Situation Analysis of China's International Trade of Virtual Water

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Abstract. Virtual water trade can facilitate the secondary allocation of water resources. International trade of virtual water is an effective means for countries with water shortage to ensure water security. This paper introduces the analytical method of international virtual water trade, calculates and analyzes the situation of international virtual water trade in China in recent years (from 2002 to 2015), and proposes countermeasures accordingly.

1. Introduction

Water, as an important strategic resource, is usually unable to be traded directly. However, by means of importing and exporting product and commodity circulation, water resources can flow in and out so as to realize virtual water trade [1]. Virtual water trade overcomes the shortcomings of importing real water, including multiple barriers, high threshold, high cost, and low ecological security. It can facilitate the secondary allocation of water resources and is considered to be an effective means to safeguard water and economic security in water-short countries by importing water-intensive products [2]. China has a large population with relatively a small amount of water, an uneven distribution of water resources in time and space, and a mismatching layout of productivity. Therefore, it is of great significance to develop virtual water trade rationally to alleviate water shortage in China [3].

2. Analytical method of international trade of virtual water

International trade covers all industry products, including agricultural products, industrial products and service products. It is suitable to analyze international virtual water trade with the input-output method [5]. Specific steps are as follows:

a. Calculate the water consumption coefficient per unit of output value of every industry in a country based on the output value and water consumption data. The direct water consumption coefficient and the total water consumption coefficient taking all indirect water use into consideration are also calculated.

Direct water consumption coefficient refers to the amount of water in its natural form used to produce a unit of goods or services, reflecting the direct water intensity of each department in producing goods or services. The calculation formula is as follows:

$$w_j = W_j / X_j \quad (1)$$

In the above formula, W_j represents the water consumption of the department j, and X_j represents the total output of the department j.

Total water consumption coefficient refers to the total amount of water resources directly used or indirectly used by intermediate input products in producing a unit of goods or services, reflecting the total water intensity of each department in producing goods or services. The calculation formula is as follows:

$$wT = w(I - \hat{a}A)^{-1} \quad (2)$$

In the above formula, wT represents the row vector of the total water consumption coefficient; w represents the row vector of direct water consumption coefficient of each department; $\hat{a}$ represents the diagonal matrix of the proportions of domestic production of each product in a country; A represents the matrix of direct consumption coefficient.

b. Assume that during the final use and intermediate input, the proportion of domestically produced products used by a department is equal to that of imported products. Make a rough estimate of the export volume of the department. The calculation formula is as follows:

$$W_j^E = wT_j \times X_j^E \quad (3)$$

In the above formula, W_j^E represents the amount of exported water of the department j, wT_j represents the total water consumption coefficient of the total output of the department j, and X_j^E represents the export value of the department j.

c. Calculate the amount of imported water using the total water use coefficient of the final product. Imported goods are produced abroad, so they do not consume water resources in a certain country. The imported water is actually the water resources saved by import. Therefore, when calculation is performed, it is not necessary to consider the technology level of a foreign country, while the water consumption situation in a certain country is the only factor that should be taken into consideration. At the same time, importing products of a certain department can not only save the direct consumption of water resources of that department, but also save the indirect consumption during the production process. Therefore, the amount of water saved by importing goods should be calculated based on the total water consumption method of the final output value of a country.

d. Collect the data of various industries and obtain the virtual water import and export volume of the whole national economy of a certain country.

3. Estimation of International Trade of Virtual Water in China

According to the input-output table issued by the National Bureau of Statistics of China [5-7], the statists released by the State General Administration of Customs, *China Statistical Yearboo*k [8], *Water Resources Bulletin* [9], and *China Environmental Yearbook* [10], based on the above analytical method, China's import and export volume of virtual water from 2002 to 2015 is calculated (for the result, see Table 1). According to calculation, in 2015, China’s volume of exported virtual water reached 4195 billion m^3, the volume of imported virtual water reached 3901 billion m^3, and the volume of net exported virtual water reached 294 billion m^3.

Table 1 Volume of imported and exported virtual water in China from 2002 to 2015 Unit: 10 billion m^3

Year	Volume of exported virtual water	Volume of imported virtual water	Volume of net exported virtual water
2002	57.6	47.5	10.1
2003	80.0	58.7	21.3
2004	85.3	69.1	16.1

2005	121.9	80.4	41.5
2006	152.7	93.8	58.9
2007	179.9	118.6	61.4
2008	211.8	132.4	79.5
2009	180.0	119.1	60.9
2010	232.2	159.9	72.3
2011	276.8	196.2	80.6
2012	297.6	204.0	93.7
2013	398.1	395.6	2.5
2014	423.2	409.5	13.7
2015	419.5	390.1	29.4

In the meantime, the volume of imported and exported virtual water in sub-industries in China in the four typical years of 2002, 2007, 2012 and 2015 was also measured (for the results, see Table 2).

