

Quantitative analysis of the impact of virtual water trade in Shandong Province with other regions

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Abstract. The theory evidence of this paper is virtual water and other related concepts, and the starting point is the regional virtual water trade between Shandong Province and other regions (such as South of China, North of China as well as the foreign countries). Input-output data of 30 provinces and cities in China (excluding Taiwan, Hong Kong, Macau, and Tibet) was consolidate as inter-regional trade of Shandong Province and South of China (or North of China) to calculate the coefficient of trade ratio in different regions and the trade situation of industries and virtual water between Shandong Province and other regions. The results show that the north, the South and abroad all have the net input of virtual water to Shandong Province in industry and agriculture. Besides, Shandong's virtual water is the net output state in the tertiary industry. In total, there is a net input of virtual water to Shandong Province in north and south and abroad. Among them, 15% of virtual water imported to Shandong is from the south, 31% from the north, and 54% from foreign countries.

1. Introduction

Shandong Province has insufficient water resources, and time and space distribution of water resources is inhomogeneous. However, the Shandong section of the eastern route of the South to North Water Transfer Project can alleviate this problem to a certain extent. Virtual water trade can complement the construction of inter-basin water diversion projects and play an important role in ensuring water security in water shortage areas[1]. At present, the research of virtual water trade in Shandong Province has made some achievements. The net output of virtual water in Shandong Province is 21.16, 16.06 and -27.73 billion m³, respectively, in 1997, 2002 and 2007 [2-4], showing a significant downward trend and gradually changes from net output to net input state. However, there is no research result on how Shandong's virtual water trade affects domestic and international water and environment. Thus, it is necessary to calculate the virtual water trade value between Shandong Province and other regions and quantitatively analyze the interregional virtual water effect brought about by the input and output of products from various industries and study the impact of Shandong Province on other regions of China and foreign water resources and the environment. The above mentioned has a great significance for alleviating the water shortage problem in Shandong Province, achieving optimal allocation of water resources, reasonably adjusting the industrial structure, realizing the sustainable development of ecological environment and social economy in the new era, and developing the environment and economy of China.

2. Material and method

According to the amount of water, the trade between Shandong Province and other domestic regions is divided into the South and the North (not including Shandong Province), and the water resources



effect of Shandong Province and other regional trade is studied from the macro and micro point of view. According to the existing input-output data, coefficient of trade ratio in different regions that can reflect the inter regional trade structure was calculated, and then the volume of virtual water trade between Shandong Province and other regions (including foreign countries) was calculated.

2.1. Data sources

Input-output data of departments of various provinces and cities[5], input-output data of various product sectors in Shandong Province input-output table (value type) in 2007 and water consumption coefficient[2].

2.2. Inter-regional economic relations in 2007

According to the amount of regional water resources, the 30 provinces, cities and municipalities in China (excepting Taiwan, Hongkong, Macao and Tibet) are divided into the South and the North. Southern cities include Jiangsu, Zhejiang, Shanghai, Hubei, Hunan, Sichuan, Chongqing, Guizhou, Yunnan, Guangxi, Jiangxi, Fujian, Guangdong, and Hainan, and northern cities include Beijing, Tianjin, Inner Mongolia, Xinjiang, Hebei, Gansu, Ningxia, Shanxi, Shaanxi, Qinghai, Henan, Anhui, Liaoning, Jilin and Heilongjiang. According to three regions of Shandong, South and North, the economic output value of each industry in input-output data of departments of various provinces and cities[5] was classified and merged. In addition, the construction industry was merged into the industry, and the transportation and warehousing, wholesale and retail trade and other service industries was combined into the tertiary industry. The economic link between Shandong Province and the South and the North, respectively is shown in Table 1. According to Table 1, the proportion of the output value of various industries of the north and the south in Shandong Province's input-output was calculated and shown in Table 2.

Table 1. Economic link between Shandong Province and Northern and Southern regions in 2007. ($\times 10^4$ yuan)

Department	Export to the South	Import from South	Export to the North	Import from North
Agriculture	340 806	888 984	684 846	1 894 403
Industry	23 799 485	12 239 833	22 019 741	23 438 011
Tertiary industry	1 558 129	1 973 955	1 547 434	2 834 169

Table 2. South and North Trade Structure(Ratio coefficient).

Department	Export to the South	Import from South	Export to the North	Import from North
Agriculture	0.332	0.668	0.319	0.681
Industry	0.519	0.481	0.343	0.657
Tertiary industry	0.502	0.498	0.411	0.589

2.3. Inter-regional input-output tables for 2007

Through investigation and statistics, the output value of various industries in Shandong Province input-output table in 2007 was obtained. From the inter-regional trade structure and Shandong Province's input-output table, the import and export value from the domestic and foreign provinces was used to derive the output value of various industries in the region, as shown in Table 3.

