$

where n, m, h represent number of production sectors, number of water resource sectors and number of waste water sectors, respectively. W_j , S^{W}_{j} represent output of water resource sectors and amount of waste water treatment, respectively. Then we have

$$\sum_{j=1}^{n} a_{ij} X_j + \sum_{j=1}^{m} t_{ij} W_j + \sum_{j=1}^{h} t_{ij}^{W} S_j^{W} + Y_i = X_i \qquad \text{(i=1,2,…,n)} \qquad (1)$$

Equations (1) can be written in matrix form

$$AX + TW + T^{W}S^{W} + Y = X \qquad (2)$$

where X, W, S^{W}, Y represent column vector of gross output of production sectors, column vector of water resource output, column vector of waste water treatment amount, and final demands vector, respectively. A, T, T^{W} represent direct input coefficient matrix of production sectors, direct input coefficient matrix of water resource sectors and direct input coefficient matrix of waste water treatment sectors, respectively.

(2) The equations of water use

$$\sum_{j=1}^{n} F_{ij} + Z_i = W_i \qquad \text{(i=1,2, … , m)}$$

where F_{ij} represents the consumption of the ith water in the jth production sector; Z_i represents the consumption of ith water in the final demands, such as, city household water consumption, rural household water consumption. Therefore the sum of left hand in the above equations reflects the total consumption of water resources in the production and living process. Particularly, when i=1,2, ···,k the above equations represent fresh water consumption, and when I=k+1, ···,m the above equations indicate recycle water use. Now we introduce the direct water input coefficient of the production sectors f_{ij} in above equations

$$f_{ij} = \frac{F_{ij}}{X_j} \qquad \text{(i=1,2, …, m; j=1,2, …, n)}$$

Then the above equations can be rewritten as follows:

$$\sum_{j=1}^{n} f_{ij} X_j + Z_i = W_i \qquad \text{(i=1,2, …,m)} \tag{3}$$

and matrix form

$$FX + Z = W \tag{4}$$

where F denotes the direct water input coefficient matrix of the production sectors $F = \left\{ f_{ij} \right\}_{m \times n}$, Z represents column vector of the water consumption in the final demands sectors and W represents amount of the total water supply (water output sector).

(3) The equations of waste water emission

$$\sum_{j=1}^{n} P_{ij} + R_i = W_i^W \qquad \text{(i=1,2, … ,h)}$$

where P_{ij} denotes the ith waste water released by the jth production sector; R_i denotes the ith waste water released in the final demand sectors (household, etc.); W^W_i denotes the total amount of ith waste water released in this period. Now we introduce the direct waste water emission coefficient p_{ij} of the jth industry sector:

$$p_{ij} = \frac{P_{ij}}{X_j} \qquad \text{(i=1,2, … ,h; j=1,2, … ,n)}$$

Then we have

$$\sum_{j=1}^{n} p_{ij} X_j + R_i = W_i^W \qquad \text{(j=1,2,…,h)} \tag{5}$$

and get in matrix form

$$PX + R = W^W \tag{6}$$

where $P = \{p_{ij}\}_{h \times n}$, $R = \{R_i\}_{h \times 1}$. Let α_i be the ratio of the treatment of ith waste water, $0 \le \alpha_i \le 1$ and α is a diagonal matrix, whose elements in diagonal are α_i. Then we have $S^W = \alpha W^W$, and put it into (2). We have

$$\begin{aligned} AX + \quad & TW + \quad T^W \alpha W^W + \quad Y = X \\ FX + \quad & \qquad\qquad\quad Z = W \\ PX + \quad & \qquad\qquad\quad R = W^W \end{aligned}$$

or in block matrix form

$$\begin{bmatrix} A & T & T^W\alpha \\ F & 0 & 0 \\ P & 0 & 0 \end{bmatrix} \begin{bmatrix} X \\ W \\ W^W \end{bmatrix} + \begin{bmatrix} Y \\ Z \\ R \end{bmatrix} = \begin{bmatrix} X \\ W \\ W^W \end{bmatrix} \tag{7}$$

that is

$$\begin{bmatrix} I-A & -T & -T^W\alpha \\ -F & 0 & 0 \\ -P & 0 & 0 \end{bmatrix} \begin{bmatrix} X \\ W \\ W^W \end{bmatrix} = \begin{bmatrix} Y \\ Z \\ R \end{bmatrix}$$

Then we have

$$\begin{bmatrix} X \\ W \\ W^W \end{bmatrix} = L \begin{bmatrix} Y \\ Z \\ R \end{bmatrix} \tag{8}$$

here

$$L = \begin{bmatrix} I-A & -T & -T^W\alpha \\ -F & & \\ -P & & \end{bmatrix}^{-1} \tag{9}$$

L is the extended Leontief's inverse. When the Y, Z, R for a certain period are projected and the related coefficients are determined, the volume of X, W and W^W can be calculated by equations (8).

On the basis of above model we compiled Shanxi water input-occupancy-output table for 1995. There are 28 industry sectors in the table. The primary input (value added) are divided into 5 parts: depreciation of fixed assets, labour income, welfare fund, profits and taxes, and others. There are 3 water resource sectors in the table: surface water, ground water and recycle water. Besides, we have a waste water sector (vertically: waste water emission; horizontally: waste water treatment). There are 7 final demand sectors: peasant consumption, non-peasant consumption, social consumption, gross fixed capital formation, changes in stocks, imports and exports (please see appendix at the end of the paper).

