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Characteristics of Water Resources Utilization and Virtual Water Trade in Hebei Province

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Abstract: Water resource is one of the main factors limiting the development of water-deficient areas. Virtual water theory and virtual water trade model were used to analyze the characteristics of water resources utilization in Hebei Province. Based on an input-output model, water resource consumptions in different sectors of the economy and virtual water in domestic and international trade in Hebei Province were analyzed. Results indicated that natural resource exploitation and processing sectors topped the list of water consumption intensity which including agriculture, forestry, animal husbandry and fisheries, nonmetal minerals and other minerals mining and dressing industries and electric power, steam and hot water producing industry. Hebei Province was the net input area in the domestic trade while the net output area in the foreign trade in 2007. The later was far more than the former which finally made Hebei Province the net output area of virtual water. The net output of virtual water was 10.521 billion m^3 in 2007, almost 52.13% of total water consumption in Hebei Province. Massive exportation of high-water-consumption products which were mainly produced by agriculture, food manufacturing industry, tobacco processing industry and metals smelting and pressing industry, intensified the pressure of water resource in Hebei Province. Thus, the exportation of high-water-consumption products should be controlled to relieve the regional contradiction between the supply and requirement of water resources.

Key words: Water consumption intensity, input-output analysis, virtual water trade

INTRODUCTION

There is a serious water resource scarcity in Hebei Province. The average water resource amount per capita is only 307 m^3, far below the international standard of extreme water shortage of 500 m^3. The annual water shortage in Hebei Province is nearly 50 billion m^3. Sharp contradiction between supply and demand of water resources not only restrict the sustainable development of social economy in Hebei Province but brings a series of serious water environ-mental and water ecological problems (Allan, 1998; Liu and Li, 2010; Ma *et al*., 2006; Velazquez, 2007). A number of studies have recognized the usefulness of the concept of virtual water for analyzing production patterns and associated water flows. The water is consumed directly in the production of goods and services and indirectly by using other goods and services as inputs. Input-output Analysis (IOA) has been applied to assess virtual water flows in many studies (Dietzenbacher and Velazquez, 2007; Guan and Hubacek, 2007). Despite substantial research on virtual water trade, researches on characteristics of virtual water flows distinguished between domestic and foreign trade for a particular region which is of great significance for regional virtual water strategy, are still relatively rare. In this study, Input-output Analysis (IOA) was conducted to analyze the characteristics of the virtual water flows in domestic and international trade in Hebei Province. The results could provide support for the regional industrial and trade structure adjustment and optimization.

MATERIALS AND METHODS

Input-output model: The general input-output table is an n×n matrix describing the flows of goods between economic sectors in monetary units which can be written in form of matrix as Eq. 1:

$$X = AX+Y \quad (1)$$

where, A is the coefficient matrix; x is a vector of sectoral output; y is a vector of final demand. To solve for x, Eq. 2 was got as follows:

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Table 1: Industry sectors and their codes in China

Industry sector	Code	Industry sector	Code
Farming, forestry, animal husbandry and fishery	01	Smelting and pressing of metals	14
Coal mining and processing	02	Metal products	15
Petrol and natural gas mining	03	General machinery and special purpose equipment manufacturing	16
Metals mining and processing	04	Transport equipment	17
Nonmetal and other mining and processing	05	Electric equipment and machinery manufacturing	18
Food production and tobacco processing	06	Communications equipment, computer and other electric equipment manufacturing	19
Textile industry	07	Instruments, meters, cultural and clerical machinery	20
Textile clothes, shoes and caps producing and leathers, furs, down and related products	08	Artworks and other products manufacturing	21
Timber, bamboo, cane, palm fiber, straw Products and furniture manufacturing	09	Abandoned resources and junk materials recycling and processing	22
Papermaking, printing, record medium reproduction, culture, education and sports facilities producing	10	Electricity, steam, hot water production and supply	23
Petroleum processing, coking products and nuclear fuel processing	11	Gas production and supply	24
Chemical industry	12	Tap water production and supply	25
Nonmetal mineral products	13	Building industry and tertiary industry	26

$$X = (I-A)^{-1}Y \quad (2)$$

where, $(I-A)^{-1}$ is the Leontief inverse matrix which shows the total production required to satisfy one unit of final demand in the economy. By pre-multiplying the direct water consumption per unit output value matrix E with final demand Y, Eq. 3 was received to describe the effects of water inputs by increasing a unit of final consumption.

