Analysis of China department water consumption efficiency

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Abstract. The water comparable non-competitive input-out model of China in 2002, 2007 and 2012 is established to calculate the department water consumption efficiency. The water direct and complete consumption coefficients of 38 departments are analysed. Agriculture and Electricity and steam supply have the highest water consumption coefficients and utilize water resource mainly by the direct way. Manufacture of food products and tobacco products, Manufacture of textiles, Manufacture of wearing apparel and leather products and Information service activities have high water complete consumption coefficients and affect water consumption mainly by the indirect way. Water complete consumption efficiency measures the efficiency from the view of final product, which reflected the department water use driving force more precisely.

1. Introduction
Water resource is prominent to Chinese social economic development. The amount of water resource is rich in China, while the amount of per capita water resource is low. China is listed in the 13 countries with the poorest water resources all over the world. With the rapid development of economy and society, water shortage problem continues to grow, which became one of the most important factors restricting the sustainable development of China [1]. The research of water consumption efficiency plays an important role in strengthening the protection and management of water resources.

Water consumption efficiency has double meanings. One is water direct consumption efficiency, which is direct water use amount for unit output in a department. The other is water complete consumption efficiency. The water consumption of intermediate inputs is also included in the departmental complete efficiency. It can be more accurate to measure the effect of each department expanding production scale on water utilization.

Input and output analysis was first proposed by Leontieff, an American economist in 1930s. It was used to represent the flow of products between different departments of the economy and society system. As an important tool to quantify the internal relations of economic systems, Input-Output Analysis has been widely used in the world, like energy, resources, environment and other issues [2, 3, 4].

Using the Input-Output Analysis, China department water consumption efficiency in 2002, 2007 and 2012 is calculated, including direct water consume efficiency and complete efficiency. The departments with higher water consumption are analysed in detail. It is profitable for the national industrial structure optimization and the management of China Total Water Consumption Control.
2. Methodology

2.1. Water direct consumption
Water direct consumption coefficient (WDC) refers to the ratio of department water consumption and department output value, which is the department increases one unit products, the water needed directly. Water direct consumption coefficient focuses on the production process of a department, and has the meaning of technical quota and production input, which constitutes the cost of the product.

\[ f_j = \frac{w_j}{x_j} \]  

\( f_j \) indicates the water direct consumption coefficient of department \( j \). \( w_j \) is water consumption of department \( j \). \( x_j \) is the output value of department \( j \).

2.2. Water complete Consumption
Water complete consumption coefficient (WCC) of a sector equal to the total water consumption increased of the entire economic system when the department added one unit production. In other words, only by increasing water consumption to WCC, one unit product can be produced. Compared with the water direct consumption coefficient, WCC is more accurate in measuring the pressure on water supplement by various departments while expanding the production scale.

According to the Input-Output Analysis and the meaning of WCC, the following equation is established.

\[ \bar{f}_j = f_j + \sum_{i=1}^{n} \bar{f}_i a_{ij} \]  

\[ \bar{F} = F(1 - A)^{-1} \]  

\( \bar{F} \) is water complete consumption coefficient vector. The element \( f_j \) is expressed as the direct and indirect water resources required to meet the final demand of department \( j \) added 1 unit production, which is also called virtual water.

In the actual economic system, there is a factor of import (input) products which affected the WCC calculation. If the intermediate input comes from import, it does not need to be produced in domestic. Import productions will not cause the depletion of water resources in domestic. To avoid exaggerating the results, the following equation is presented.

\[ \bar{F}' = D(1 - A^d)^{-1} \]  

\( A^d = [a_{ij}]_{n \times n} \). \( a_{ij}^d = l_{ij} a_{ij} \). \( l_{ij}^d \) is the domestic products ratio of department \( j \). \( A^d \) presents domestic consumption coefficient of products. The acquisition of \( A^d \) is the most difficulty in the WCC calculation.

2.3. Water indirect consumption
The water indirect consumption efficiency refers to the ratio of water complete consumption coefficient to water direct consumption coefficient.

\[ \delta = \frac{\bar{F}'}{F} \]  

\( \delta \) is called water use multiplier. It can reflect the degree of indirect driving to local water consumption by the department production activities.

3. Case study

3.1. Water input-output model

3.1.1 Data base. The basic input-output tables is compiled by the National Bureau of Statistics. The department classification in 2002, 2007 and 2012 has a little different, so some departments are
merged in this paper. There are 38 departments including Agriculture (including agriculture, forestry farming and fishery), Coal mining, Oil and gas mining, Metal mining and selecting, Construction, Finance and so on.

3.1.2 Comparable input-output table. This research aimed at comparing the water consumption efficiency in the history. On time scale, price factor is the most important factor affecting social and economic value. Time scale analysis requires unified data base. The double deflation method [5] is used to convert the input-output table into the base year price benchmark to get the comparable input-output table. The year of 2007 is selected as the base year. The price index of all kinds of products comes from the website of the National Bureau of Statistics.

3.1.3 Non-competitive input-output table. The basic table only lists the total imports. Non-competitive input-output tables need to distinguish imported products from intermediate products so as to avoid exaggerating water consumption results. Suppose that the intermediate input consumed by each department in the production process has the same domestic proportion. Suppose that the fixed assets and the intermediate inputs have the same domestic proportion in the same sector.