From appendix we can find that total consumption of fresh water, including surface water and ground water, was 5742.50 million cubic meters (M m^3) in 1995. Of which 5299.39 M m^3 was consumed in production sectors, accounting for 92.28 per cent of all fresh water; 443.11 M m^3 was consumed as living use, accounting for 7.72 per cent of all fresh water. In appendix we also can find the figure of recycle water used in every sector and the recycle rate (rate of recycle water on the total water) in the production sector. In 1995 the recycle rate for all production sectors was 59.76 per cent and that for industry was 85.48 per cent. The figures were higher than the figures in 1990. In 1990 the recycle rate for all production sectors was 52.39 per cent and that for industry was 83.10 per cent. In 1995 the total amount of waste water emission in Shanxi was 1007.69 M m^3, of which that released by all production sectors was 889.43 M m^3, and that released by the urban households was 118.26 M m^3 (There aren't figure of waste water emission by rural household). It is noted that growth rate of waste water emission is very high. In 1990 the total amount of waste water emission was 853.37 M m^3. In five years it increased by 18.08 %.

3. Total Water Input Coefficients

Direct fresh water input coefficient f_j is the amount of fresh water consumed by per unit of output value in sector j . Its calculating formula is:

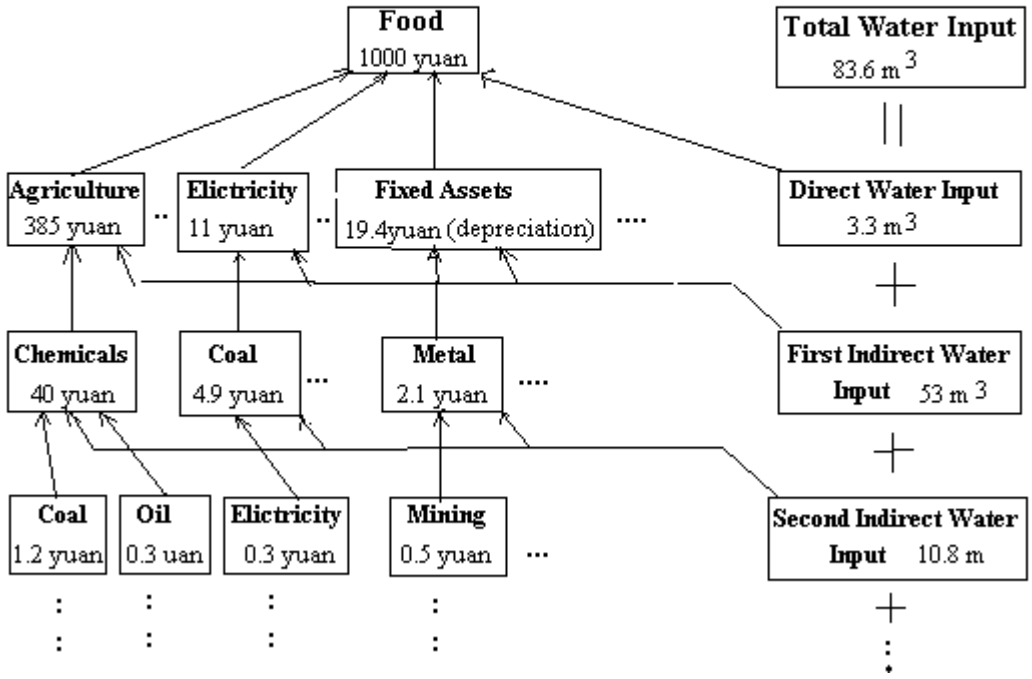
$$f_j = \sum_{i=1}^{k} F_{ij} / X_j = \sum_{i=1}^{k} f_{ij} \qquad (j=1,2, \dots, n)$$

Water is not only consumed directly, but also indirectly. For example in food manufacturing sector agricultural products, electricity, coal, paper, chemicals, agricultural machinery and others are used. In the production process of agricultural products, electricity, coal, paper, chemicals and others water is consumed also. In the production process of agricultural products chemicals and others are used, and they also consume water. The total water input coefficient is the sum of direct water input and all indirect water input. The following graph will explain the concept of total water input of food manufacturing sector (graph 1)

Graph 1

Direct Water Input and Total Water Input

Per 1000 yuan Output Value of Food Industry



We give following formula to calculate total water input coefficients

$$\overline{f}_j = f_j + \sum_{k=1}^{n} \overline{f}_k a_{kj} + \sum_{k=1}^{n} \overline{f}_k \beta_k d_{kj} \qquad (j=1,2,\ldots,n) \qquad (10)$$

where $\overline{f}_j$ represents total water input coefficient of jth sector. d_{kj} represents direct occupancy coefficient of kth fixed asset by jth production sector:

$$d_{kj} = \frac{D_{kj}}{X_j} \qquad (k,j=1,2,\ldots,n)$$

β_k is the depreciation rate of kth fixed asset. Above equations (10) can be rewritten in matrix form

$$\overline{f} = f + \overline{f} A + \overline{f} \beta D \qquad (11)$$

where f, $\overline{f}$ are direct water input coefficient vector and total water input coefficient vector, respectively. β is diagonal matrix of fixed assets depreciation rate and D is direct occupancy coefficient matrix of fixed assets. $D = \{D_{ij}\}_{n \times n}$. Then we have

$$\overline{f} = f (I - A - \beta D)^{-1} \qquad (12)$$

Using data of appendix in the paper, we can get following total fresh water input coefficients of 28

production sectors for Shanxi province (table 2).