2.4. Interregional virtual water trade in 2007

In order to avoid repeated calculation of water consumption among industries, the virtual water trade volume was calculated by multiplying the output value of each industry and its direct water consumption coefficient. The direct water consumption coefficients of agriculture, industry and the tertiary industry are 35.588×10^{-3} , 0.4397×10^{-3} and 0.2878×10^{-3} m³/yuan[2], respectively. The volume

of virtual water in trade of Shandong Province and other regions was obtained, as shown in Table 4.

3. Result and analysis

According to Table 4, the diagrammatic sketch of virtual water trade between Shandong Province and other regions is shown in Figure 1.

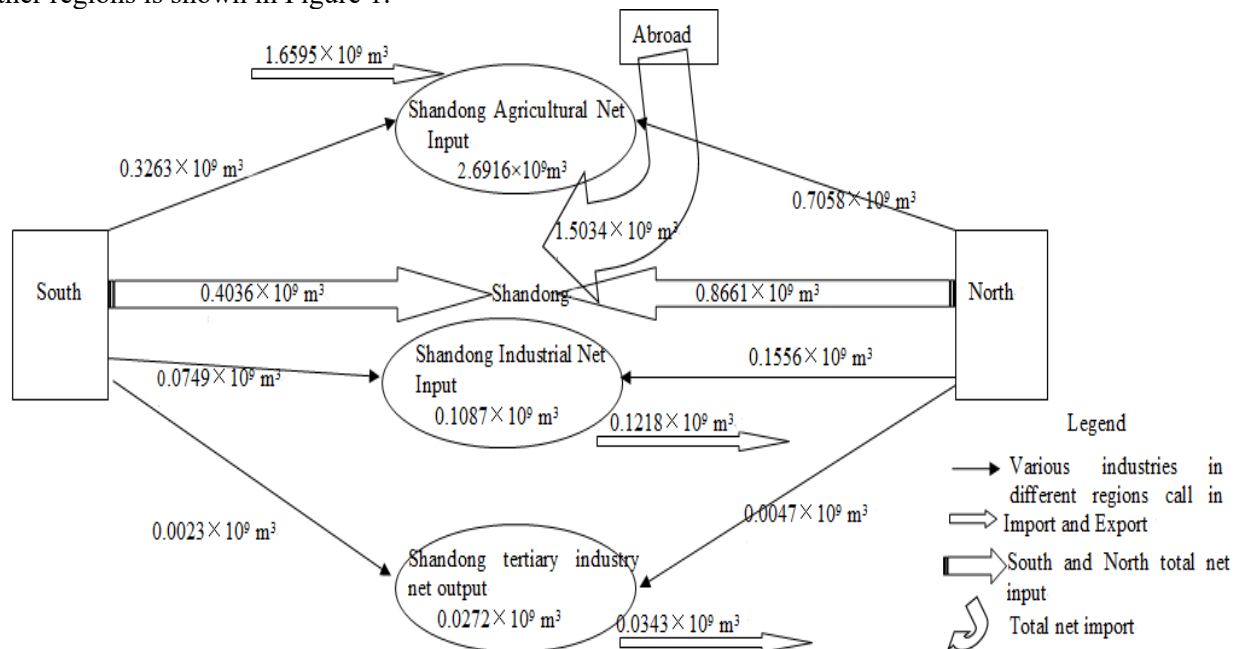


Fig. 1. The virtual water trade between Shandong Province and other regions.

Table 3. Inter-regional export-import in Shandong Province in 2007. ($\times 10^4$ yuan)

Department	Export to the South	Import from South	Net export to the South	Export to the North	Import from North	Net export to the North
Agriculture	239 244	1 156 228	-916 984	480 758	2 463 893	-1 983 135
Industry	9 965 135	9 464 837	500 298	9 219 935	18 124 182	-8 904 247
Tertiary industry	1 087 594	1 900 452	-812 858	1 080 128	2 728 635	-1 648 507
Total	11 291 973	12 521 517	-1 229 544	1 078 0821	23 316 710	-12 535 889
Department	Export	Import	Net Export	Total Export	Total Import	Total net Export
Agriculture	4 052 618	8 715 701	-4 663 083	4 772 620	12 335 822	-7 563 202
Industry	41 044 889	13 352 350	27 692 539	60 229 959	40 941 369	19 288 590
Tertiary industry	13 307 902	1 379 321	11 928 581	15 475 624	6 008 408	9 467 216
Total	58 405 409	23 447 372	34 958 037	80 478 203	59 285 599	21 192 604

Table 4. Virtual water trade between Shandong Province and other regions. ($10^9 m^3$)

