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Virtual water export and import in china's foreign trade: A quantification using input-output tables of China from 2000 to 2012

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ABSTRACT

Import virtual water is an effective way to alleviate water shortage. Since China is a country that suffers severely from the lack of water resources, it is badly needed to research in virtual water export and import in China's foreign trade. This paper conducted thorough research on these issues and lucubrated on the detailed destinations and origins of China's virtual water export and import using the input-output model. Moreover, the factors that affect China's virtual water trade have also been studied in this paper. The results indicated that: (1) from 2000 to 2012, the volume of virtual water export increased from 65.2 billion tons to 114.1 billion tons, and its import volume increased from 62.4 billion tons to 108.7 billion tons. China was a net exporter of virtual water; (2) the export of virtual water was mainly exported by sectors such as Textile &Garment and Leather Products, General Machinery and Equipment Manufacturing Industry, the import of virtual water was mainly imported by Agriculture, Petrochemical industry; (3) China has net exported large amounts of virtual water to developed areas such as the US, the European Union, and Japan, and has net imported from emerging economies and resource-oriented regions such as Taiwan (China), ASEAN, Brazil, Korea, Australia and Russia. Based on these conclusions, this paper proposed that China's foreign trade structure needed to be adjusted to relieve the water shortage by the following methods the first is appropriately lower the export proportion of products from sectors such as Food, Beverage & Tobacco Products, Petrochemical Industry, which exported a large proportion of virtual water; the second is to enlarge the export proportion of products with low water consumption, such as service industry; the third is to make full use of the water saving effect of import.

1. Introduction

Water is a crucial natural resource for the survival of human beings, and also a strategic resource for the sustainable development of economy of a country (region). At present, many countries have suffered from water scarcity. It is estimated by the United Nations that there will be a population of 2–2.7 billion facing the problem of water shortage till 2050, and the per capita water resource will decrease by more than 1/3 globally in the next 20 years (United Nations, 2003). Among these countries, China suffered most from water shortage in that its per capita available water resource is only 2300 m^3, less than 1/4 of the world per capita, ranking the 110th globally, and is one of the 13 countries that most lack of water resources in the world. There are also considerable regional diversities between South and North China, the per capita available water resource in South China is about 3600 m^3, much more than 720m^3 in North China (He et al., 2011). Besides, among 699 cities of China, 400 have insufficient supply of water perennially, and 110 are threatened by water scarcity, which have significantly restricted the sustainable development of China's national economy (Huang and Qin, 2009).

On the other hand, China's foreign trade value has been booming since China joined the WTO in 2001. The import and export volume increased from RMB1863.8 billion and RMB2063.4 billion in 2000 to RMB14388.3 billion and RMB12035.8 billion in 2014, and China has become the No. 1 trading country in the world (China's National Bureau of Statistics, 2015). Owning to the water consumption during the manufacturing process of the commodity, there is hidden water in the commodity, which is called "virtual water" (Allan, 1993). Such massive imports and exports of commodities

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have inevitably led to the fact that China has exported and imported a great amount of virtual water.

In 1999, Prof. Allan proposed the point that a country (region) could implement the virtual water trade strategy to import water resource intensive products from another country (region), and to reduce the exports of products with high water consumption, in order to import (virtual) water resources and save its own water resources. It is expensive to import or export real water, so the trade of virtual water has overcome this drawback, and is an effective way to deal with water shortage for countries with scarce water resources (Allan, 1999; Hoekstra, 2003). In the past 20 years, the trade flow and trade volume of virtual water among all countries has at least doubled (Dalin et al., 2012). With the rapid development of China's international trade, the water shortage problem will be alleviated to a large extent through the virtual water trade strategy – to adjust China's foreign trade structure, cut down virtual water export and increase virtual water import.

However, the first problem for implementing virtual water trade strategy is to grasp relevant information such as the import and export volume, the destination and source of virtual water trade and its changes with time goes by. From present literature, researchers have not investigated the abovementioned problem quantitatively. Therefore, this paper based on previous studies on virtual water trade, adopted the input-output tables of China from 2000 to 2012 and detailed trade data of subsectors between China and its trade partners to investigate these problems, and put forward corresponding suggestions on the adjustment of the foreign trade structure.

2. Literature reviews

Initially, the object of quantitative study on virtual water trade is mainly agricultural products. Firstly, this is because that crops contain abundant water resources and thus water consumption in agriculture accounts for a great part of global water consumption, and therefore, agriculture sector bears the largest water consumption in the world. Secondly, the calculation of the virtual water content in industrial and service products is complicated, and the actual water consumption of industrial products is less than that of agriculture products, and thus often being neglected. The calculation methods for the virtual water content in crops in most studies origin from the Penman formula proposed by FAO (the UN Food and Agriculture Organization).