From table 2 we can find that for some sectors the difference between direct total water coefficient and total water input coefficient is very big. For example, in food sector direct water input coefficient is 3.3 m^3 per thousand yuan, but total water input coefficient is 83.6 m^3 per thousand yuan. It is because in food production process a great quantity of agricultural products is consumed which are water-consuming products.

Table 2 Direct fresh water input coefficients and total fresh water input coefficients for Shanxi Province

Units: Cubic meter water per 1000 yuan gross output value

Sector	Direct water coefficient	Total water coefficient	Sector	Direct water coefficient	Total water coefficient
1.Agriculture	121.0	155.8	15.Primary metals	5.6	29.1
2.Coal	3.2	24.0	16.Metal products	1.0	22.7
3.Metal Ore	20.2	41.4	17.Machinery	3.2	26.1
4.Other Mining	2.8	22.5	18.Transport equipment	0.8	25.1
5.Food	3.3	83.6	19.Electric machinery	1.5	25.7
6.Textiles	3.2	61.1	20.Electronic equipment	1.7	21.3
7.Wearing	0.8	45.4	21.Instruments	2.9	27.1
8.Sawmills	2.7	26.2	22.Machinery repair	3.4	26.2
9.Papers	12.1	45.4	23.Other industry	11.5	40.0
10.Electricity	44.4	61.9	24.Construction	3.7	22.2
11.Oil refineries	0.4	25.8	25.Freight transport	5.8	21.9
12.Coking	4.0	24.8	26.Commerce	1.6	25.9
13.Chemicals	11.1	41.3	27.Passenger transport	1.8	20.8
14.Building material	1.9	25.0	28.Services	4.4	19.2

4. Total Water Export and Total Water Import

We can use total water input coefficients to study the total water export and total water import. For example, 200 million tons of coal was exported from Shanxi to other provinces. The total fresh water input coefficient is 2.68 m^3 per ton (direct fresh water input coefficient of coal is 0.435 m^3 per ton), so it means that 536 M m^3 of fresh water was exported to other provinces. On the other hand, Shanxi imported 2 million ton of grain from other provinces. For the total fresh water input coefficient of grain is 800 m^3 per ton, it means that Shanxi imported about 1600 M m^3 of fresh water from other provinces.

The total water export W^E is equal to the sum of exports product the total fresh water input coefficients of all sectors. Its calculating formula follows

$$W^E = \sum_{j=1}^{n} \overline{f}_j Y_j^E \tag{13}$$

where Y^E_j represents export of jth sector.

The total water import W^I is the sum of imports product the total water input coefficients of all sectors, calculated by the Shanxi coefficients. Similarly, the formula is

$$W^I = \sum_{j=1}^{n} \overline{f}_j Y_j^I \tag{14}$$

where Y^I_j represents import of jth sector.

On the basis of Shanxi water resource input-occupancy-output tables for 1990, and using formulae (13) and (14), we get that the total water export of Shanxi in 1990 is 1979.26 M m^3, and total water import is 2602.21 M m^3. It means that the total water import amount is bigger than the total water export amount in 1990. Then, we use the table for 1995, and get that the total water export of Shanxi in 1995 is 1429.86 M m^3, and total water import is 1389.86 M m^3. It means that there is only a small deference between the total water export amount and the total water import in 1995. It is because in 1990 the imports of agricultural products (1613.34 million yuan) is much bigger than the exports of agricultural products 676.08 million yuan), and in 1995 the imports of agricultural products (794.99 million yuan) is less than the exports of agricultural products (1069.83 million yuan).

5. Direct Waste Water Emission and Total Waste Water Emission

Direct waste water emission coefficient p_j is the amount of waste water released by unit output of jth production sector. Similarly, we can calculate the total waste water emission coefficient $\bar{p}_j$ as follows:

$$\bar{p}_j = p_j + \sum_{k=1}^{n} \bar{p}_k a_{kj} + \sum_{k=1}^{n} \bar{p}_k \beta_k d_{kj} \qquad (j=1,2,\ldots,n) \qquad (15)$$

The above equations can be rewritten in matrix form

$$\bar{p} = p + \bar{p} A + \bar{p} \beta D \qquad (16)$$

then we have

$$\bar{p} = p (I - A - \beta D)^{-1} \qquad (17)$$

Using the data in appendix we got following results (table 3)

Table 3 Direct waste water emission coefficients and total waste water emission coefficients for Shanxi Province