3.1.4 Water input-output model. Water consumption data is taken into the input-out table to establish water input-output model. Water consumption data of China comes from Water resource bulletin. It only has domestic water consumption (urban and rural), agriculture consumption, industry consumption (thermal power and nuclear power industry, other industry) and artificial ecological water consumption. Water used in 38 departments need to be calculated.

According to water use structure [6], the domestic water consumption is decomposed in this paper. A part of the domestic water is put into Construction or Service industry water consumption, and the remaining is put into the final demand of urban and rural. According to the 2008 economic census data, above scale industrial water use census data in 2010, the data needed in 38 department water input-output model is calculated.

3.2. Results

3.2.1 Department water direct consumption. According to the direct consumption coefficient, the nine departments with the highest water direct consumption is Agriculture, Electricity and steam supply, Other manufacturing, Manufacture of paper products and printing, education, sporting products, Non-metallic minerals and other mining, Metal mining and selecting, Manufacture of non-metallic mineral products, Education and Manufacture of chemical products. In 2012, the water direct consumption coefficient of Agriculture is 645(ton/ 10,000 yuan), which was reduced by 29% compared to 2002. The coefficient of Electricity and steam supply is 103.9 (ton/ 10,000 yuan), reduced by 74% compared to 2002. The efficiency of water use increased greatly.
products and nuclear fuel products, 12. Manufacture of chemical products, 13. Manufacture of non-metallic mineral products, 14. Manufacture of metal smelting and rolling, 15. Manufacture of metal products, 16. Manufacture of general and special equipment, 17. Manufacture of transport equipment, 18. Manufacture of electrical machinery and equipment, 19. Manufacture of communications equipment, computers and other electronic equipment, 20. Manufacture of instrumentation and office machinery products, 21. Other manufacturing 22. Waste recovery and management, 23. Electricity and steam supply, 24. Gas supply, 25. Water collection, treatment and supply 26. Construction, 27. Wholesale and retail trade, 28. Transport, warehousing and postal activities, 29. Accommodation and food service activities, 30. Information service activities, 31. Finance, 32. Estate, 33. Leasing and business services, 34. Scientific research, residential services and other services, 35. Education, 36. Health, social security and social welfare, 37. Culture, sports and entertainment, 38. Public administration and social organization.

Figure 1. Water direct consumption (ton/10,000 yuan)

The water direct consumption of Other manufacturing and Waste recovery and management increased in 2012 is due to the sector classification and water use data collection changes in the departments.

3.2.2 Department water complete consumption. The departments with the highest water complete consumption coefficient are Agriculture, Manufacture of food products and tobacco products, Electricity and steam supply, Manufacture of textile, Other manufacturing, Manufacture of wood products and furniture, Manufacture of wearing apparel and leather products, Information service activities, Manufacture of chemical products.

The departments with the highest water complete consumption and water direct consumption are quite different. The Manufacture of textile and Manufacture of food products and tobacco products have a large water complete consumption as intermediate inputs required a large amount of water.

Compared with 2002, most of department water complete consumption decreased gradually in 2012. Water complete consumption coefficient of Agriculture decreased by 16.4%. WCC of Manufacture of food products and tobacco products fell 27.3%, Production and supply of Electricity and steam supply decreased by 33.8%.

Figure 2. Water complete consumption (ton/10,000 yuan)

3.2.3 Water indirect consumption. The water indirect consumption can be calculated by comparing the WDC and WCC. The smaller the water use multiplier, the smaller the gap between WCC and WDC. The department of Agriculture and Electricity and steam supply, which have a high water direct consumption and a low water multiplier, utilize water resource directly, and the indirect effect on the water use of other department is only a little.

These departments including Manufacture of food products and tobacco products, Manufacture of textile, Manufacture of wearing apparel and leather products, Information service activities, have a low direct water consumption coefficient and a high water multiplier, which need to consume goods.
and services from other sectors to meet their own needs. They have more effect on water consumption by the indirect way.

![Water direct and indirect consumption (ton/10,000 yuan)](image)

*Except Agriculture.

**Figure 3.** Water direct and indirect consumption (ton/10,000 yuan)

4. Conclusion
A comparable non-competitive input-output table of 38 departments in China is completed. And an extended water input-output model is established by combining with the water resource consumption in departments. The model removes the price different of each year, and separates the influence of imported products on the national water consumption.

The nine departments with the highest water direct consumption is Agriculture, Electricity and steam supply, Other manufacturing, Manufacture of paper products and printing, education, sporting products, Non-metallic minerals and other mining, Metal mining and selecting, Manufacture of non-metallic mineral products, Education and Manufacture of chemical products.

The departments with the highest water complete consumption coefficient are Agriculture, Manufacture of food products and tobacco products, Electricity and steam supply, Manufacture of textile, Other manufacturing, Manufacture of wood products and furniture, Manufacture of wearing apparel and leather products, Information service activities, Manufacture of chemical products. With a high water multiplier, the departments of Manufacture of food products and tobacco products, Manufacture of textile, Manufacture of wearing apparel and leather products and Information service activities, have more effect on water consumption by the indirect way.

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