$$\text{Total water consumption} = E(I-A)^{-1}Y \quad (3)$$

Virtual water flows: Virtual water in products includes the total water consumption from mining and proceeding of raw material, products manufacturing and transportation. Three indicators, direct water intake per unit of value-added output, total water intake per unit of value-added output and total water intake per unit of final consumption, were adopted to depict the characteristics of water consumption intensity in Hebei Province. The amount of import virtual water in the products from sector j can be calculated by Eq. 4 and the amount of export virtual water in the products from sector j can be calculated by Eq. 5:

$$f_j^{import} = \sum_k p_{jk}^{import} (\bar{b}_e^{import})_{jk} \quad (4)$$

$$f_j^{export} = p_j^{export} (\bar{b}_e)_j \quad (5)$$

where, p_{jk}^{import} is the value of the imported products in sector j. $\bar{b}_e^{import}$ is the total water intake per unit of final consumption of products from the k country or the k source in domestic in sector j. p_j^{export} is the value of the exported products in sector j. $\bar{b}_e$ is the coefficient of water intake per unit of final consumption in sector j. The amount of the net water import in sector j then can be calculated by Eq. 6. The sector j is the net importer of virtual water when $f_j^{net} > 0$ while a net exporter of virtual water when $f_j^{net} < 0$:

$$f_j^{net} = f_j^{import} - f_j^{export} \quad (6)$$

Data resource and industry code: The data of industrial added value in 2007 were from the yearbook of Hebei's economy 2008. The data of water consumption in industry in 2007 were from the yearbook of Hebei's economy 2009. The industry sectors and their codes were in the Table 1.

RESULTS AND DISCUSSION

Table 2 outlines the level of industrial water consumption in 2007 in Hebei Province. Mining industry has the highest level of direct water intake per unit of value-added output in Hebei Province. Agriculture, electricity production industry, tap water production industry, papermaking and printing industry are followed. Meanwhile, the total water intake per unit value-added output of mining and processing industry is the highest. Ores industry, food production and tobacco processing industry, agriculture, textile industry and electricity production industry also have higher total water intake. The food production and textile industry had high levels of indirect water intake per unit value-added output because of their extensive consumption of agricultural goods. Mining industry tops in the list of total water intake per unit final consumption. Agriculture, food produc-tion and tobacco processing industry, electricity production industry, textile industry, water production industry and papermaking and printing industry are also have high level of total water intake per unit final consumption. The three industries which consumed the

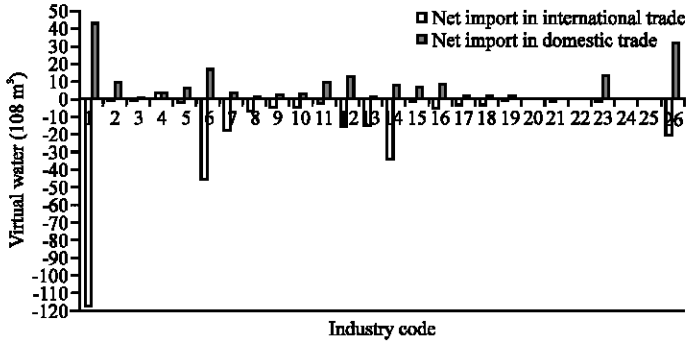

Fig. 1: Net export of virtual water in different industry sectors in Hebei Province

Table 2: Water consumption intensity in different industry sectors in Hebei Province