Units: Cubic meter water per 1000 yuan output value

Sector	Direct waste water coefficient	Total waste water coefficient	Sector	Direct waste water coefficient	Total waste water coefficient
1.Agriculture	0	3.58	15.Primary metals	3.13	12.96
2.Coal	3.72	10.81	16.Metal products	0.44	9.42
3.Metal Ore	14.44	23.03	17.Machinery	1.96	11.36
4.Other Mining	1.47	8.07	18.Transport equipment	0.34	10.06
5.Food	1.37	6.38	19.Electric machinery	1.11	10.96
6.Textiles	2.09	9.82	20.Electronic equipment	1.10	8.60
7.Wearing	0.37	8.86	21.Instruments	1.88	10.54
8.Sawmills	1.11	9.47	22.Machinery repair	0.68	9.72
9.Papers	8.57	18.78	23.Other industry	2.33	13.05
10.Electricity	11.26	18.12	24.Construction	2.42	9.91
11.Oil refineries	0.18	9.64	25.Freight transport	3.83	9.53
12.Coking	1.90	10.50	26.Commerce	1.00	5.45
13.Chemicals	7.19	17.96	27.Passenger transport	1.11	6.39
14.Building material	0.69	9.31	28.Services	2.70	7.13

Similarly, using total waste water emission coefficients we can calculate the total waste water

amount, contained in the all export products and that contained in the all import products. They are 482.75 M m^3 and 424.18 M m^3, respectively.

6. Economic Value of Water

We used following two methods to estimate the economic value of water in Shanxi

(1) Translog production function

According to our calculation the water price of Wanjiazhai Yellow River Diversion Project is about 4.9 yuan per ton (m^3). It is a high price, because the actual water price for industry and urban life use is about 1.3 yuan per ton. We select the translog function as Shanxi industry production function and take capital (K), labour force (L) and water consumption (W) as the independent variables. Y is the gross output value in industry of Shanxi. The model is estimated on the data of 1965-1995[1]:

$$\begin{aligned} LnY = {} & 14.1287 - 1.0087 Ln\,L - 5.2303 LnW - 0.4979 (Ln\,K)^2 + 1.3255 (LnK)(LnL) + \\ & \quad (-4.1255) \qquad (-1.5737) \qquad (-2.6534) \qquad (3.3589) \\ & + 1.5766 (LnW)(LnK) - 0.1884 (LnK)(LnL)(LnW) \\ & \quad (1.8745) \qquad (-1.9989) \end{aligned}$$

$R^2 = 0.998$ Number of observations 31 (1965-1993)

From the model we find that marginal gross output value of water $\partial Y / \partial W$ in 1995 is 24.08 yuan per ton in Shanxi industry and marginal value added of water in 1995 is 6.65 yuan per ton (ratio of value added on gross output value for Shanxi in 1995 is 27.62%). The average marginal value added of water from 1990 to 1995 is 6.34 yuan. Because the marginal value added of water is greater than the cost of water, the result indicates that using water of Wanjiazhai Yellow River Diversion Project to industry would be benefit.

(2) Linear programming model

The water resource linear programming model is constructed on the basis of input-output model. The object function is to maximize gross output product (GDP) and fresh water resource is the most important constraint .

$$\begin{aligned} \text{maximize} \quad & e\,(I - A)\,X \\ \text{subject to} \quad & (I - A)\,X = Y \\ & F\,X + Z^0 \le W^0 \\ & X^h \ge X \ge X^l \\ & Y^h \ge Y \ge Y^l \end{aligned}$$

where e is a unit row vector, whose elements are 1. Y is final demand column vector. F is fresh water direct input coefficient row vector. Z^0 is water demand in living use. W^0 is total fresh water resource amount in the year. X^h and X^l are high limit and low limit of output X, respectively. Y^h and Y^l are high limit and low limit of final demands Y, respectively.

Using simplex method we got the solution of the above original linear programming model and the dual linear programming model. The shadow price of water in the dual model is 6.7 yuan per ton. It means that if we use a ton of fresh water rationally, the GDP in Shanxi will increase by 6.7 yuan.

In agriculture the economic value of water is much lower than in industry and in other sectors. We will find in following survey's data (table 4)

[1] The figure in brackets is value of t test.

Table 4 Relationship between water use and winter wheat yield in Yuncheng, Shanxi

	Unit	Number of irrigation				
		0	1	2	3	4
Water from irrigation	m^3/mu	0	40	80	120	180
Water from rain	m^3/mu	159	156	151	146	134
Total water	m^3/mu	159	196	231	266	314
Winter wheat yield	kg/mu	246	304	345	378	402
Marginal Yield (dX/dW)	kg/m^3		1.45	1.03	0.83	0.60
Marginal value of water	yuan/m^3		1.81	1.29	1.04	0.75

(Source: Institute of Water Resource and Irrigation, Shanxi Province, Taiyuan. Because data of water from rain is not exact, we calculate marginal yield on the basis of irrigation water. Wheat price in Shanxi was 1.25 yuan/kg 15 mu is equal to a hectare)

From table 5 we can find that the marginal yield of wheat from water (dX/dW) is decreasing. When irrigation water is 40 m^3 per mu, the marginal yield is 1.45 kg of wheat per m^3 of water. According to the above data the marginal output value of water is from 0.75 yuan to 1.81 yuan. The maximum of marginal output value is 1.81 yuan.

In Linfen the marginal value per m^3 of water for wheat is 1.47 yuan (one irrigation), 1.35 yuan (two irrigation) and 0.97yuan (three irrigation).

For corn in Yanbei the marginal value per m^3 of water is 1.33 yuan (one irrigation), 0.70 yuan (two irrigation) and 0.13 yuan (three irrigation). In Yuncheng the marginal value is 0.78, 0.45 and 0 yuan. In Jinzhong that is 0.95, 0.83 and 0.23 yuan.