Department	Export to the South	Import from South	Net output to the South	Export to the North	Import from North	Net export to the North
Agriculture	0.085 1	0.411 5	-0.326 3	0.171 1	0.876 9	-0.705 8
Industry	0.012 3	0.087 2	-0.074 9	0.011 3	0.166 9	-0.155 6
Tertiary industry	0.003 1	0.0055	-0.002 3	0.003 1	0.007 9	-0.004 7
Total	0.100 5	0.504 1	-0.403 6	0.185 5	1.051 6	-0.866 1
Department	Export	Import	Net Export	Total Export	Total Import	Total net Export
Agriculture	1.442 2	3.101 7	-1.659 5	1.698 5	4.390 1	-2.691 6
Industry	0.180 5	0.058 7	0.121 8	0.204 1	0.312 8	-0.108 7
Tertiary industry	0.038 3	0.004 0	0.034 3	0.044 5	0.017 3	0.027 2
Total	1.661 0	3.164 4	-1.503 4	1.947 1	4.720 2	-2.773 1

Figure 1 shows that in agriculture, Shandong Province imported virtual water from the North and the South and abroad, indicating that Shandong Province has increased the amount of imported grain. This virtual water strategy is conducive to the protection of water resources and sustainable economic development in Shandong Province. In industry, three regions also have virtual water net input to Shandong Province, which saves industrial water, but from the perspective of water resources security in future, Shandong Province still needs to increase industrial water-saving efforts and vigorously develop water-saving industries. In the tertiary industry, virtual water of Shandong Province still is a net output state, but the tertiary industry consumes less water resources. So, it will be a key development industry in the future, which is within a reasonable range.

In terms of total amount, Shandong Province imported virtual water from the North and South and abroad. Among them, 15% of virtual water imported to Shandong Province is from the South, 31% from the North, and 54% from foreign countries. This is beneficial for the water resources and environmental security of Shandong Province, but will make environmental pressure on other regions. Because of the South has sufficient water resource, the net input of virtual water from the South to Shandong Province is relatively reasonable in the overall economic and environmental development. However, about 31% of the virtual water in Shandong Province was imported from the water-poor northern region, which poses a threat to the water resources and ecological environment in the North. In the North, given that the water resources is relatively abundant in the Northeast and relatively poor in the Northwest and North China, Shandong Province should increase trade with the Northeast and reduce trade with North China and Northwest for ensuring the sustainable development of the economy and water resources in Shandong Province and northern China. From the perspective of nationwide sustainable development, it is necessary to adjust China's economic and trade structure as a whole and minimize the output of virtual water in the northern region. Meanwhile, Shandong Province should also increase trade with the South, which has sufficient water resources, and then the shortage of water resources is alleviated in Shandong Province to some extent.

In addition, the change of the virtual water import and export volume in Shandong Province from 1992 to 2007 was an objective result of the interaction of various factors such as water resources, social and economic development, and market economy adjustment. However, in water-scarce northern region, the adjustment of economic structure should be taken from the strategic perspective of water balance, and especially in agricultural production, the problem of groundwater over-exploitation in the North China Plain should be avoided repeating.

Given that the reuse of the agricultural returning water in downstream, this amount of water should be deducted, theoretically, when calculating the direct water consumption coefficient of agriculture. It has been roughly calculated that the average agricultural water use rate in Shandong Province is 76%, and the direct water consumption coefficient of agriculture becomes $27.069 \times 10^{-3} \text{ m}^3/\text{yuan}$ after deducting the return water. Based on the above-mentioned quantitative calculation of inter-regional virtual water trade, the net input of virtual water in Shandong Province was calculated as $2.129 \times 10^9 \text{ m}^3$ after deducting agricultural return water. However, there are many kinds of irrigation areas such as well irrigation area, Yellow River irrigation area and reservoir irrigation area in Shandong Province. Therefore, it is relatively complex to accurately deduct return water and calculate the agricultural water consumption rate, which needs further research.

For the two important sources of data in the article, the reference [5] is the same as the total input-output volume in Input-Output Table (Value Type) of Shandong Province in 2007, but the inputs and outputs of various departments, imported and exported are not the same. The reason is that the former is calculated based on the principle of gravitation while the latter is derived from survey statistics, which is more reliable than the former.

4. Conclusion

(1) The north, the South and abroad all have the net input of virtual water to Shandong Province in industry and agriculture. Besides, Shandong's virtual water is the net output state in the tertiary industry.

(2) In total, there is a net input of virtual water to Shandong Province in north and south and abroad. Among them, 15% of virtual water imported to Shandong is from the south, 31% from the north, and 54% from foreign countries.

(3) The input of virtual water is beneficial to the water resources and environmental security in Shandong, but for the water-starved north, 31% of the virtual water is imported from the north, posing a threat to the water resources and ecological environment in the north. China's economic and trade structure should be adjusted by minimizing the output of virtual water in the northern region, increasing the water resources trade with the south. On the premise of alleviating the pressure of water resources in the north, water resources shortage in Shandong Province can be alleviated.

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