Industry code	Direct water intake (m^3) per 10,000 Yuan industrial added value	Total water intake (m^3) per 10,000 Yuan industrial added value	Total water intake (m^3) per 10,000 Yuan final consumption
01	863.0148	1109.3443	650.9121
02	41.8517	180.5192	76.9054
03	11.0973	86.1383	51.3727
04	52.6391	232.2400	90.9289
05	1641.3495	2001.4470	788.1758
06	19.0780	1458.5731	327.8429
07	22.2060	1072.0107	255.0518
08	15.3227	583.3846	167.5732
09	4.6242	298.4138	99.7954
10	114.5738	634.3971	174.5728
11	29.7657	455.6661	65.2155
12	57.0897	534.1593	139.0532
13	16.2436	440.6705	111.9223
14	28.8793	426.6744	82.6956
15	7.4133	295.7390	69.8387
16	4.2503	229.6208	63.4600
17	10.6081	357.9393	68.8804
18	3.9899	264.3301	67.3745
19	8.8366	232.0091	71.2652
20	5.6037	150.2464	53.1594
21	8.8092	236.2169	85.4025
22	7.2505	12.1077	10.3884
23	738.8277	974.8699	290.0656
24	9.0773	236.9872	57.3696
25	195.9941	404.4851	186.2141
26	5.8697	142.4238	68.5223

most water, the mining and processing of non-metal ores and other ores, farming, forestry, animal husbandry and fishery, food production and tobacco processing, were the resources mining and processing industries. Therefore, industries which consume the most water while producing low value-added products should be strictly controlled to improve the efficiency of the direct use of water resources and the other indirect resource-consumed products.

Virtual water in international trade and domestic trade in Hebei Province is presented in Table 3. Results indicated that Hebei Province imported 20.56 billion m^3 of virtual water from other areas and exported 1.65 billion m^3 to other areas in domestic trade in 2007 which resulted in net import virtual water of 18.91 billion m^3. By sector, all industries in Table 1 were the net importers of virtual water. Agriculture industries has the highest level of net import of virtual water, followed by tertiary industry, food production and tobacco processing industry, electricity production industry, chemical production industry, petroleum processing industry and coking production industry (Fig. 1). Most of these industries are related to agricultural and energy production. In 2007, net import of virtual water for these above industries represents 72.49% of the total virtual water importation of all industries. Thus, the above industries are expected to play important roles in relieving the pressure on water resources in Hebei Province.

Results from virtual water model indicated that Hebei Province imported 1.16 billion m^3 of virtual water from

Table 3: Virtual water in different industry sectors in Hebei province (billion m^3)

			International trade		Domestic trade		
Code	Virtual water in imported products	Virtual water in exported products	Imported	Net import	Import	Net import	Total Net import
1	0.49	12.10	4.40	-11.61	0.14	4.27	-7.35
2	0.00	0.07	0.99	-0.07	0.04	0.95	0.88
3	0.00	0.09	0.11	-0.09	0.00	0.11	0.03
4	0.24	0.05	0.32	0.19	0.00	0.32	0.51
5	0.03	0.17	0.64	-0.14	0.01	0.63	0.49
6	0.06	4.59	1.83	-4.54	0.16	1.67	-2.86
7	0.01	1.74	0.60	-1.73	0.19	0.41	-1.32
8	0.01	0.66	0.20	-0.64	0.11	0.09	-0.55
9	0.00	0.43	0.23	-0.43	0.02	0.22	-0.21
10	0.02	0.43	0.37	-0.41	0.01	0.35	-0.06
11	0.00	0.19	0.96	-0.19	0.01	0.95	0.77
12	0.12	1.63	1.58	-1.51	0.30	1.28	-0.22
13	0.00	1.50	0.23	-1.50	0.07	0.17	-1.33
14	0.02	3.39	1.06	-3.37	0.24	0.82	-2.56
15	0.00	0.11	0.68	-0.11	0.08	0.60	0.49
16	0.05	0.55	0.89	-0.50	0.05	0.84	0.34
17	0.00	0.28	0.26	-0.28	0.06	0.20	-0.08
18	0.01	0.32	0.15	-0.31	0.02	0.13	-0.18
19	0.01	0.04	0.22	-0.03	0.04	0.18	0.15
20	0.00	0.01	0.06	-0.01	0.01	0.06	0.05
21	0.00	0.10	0.02	-0.10	0.01	0.01	-0.09
22	0.00	0.00	0.01	0.00	0.00	0.01	0.01
23	0.00	0.05	1.36	-0.05	0.00	1.36	1.31
24	0.00	0.00	0.03	0.00	0.00	0.03	0.03
25	0.00	0.00	0.02	0.00	0.00	0.02	0.02
26	0.06	2.07	3.32	-2.01	0.11	3.22	1.21
Total	1.16	30.59	20.56	-29.43	1.64	18.91	-10.52