For cotton the marginal value of water is higher than that in wheat and corn. In Yuncheng and Jinzhong the marginal value per m^3 of water is 2.43 (one irrigation), 2.43 (two) and 0.73 yuan. In Linfen that is 3.15, 0.97 and 0, respectively.

In Shanxi the ratio of value added in gross output value of agriculture in 1995 is 61.58 % (appendix). Then according to above data the maximum of marginal value added of water for wheat, corn and cotton is less or equal to 1.11 yuan, 0.82 yuan and 1.94 yuan, respectively.

7. Conclusion and Suggestion

According to the characteristics of Shanxi natural resource, we made suggestion to the Shanxi government for creating a water resource-saving national economy system, including water resource-saving production system and water resource-saving consumption system.

(1). Changing the structure of economy and reducing output of sectors with high total water input coefficients. For example rice is water-consuming crop. It is necessary to stop the paddy production and import rice from the other provinces. Electricity is also a sector with high total water input coefficient (181.1 m^3 per thousand yuan), it is better for Shanxi to export coal and produce more electricity in other province. To develop sectors in light industry and tertiary industry with less water input coefficient is also important for Shanxi.

(2). Constructing water-saving irrigation system and raising the industry water recycle rate further. In Shanghai as in other provinces of China the most of fresh water is consumed in agriculture. Agricultural water consumption accounts for 63.26 % of total fresh water consumption. In 1995 the fresh water consumption in irrigation is 3409.08 M m^3, accounting for 59.37 % of total fresh water consumption. Because of lack of capital the most irrigation cannel is made of soil, more than 60 % water was lost in the water transfer process. It is very important to expand pipe transmit water techniques and

water-saving irrigation techniques to decrease the water lose rate. The recycle rate of Shanxi industry in 1990, 1992 and 1995 are 81.17%, 82.72% and 85.48 %, respectively. It is suggested to raise the rate to 88 % in 2000 and 92 % in 2010.

(3) Increasing waste water treating and reusing rate. At present the capacity for waste water treatment in Shanxi is very low, and the untreated waste water with high pollutants seriously pollutes the environment and produces great impact to the people's health. It is suggested by us that to use the foreign investment to construct waste water treatment plants and to treat 15 % waste water in 2000. The most treated waste water can be reused in industry and in agriculture (for cotton, fiber crops, tobacco, etc.). The cost of treating waste water is about 1.7 yuan per ton which is much lower than the fresh water cost from Yellow River.

(4). Increasing the amount of rural life water and city life water. The rural life of water consists of two parts: household life use and animal use. In 1995 there was 23.41 million agricultural population in Shanxi. The amount of rural life water use was 248.71 M m^3. Per capita rural life water was 29.11 L / person·day. In urban area the level was higher. In 1995 there was 7.36 non-agricultural population. The amount of city life water consumption was 351.91 M m^3. Per capita water consumption was 131.0 L / person·day, of which, city household water consumption was 72.4 L / person·day. It is important to raise the per capita water consumption level in 2010 to 50 L / person·day for rural area and to 145 L / person·day for urban area. Then the amount of life water consumption will be increased by 400 M m^3. The annual delivery water volume of WYSDP is 1200 M m^3 at final. We suggested that one third of the water volume would be used as people life consumption.

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Appendix

Shanxi Water Resource Input-Occupancy-Output Table of 1995 at Current Producers' Prices