There are now mainly two specific methods to measure the virtual water content in products: one is to investigate the production tree of different products proposed by Chapagain and Hoekstra (2003); the other is to categorize and differentiate products into agricultural products, industrial products and animal products and etc. (Zimmer and Renault, 2003). Many studies have focused on agriculture, and even directly adopted the trade volume of virtual water in agriculture among countries (regions) to measure the whole status of the virtual water trade among relevant areas. For instance, Novo et al. (2009), Affuso (2010) and El-Sadek (2010) took Spain, North America and Egypt respectively as examples to study the effects of international trade of agricultural products on the water resource and food security in these areas with virtual water embedded in food as measuring object. Roson and Sartori (2010) and Antonelli et al. (2012) concentrated on the Mediterranean regions, illustrated the virtual water flow among these countries, and pointed out that the virtual water trade in agriculture among these countries had achieved the reasonable allocation of water resources and alleviated the water scarcity in relevant countries. Some other researchers focused on a global level. They calculated the global flow of virtual water based on the food trade among all countries. According to their findings, in respect of the international trade of virtual water in agriculture, countries such as America, Canada, Thailand, and India are major net exporters of virtual water, while countries such as Holland, Japan and Korea are major net importers of virtual water (Aldaya et al., 2010; Hoekstra and Chapagain, 2007; Hoekstra and Hung, 2005; Schwarz et al., 2015; Biewald et al., 2014).

Some researchers have looked at the water use or virtual water trade in agriculture in China. Cao et al. (2015) and Liu et al. (2015) calculated the water consumption of grain cultivation in China; the result was approximately 689.04 billion m^3. Shi et al. (2014) selected 27 main crops, measured the virtual water trade among China and other trade partners from 1986 to 2009, and found that China had net exports of virtual water to Asia, Africa and Europe, but had net imports from America, and overall it tended to be an net importer of virtual water. Zhang et al. (2016) found that China's virtual water export in agriculture had been declining while the import had been increasing, which is related to the booming of the imports of agriculture products.

However, the virtual water is not only essential for crops, but also deeply rooted in the whole social economy and in all walks of life. With further exploration on virtual water trade, researchers have increasingly realized the limitation of using virtual water in agriculture as a substitute for the virtual water trade among regions. Zhu and Gao (2009) calculated the virtual water volume in China's foreign trade in all industries, and the results manifested that the exports of virtual water surpassed the imports and the gap was expanding. Zhu (2014) calculated the virtual water volume in China's foreign trade in all industries in 2010, and the results illustrated that some industrial products with high water consumption accounted for a large proportion in China's export trade, and this was the vital reason that China became a net exporter of virtual water. Compared with the findings of Zhang et al. (2016), it can be seen that the status of China's foreign trade of virtual water goes quite opposite when the research object transferred from agriculture to all industries, which also proved the limitation of studying only virtual water trade in agriculture. With the continuous global industrialization, and the rapid expansion of the trade flow in industries and service industries among various countries, it is necessary to measure the trading status of virtual water in all industries among various countries (regions), so as to evaluate the effects of international trade on water resources in relevant areas. For this purpose, Van Oel et al. (2009) conducted a quantitative study on the external water footprint (EWFP) of Holland, and found that up to 89% of the water footprint came from external regions, and 60% of which were from industrial products. Islam et al. (2006) and Orlowsky et al. (2014) launched a qualitative study on the water resources and virtual water trade in various countries, and indicated the need for some countries to conduct virtual water trade. However, restricted by their research method, they failed to calculate the virtual water trade volume in all industries among various regions.

According to Su and Ang (2012), the SDA (structural decomposition analysis) can be used to analyze the driving forces to the changes of virtual water and time-series virtual water estimate. In addition, the SDA can also be applied on the multi-region comparisons of water use or carbon emission performance (Su and Ang, 2016). For instance, Yang et al. (2016) analyzed on the growing water use in China during 1997–2007 by applying the dynamic SDA model. Zhi et al. (2014) studied the water footprint changes in the Haihe River basin in China with the help of IO tables and SDA model.

Since the manufacturing process of industrial products is intricate, and relevant to various sectors in the whole economic system, the quantitative measurement of the virtual water in industrial or service products has always been the difficulty in this field. The input-output model with water consumption coefficient belongs