foreign countries and exported 30.59 billion m^3 to other countries in international trade in 2007 which resulted in a net export virtual water of 29.43 billion m^3. Industries with high levels of net export of virtual water included agriculture, food production, metals production, tertiary industries and construction, textile production, chemical production and non-metallic mineral production (Fig. 1). Most of these industries were related to agricultural production and material processing. In 2007, the above industries consumed 89.25% of the total exported virtual water. In particular, the net export of virtual water of the farming, forestry, animal husbandry and fishery industries reached 11.614 billion m^3, accounting for 39.46% of the total export of virtual water. Earning low profits from foreign exchange, the farming, forestry, animal husbandry and fishery industry contributed only 10.69% to total trade surplus and exerted intensive pressure on water resources and the environment in Hebei Province.

In light of international and domestic trade, the net export of virtual water from Hebei Province amounted to 10.521 billion m^3, representing 52.13% of total water consumption of the Province and 87.77% of provincial water resources in 2007. Among 26 industry sectors, 12 of them exported virtual water and 14 imported virtual water. Agriculture industry has the highest level of net export of virtual water, followed by food production industry, metal production industry, non-metallic mineral production industry and textile industry. Industries with high levels of net import of virtual water included the production and supply of electricity and heat, tertiary industries and construction, mining and washing of coal and mining and processing of metal ores.

Export of products which require a high level of water consumption to produce their products is placing great pressure on water resources and aquatic environments in Hebei Province. Ma *et al.* (2006) and Guan and Hubacek (2007) come to the same conclusion. Guan and Hubacek (2007) found that North China as a water scarce region virtually exports about 5% of its total available freshwater resources while accepting large amounts of wastewater for other regions' consumption. Ma *et al.* (2006) pointed out that North China exports large amount of virtual water to South China though grain trade. The current trade structure is not very favorable with regards to water resource allocation and efficiency. Thus, adjustment of the trade structure in Hebei Province is proposed. Export duty fees on the products which requiring large amounts of water to produce should be increased. The exports of high virtual water content products should be reduced which are mainly from agriculture production, iron and steel production, food production, chemical and non-metallic mineral production.

Raw materials and other products with high amounts of virtual water could be imported from water rich regions in China to relieve the pressure on local water resources and aquatic environments in Hebei Province.

CONCLUSION

Industries with high levels of direct and total water intake are agriculture, electricity production, metal production, chemical production and mining industry. Water resource conservation strategy should be emphasized in these industries.

In 2007, the net export of virtual water of Hebei Province totaled 10.521 billion m^3, representing 52.13% of total water consumption of the Province and 87.77% of provincial water resources in international and domestic trade. In domestic trade, Hebei Province was a net importer of virtual water, with net virtual water import of 18.911 billion m^3 in 2007. In international trade, the Province exported virtual water, with a net export of 29.432 billion m^3. Export of products which require high levels of water consumption resulted in the export of a huge amount of virtual water and exerted mounting pressure on local water resources and the environment.

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