		Intermediate Demands							
	Units	1	2	3	4	5	6	7	8
1.Agriculture	10000	513966	31533	421	4	402724	108970	463	0
2.Coal	Yuan	16786	86405	2362	6245	14143	7570	850	4044
3.Metal Ore		0	999	31419	208	0	2	0	0
4.Other Mining		134	136459	1749	46576	913	925	318	7693
5.Food		16009	10624	0	505	163500	1652	6020	79
6.Textiles		227	13729	1532	214	4561	111025	75898	4410
7.Wearing		538	25084	728	1384	1078	5134	16049	70
8.Sawmills		135	12718	558	145	589	187	60	7359
9.Papers		5773	20515	2281	530	27830	2236	546	426
10.Electricity		46341	225276	15263	34499	11559	13386	934	1954
11.Oil refineries		8751	53489	9582	22139	2353	2112	279	686
12.Coking		7139	6776	656	1670	232	125	0	60
13.Chemicals		312158	227257	11899	11555	20606	68725	13266	6227
14.Building material		11851	182144	4232	15291	24747	2725	36	754
15.Primary metals		4261	263250	11817	7941	4558	2790	110	6864
16.Metal products		5010	336674	734	2543	8303	1726	128	4127
17.Machinery		16883	317941	2237	4223	2405	10717	78	750
18.Transport equipment		9869	13861	1760	2765	952	574	36	169
19.Electric machinery		15918	64014	885	651	6711	1145	87	2262
20.Electronic equipment		3	44759	338	2295	103	500	0	0
21.Instruments		48	46341	130	621	105	178	19	70
22.Machinery repair		2467	34861	506	500	1411	13	35	2198
23.Other industry		0	66332	88	322	207	3322	1863	60
24.Construction		0	13240	1072	2821	1466	653	13	0
25.Freight transport		60826	156938	13670	28557	57667	49846	2583	3380
26.Commerce		54053	167048	5340	7778	49506	18777	8226	3237
27.Passenger transport		0	17166	794	1471	1643	968	207	210
28.Other service		42226	72690	4551	7358	9399	10147	1868	1020
Sub-Total		1151372	2648123	126604	210811	819271	426130	129972	58109
Depreciation		70996	241363	10010	27612	20253	19086	1744	1921
Compensation of Labors		1101715	843099	38189	55317	67578	68970	15576	10679
Net taxes of production		1780	201091	16363	18644	83270	18622	4248	2692
Operating surplus		670888	274454	29431	40712	55437	-2833	4230	2370
Total of value added		1845379	1560007	93993	142285	226538	103845	25798	17662
Total inputs		2996751	4208130	220597	353096	1045809	529975	155770	75771
Fresh Water	M CM	3632.89	133.17	44.53	9.90	34.43	16.71	1.28	2.05
1.Surface		1688.18	36.28	12.13	2.70	9.38	4.55	0.35	0.56
2.Ground		1944.71	96.89	32.40	7.20	25.05	12.16	0.93	1.49
Recycle water			161.35	24.20	2.42	26.40	47.93	0.15	0.46
Total		3632.89	294.52	68.73	12.32	60.83	64.65	1.43	2.51
Recycle-Rate	%		54.78	35.21	19.63	43.40	74.15	10.54	18.16
Waste water emissio	M.CM		156.51	31.86	5.17	14.36	11.06	0.58	0.84
Circulating capital	10000	529634	3115425	107739	258638	745885	396371	140008	38205
Fixed capital	yuan	656028	6392438	141370	348738	690830	451996	69841	33990
Total Capital		1185662	9507863	249109	607376	1436715	848367	209849	72195
Labour force	10000	636.00	110.78	6.10	10.90	13.40	13.76	3.39	1.80

		Intermediate Demands							
	Units	9	10	11	12	13	14	15	16
1.Agriculture	10000	20819	32	38	565	28638	2502	477	62
2.Coal	Yuan	11764	497759	586	420357	53379	150014	127615	11041
3.Metal Ore		0	175	3	394	31	8989	152924	29
4.Other Mining		9020	6041	1200	6532	68819	112722	36170	1788
5.Food		327	282	42	2066	13725	1508	1106	299
6.Textiles		6066	872	56	2766	38988	4606	3721	2061
7.Wearing		542	1857	238	7695	4201	8191	4222	1026
8.Sawmills		3597	930	45	4904	3751	3809	4090	2692
9.Papers		104121	2849	201	5689	24894	20808	5112	4113
10.Electricity		12023	19171	1721	47438	94157	131733	136308	21875
11.Oil refineries		1649	18452	5252	15271	13779	23396	33197	8435
12.Coking		77	149	20	54126	43770	53165	181042	9289
13.Chemicals		42103	14699	1273	43066	668852	89120	82090	33671
14.Building material		2481	20684	312	27331	26379	86351	78304	18639
15.Primary metals		25297	22112	2077	55968	49975	91425	942133	331927
16.Metal products		4532	5107	772	45068	25751	43295	26368	13183
17.Machinery		7552	6510	1313	68285	22935	47112	59774	13761
18.Transport equipment		567	3499	138	10349	3629	5873	19334	2260
19.Electric machinery		1772	8327	327	13690	7531	10895	21034	6278
20.Electronic equipment		2730	1871	58	2677	1567	936	2090	498
21.Instruments		2039	2665	549	9988	3095	3491	9955	1876
22.Machinery repair		2013	604	51	4766	9285	5764	2676	978
23.Other industry		1807	185	85	1335	4134	16727	20324	823
24.Construction		169	1551	15	798	823	5766	3939	222
25.Freight transport		18896	99081	1106	212849	111349	128233	132254	36619
26.Commerce		12341	11677	837	29656	68593	35622	60239	22528
27.Passenger transport		856	2489	237	5193	5498	5786	4005	2579
28.Other service		5924	5503	669	27081	28279	42398	27727	12281
Sub-Total		301084	755133	19221	1125903	1425807	1140237	2178230	560833
Depreciation		8969	114635	472	40127	49080	61710	82125	18403
Compensation of Labors		44963	110251	1513	90764	223857	200947	321961	98950
Net taxes of production		27314	137305	666	56594	94179	82853	149695	52146
Operating surplus		29820	73571	827	114400	58678	58512	128423	40684
Total of value added		111066	435762	3478	301885	425794	404022	682204	210183
Total inputs		412150	1190895	22699	1427788	1851601	1544259	2860434	771016
Fresh Water	M CM	49.81	529.22	0.08	56.47	205.33	29.32	161.31	7.54
1.Surface		13.57	144.16	0.02	15.38	55.93	7.99	43.94	2.05
2.Ground		36.24	385.05	0.06	41.09	149.39	21.34	117.37	5.48
Recycle water		39.29	5767.04	0.00	120.43	787.70	32.64	771.69	3.69
Total		89.11	6296.25	0.08	176.89	993.02	61.97	933.00	11.23
Recycle-Rate	%	44.10	91.59	0.00	68.08	79.32	52.68	82.71	32.89
Waste water emissio	M.CM	35.30	134.11	0.04	27.17	133.07	10.64	89.42	3.41
Circulating capital	10000	211682	585282	13633	837347	1146166	1117053	1859950	435209
Fixed capital	yuan	294561	2899212	10382	688412	1597434	1546132	2346297	298594
Total Capital		506243	3484494	24015	1525759	2743600	2663185	4206247	733803
Labour force	10000	8.94	13.10	0.26	16.05	27.79	41.33	36.58	15.14