Table 2 Volume of imported and exported virtual water in sub-industries in typical years Unit: 10 billion m^3

Industry	**2002**		**2007**		**2012**		**2015**	
	Export	**Import**	**Export**	**Import**	**Export**	**Import**	**Export**	**Import**
Garment, leather, feather and other fiber products manufacturing	6.0	0.9	13.7	1.2	22.7	2.1	49.9	3.2
Electronics and communication equipment manufacturing	3.9	4.4	19.0	12.0	31.4	20.6	48.5	35.3
Wholesale and retail	3.6	0.0	6.4	0.0	10.6	0.0	48.1	81.2
Textile industry	8.4	3.7	28.4	2.3	46.9	4.0	31.2	5.2
Other manufacturing	0.8	0.2	2.9	0.4	4.7	0.7	27.5	4.5
Instrumentation and cultural office machinery manufacturing	2.2	2.4	5.4	5.4	8.9	9.3	25.3	6.6
Electrical equipment and machinery manufacturing	2.5	2.1	9.6	4.0	15.9	6.9	24.3	8.3
chemical industry	5.1	8.5	19.1	20.0	31.7	34.4	23.6	32.2
Food manufacturing and tobacco processing	4.4	2.6	10.6	7.3	17.5	12.5	22.9	22.0

mechanical industry	1.5	3.6	7.5	7.6	12.4	13.1	17.4	11.0
Metal smelting and rolling processing	1.0	3.7	12.3	8.6	20.4	14.8	17.1	12.6
Agriculture	5.5	7.9	8.7	25.1	14.3	43.2	15.0	66.7
Metal products	1.6	0.8	5.9	0.8	9.7	1.4	12.6	2.3
Transportation equipment manufacturing	0.7	1.0	3.8	2.9	6.3	4.9	11.4	10.3
Tourism	0.2	0.0	0.7	0.5	1.1	0.9	10.4	33.6
Non-metallic mineral products	0.6	0.3	2.2	0.5	3.7	0.8	7.0	1.6
Accommodation and catering	1.8	0.0	4.2	2.5	6.9	4.2	6.2	0.0
Cargo transportation and warehousing	1.6	0.3	5.0	1.1	8.2	1.9	3.9	9.9
Residents and other service industries	1.2	0.6	0.5	0.3	0.7	0.5	3.9	3.4
Wood processing and furniture manufacturing	1.7	0.5	6.8	0.6	11.3	1.1	3.6	2.4
Paper printing and stationery manufacturing	1.7	1.0	4.4	1.3	7.3	2.3	3.3	3.0
Petroleum processing and coking industry	0.4	0.8	1.3	2.0	2.1	3.4	3.0	3.1
Post and telecommunications and information service software	0.1	0.1	0.4	0.3	0.7	0.5	1.7	1.0
Financial insurance	0.0	0.2	0.1	0.1	0.1	0.1	0.7	1.9
Education, Culture, Art and Radio, Film and Television	0.2	0.1	0.0	0.1	0.1	0.1	0.5	0.6
Non-metallic mining and dressing	0.2	0.2	0.2	0.3	0.3	0.5	0.3	0.6
Oil and gas extraction	0.1	0.8	0.1	3.9	0.2	6.8	0.2	10.2
Coal mining and selection	0.2	0.0	0.3	0.2	0.5	0.4	0.1	1.3
Metal mining and dressing	0.0	0.7	0.2	7.1	0.3	12.3	0.0	16.2
Electricity and heat production and supply	0.3	0.1	0.5	0.1	0.8	0.2	0.0	0.2

Administrative agencies and other industries	0.1	0.1	0.1	0.1	0.1	0.2	0.0	0.0
Total	57.6	47.5	179.9	118.6	297.6	204.0	419.5	390.1

4. Conclusion and suggestions

4.1. China's virtual water trade surplus has shown a trend of rapid growth, further aggravating the contradiction of water shortage.

According to the calculation results, China's virtual water trade surplus showed a trend of rapid growth. During the 13 years from 2002 to 2015, China's exported virtual water volume increased from 576 billion m^3 to 4195 billion m^3, an increase of 6.3 times; imported virtual water volume increased from 475 billion m^3 to 3901 billion m^3, an increase of 7.2 times. Although the growth rate of China's virtual water export is higher than that of virtual water import, China's virtual water export have always been larger than export in terms of absolute value, thus a trade surplus. From the specific values, China's net export of virtual water increased from 101 billion m^3 in 2002 to the peak of 937 billion m^3 in 2012, and then fell back to an average of 152 billion m^3 during 2013 and 2015. The net export of virtual water has intensified the pressure on China's water shortage and has brought severe challenges to China's water security.

4.2. Large export volume of high-water-consumption products is an important reason for the high net export volume of virtual water in China.