		Intermediate Demands							
	Units	17	18	19	20	21	22	23	24
1.Agriculture	10000	33	17	66	0	0	19	1499	166
2.Coal	Yuan	24437	3884	1261	130	493	2492	3982	9430
3.Metal Ore		4023	53	433	0	0	95	2192	0
4.Other Mining		6657	914	717	58	69	816	1349	39766
5.Food		660	166	344	15	24	157	1126	1492
6.Textiles		2309	886	950	15	44	528	1156	388
7.Wearing		2115	513	226	48	163	457	356	1122
8.Sawmills		7703	622	331	71	97	381	293	16050
9.Papers		3011	1787	3126	50	215	309	936	4554
10.Electricity		25532	5792	2789	207	563	2550	4740	14317
11.Oil refineries		6338	1439	1298	48	288	1479	1565	29574
12.Coking		5862	709	953	2	33	783	3337	520
13.Chemicals		39478	8004	21697	2410	1441	5392	24946	8594
14.Building material		22670	6690	19257	73	118	5765	3425	357460
15.Primary metals		331885	43036	76452	1205	3869	27132	19190	462908
16.Metal products		30786	5870	2723	296	1060	4672	2498	21686
17.Machinery		94431	15230	8014	309	1118	6958	4592	57745
18.Transport equipment		2732	87902	339	590	61	5256	2331	17995
19.Electric machinery		38511	6151	17301	808	687	3892	2552	34102
20.Electronic equipment		1704	1728	40	17407	3986	1973	6663	3336
21.Instruments		1834	582	1002	43	905	810	525	1831
22.Machinery repair		882	1206	247	3	132	1851	611	5223
23.Other industry		1714	22	98	6	223	5268	1757	246
24.Construction		836	177	91	0	0	295	129	132468
25.Freight transport		37312	8150	8600	485	973	4554	8594	84789
26.Commerce		29823	10612	8210	3033	1033	3889	5344	48506
27.Passenger transport		3303	609	526	115	268	242	700	10536
28.Other service		15530	4042	3169	881	1071	1180	2748	14447
Sub-Total		742111	216793	180260	28308	18934	89195	109136	1379251
Depreciation		30899	3181	7786	1137	3173	2662	1252	49949
Compensation of Labors		148913	15780	30074	6341	5097	17304	12554	409476
Net taxes of production		38299	2823	9937	802	949	4241	3125	79142
Operating surplus		-10521	6104	-3219	-940	-4316	1026	1919	55232
Total of value added		207590	27888	44578	7340	4903	25233	18850	593799
Total inputs		949701	244681	224838	35648	23837	114428	127986	1973050
Fresh Water	M CM	30.37	2.05	3.47	0.62	0.69	3.85	14.69	72.32
1.Surface		8.27	0.56	0.94	0.17	0.19	1.05	4.00	19.70
2.Ground		22.09	1.49	2.52	0.45	0.50	2.80	10.69	52.62
Recycle water		77.97	1.87	3.61	0.29	0.66	0.00	0.03	0.00
Total		108.34	3.93	7.08	0.91	1.36	3.85	14.72	72.32
Recycle-Rate	%	71.97	47.70	51.04	31.60	48.94	0.00	0.22	0.00
Waste water emissio	M.CM	18.59	0.83	2.49	0.39	0.45	0.78	2.98	47.71
Circulating capital	10000	914471	212644	202525	60606	29976	102216	92800	1361205
Fixed capital	yuan	863783	211455	183467	56401	30394	114803	57204	674606
Total Capital		1778254	424099	385992	117007	60370	217019	150004	2035811
Labour force	10000	21.98	2.97	5.28	1.20	0.97	2.92	2.62	78.50

		Intermediate Demands				Total Intermed.	Consumption		
	Units	25	26	27	28	Demands	Peasant	Non-Peast	Social
1.Agriculture	10000	22	97363	0	14735	1225134	852512	411449	9610
2.Coal	Yuan	22275	35683	5142	36262	1556391	43539	22074	97
3.Metal Ore		0	0	0	0	201969	0	0	0
4.Other Mining		2157	5988	561	1986	498097	414	1136	335
5.Food		437	147175	1027	28928	399295	273843	391379	23880
6.Textiles		2402	4713	437	9700	294260	84897	93480	8215
7.Wearing		3381	4972	2011	10082	103483	92582	170823	3534
8.Sawmills		7812	7395	2103	6166	94593	26227	48605	1074
9.Papers		10889	23628	4545	130425	411399	24688	23762	4064
10.Electricity		28739	25875	5984	39819	970545	11982	32914	4569
11.Oil refineries		196991	23823	32961	26579	541205	5494	10260	2578
12.Coking		418	4151	74	10298	385436	3017	19709	1068
13.Chemicals		98940	8905	11754	94521	1972649	50098	73464	5141
14.Building material		9110	46066	6083	19391	998369	32170	6511	851
15.Primary metals		98806	16022	7155	6793	2916958	0	0	826
16.Metal products		17985	7779	4806	18390	641872	47163	63595	2092
17.Machinery		8799	8561	1123	32527	821883	37586	64381	4336
18.Transport equipment		109511	15587	19743	14786	352468	10913	7114	3180
19.Electric machinery		13354	5786	1331	10393	296395	41823	122384	4722
20.Electronic equipment		5298	6882	1363	52318	163123	85055	169124	7184
21.Instruments		2459	309	1886	8257	101613	0	0	962
22.Machinery repair		3944	5014	471	8166	95878	0	0	0
23.Other industry		338	10422	0	999	138707	0	5036	19
24.Construction		11373	90590	7229	74074	349810	0	0	0
25.Freight transport		43531	55612	8368	83200	1458022	29501	54174	2845
26.Commerce		119531	245658	12184	82852	1126133	349448	439912	46372
27.Passenger transport		9391	52487	2645	38108	168032	73551	87025	7987
28.Other service		110765	290771	30444	209226	983395	177124	193277	1261562
Sub-Total		938658	1247217	171430	1068981	19267114	2353627	2511588	1407103
Depreciation		97648	78749	76875	224011	1345828			
Compensation of Labors		300416	365715	68824	943608	5618431			
Net taxes of production		118443	159599	20577	134916	1520315			
Operating surplus		265575	324270	-7949	233403	2440188			
Total of value added		782082	928333	158327	1535938	10924762			
Total inputs		1720740	2175550	329757	2604919	30191876			
Fresh Water	M CM	99.78	35.82	6.01	115.68	5299.39	248.71	194.40	
1.Surface		27.18	4.35	0.72	14.01	2118.32	60.80	23.53	
2.Ground		72.60	31.47	5.28	101.68	3181.08	187.91	170.87	
Recycle water		0.00	0.00	0.00	0.00	7869.83	0.00	0.00	
Total		99.78	35.82	6.01	115.68	13169.22	248.71	194.40	
Recycle-Rate	%	0.00	0.00	0.00	0.00	59.76	0.00	0.00	
Waste water emissio	M.CM	65.84	21.79	3.65	70.38	889.43	NA	118.26	
Circulating capital	10000	1170511	4521162	14383	325941	20546667			
Fixed capital	yuan	7267344	2004281	21894	3936883	33888770			
Total Capital		8437855	6525443	36277	4262824	54435437			
Labour force	10000	66.66	91.98	12.14	217.88	1460.40			

	Units	Gross Fixed Capital Formation	Increase in Stocks	Exports	Imports	Total Final Demands	Total Output
1.Agriculture	10000	330275	140287	106983	79499	1771617	2996751
2.Coal	Yuan	0	328670	2257359	0	2651739	4208130
3.Metal Ore		0	27819	0	9191	18628	220597
4.Other Mining		0	-37820	0	109066	-145001	353096
5.Food		0	52868	80330	175786	646514	1045809
6.Textiles		0	67653	122225	140755	235715	529975
7.Wearing		0	-10529	8542	212665	52287	155770
8.Sawmills		17182	-16804	3842	98948	-18822	75771
9.Papers		10	-8479	2368	45662	751	412150
10.Electricity		0	0	188128	17243	220350	1190895
11.Oil refineries		0	17	1067	537922	-518506	22699
12.Coking		0	128067	890491	0	1042352	1427788
13.Chemicals		0	52679	38158	340588	-121048	1851601
14.Building material		12315	224080	281597	11634	545890	1544259
15.Primary metals		0	45424	145239	248013	-56524	2860434
16.Metal products		45358	3179	22734	54977	129144	771016
17.Machinery		513971	-6648	25572	511380	127818	949701
18.Transport equipment		198084	3672	15653	346403	-107787	244681
19.Electric machinery		72885	1254	18599	333224	-71557	224838
20.Electronic equipment		42059	-8821	3663	425739	-127475	35648
21.Instruments		20994	-2580	1585	98737	-77776	23837
22.Machinery repair		18550	0	0	0	18550	114428
23.Other industry		0	-15776	0	0	-10721	127986
24.Construction		1623240	0	0	0	1623240	1973050
25.Freight transport		67534	6194	190724	88254	262718	1720740
26.Commerce		178178	9165	168914	142572	1049417	2175550
27.Passenger transport		0	0	3280	10118	161725	329757
28.Other service		0	0	0	10439	1621524	2604919
Sub-Total		3140635	983571	4577053	4048815	10924762	30191876
Depreciation							
Compensation of Labors							
Net taxes of production							
Operating surplus							
Total of value added							
Total inputs							
Fresh Water	M CM					443.11	5742.50
1.Surface						84.33	2202.65
2.Ground						358.77	3539.85
Recycle water							7869.83
Total						443.11	13612.33
Recycle-Rate	%						57.81
Waste water emissio	M.CM					118.26	1007.69
Circulating capital	10000						
Fixed capital	yuan						
Total Capital							
Labour force	10000						

(Source: The table was constructed by Chen Xikang and his assistants on the basis of Shanxi Input-Output Table of 1995, compiled by Shanxi Statistical Bureau, and Shanxi Water Resource Annual Report (1995), edited by Shanxi Water Conservancy Bureau)