From 2013 to 2015, China's net export volume of virtual water was effectively controlled, mainly relying on a substantial increase in the net export volume of virtual water. However, net export volume of some high-water-usage industries is still huge, which is an important reason for net export volume of virtual water in China to remain large.

Specifically, the net export of virtual water of garment, leather, feather and other fiber products manufacturing increased from 506 billion m^3 in 2002 to 467.3 billion m^3 in 2015, an increase of about 8 times. In addition, the net export volume of electric equipment and machinery and other manufacturing also continues to increase. Instrumentation and cultural office machinery manufacturing remained stable in the net import volume of a small amount of virtual water in the early stage. But in 2015, its net export of virtual water suddenly jumped up.

The net export volume of virtual water in textile industry increased from 46.7 billion m^3 in 2002 to 429 billion m^3 in 2012. By taking effective controlling measures, it decreased to 260.4 billion m^3 in 2015, but still remained high. In addition, net export of virtual water of wholesale and retail and tourism in 2015 was also effectively controlled, and realized the net import of virtual water.

Agriculture is the main contributor to China's net import of virtual water. Its volume increased from 24 billion m^3 in 2002 to 516.8 billion m^3 in 2015, an increase of approximately 20.5 times. Agriculture is the backbone of balancing China's import and export of virtual water and safeguarding China's water security.

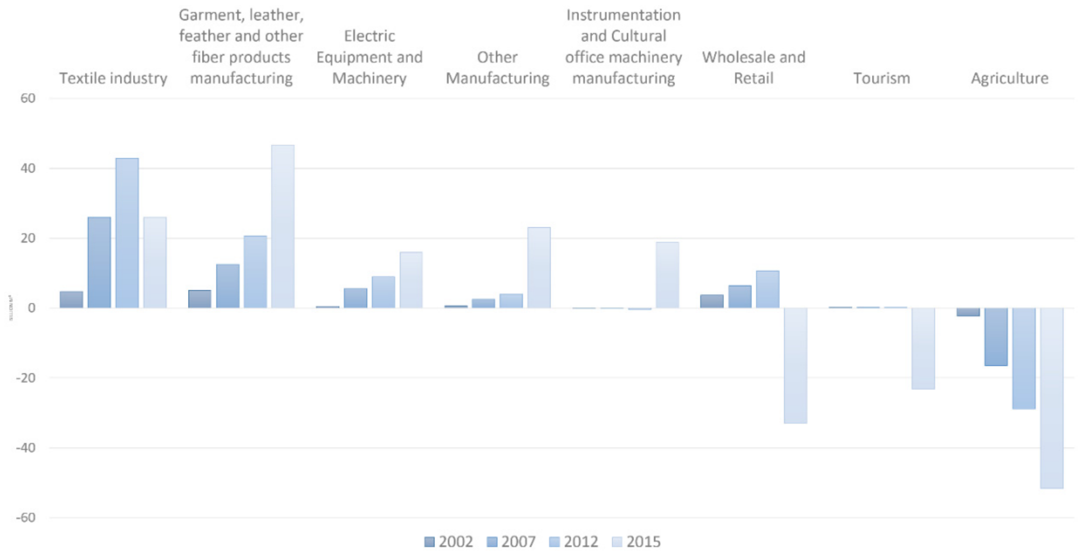

Figure 1 Changes in the net export volume of virtual water in China (2002, 2007, 2012, 2015)

4.3. Suggested countermeasures

4.3.1. Regard import and export volume of virtual water resources as an important reference in making national trade policies. The growth trend of net export of virtual water has further aggravated China's water shortage. Continued increase in the net export of virtual water will pose serious challenges to China's water security in the future. Under this circumstance, the Chinese government should consider virtual water as an important factor in making national trade policies, formulate relevant policies, make plans to optimize import and export and product catalogues, encourage the export of low-water-consumption products and the import of high-water-consumption products; properly reduce import tariffs on water-consuming products; expand the scope and scale of imported high-water-consuming products, while increase the import of high-water-consuming products and primary products; reasonably increase export tariffs on water-consuming products and limit the export of high-water-consumption and high-pollution products; adjust the industrial structure and rationally regulate the flow of virtual water to balance virtual water trade.

4.3.2. Further encourage the development of overseas agriculture. China has a large population but insufficient agricultural water and soil resources. Making use of overseas grain production resources is an important means to promote the virtual water balance of food. Specific measures include the following: introduce guiding trade policies to encourage the development of overseas agriculture; encourage Chinese companies to develop agriculture by purchasing or leasing land abroad, and establish a stable supply channel of overseas virtual water; at the same time, appropriately expand the scope and scale of products for importing virtual water from water-rich countries, including feed wheat, corn, beans, cotton, oilseeds, sugar, etc.; adjust China's domestic layout of agricultural production and planting industry to decrease traditional agricultural industry production featuring high water consumption and low-efficiency while support the development of low-water-consumption and high-efficiency industries.

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