Gao and Yu *Economic Structures* (2018) 7:4
https://doi.org/10.1186/s40008-018-0104-4

Journal of Economic Structures

RESEARCH

Open Access

# Assessment of the economic impact of South-to-North Water Diversion Project on industrial sectors in Beijing

Yuning Gao and Miao Yu*

*Correspondence: yu-m14@mails.tsinghua.edu.cn
School of Public Policy and Management, Tsinghua University, Haidian District, Beijing 100084, China

**Abstract**

In order to address the serious water shortage problem in northern China, China has launched the South-to-North Water Diversion Scheme, which is a large-scale inter-basin water diversion project. With Beijing as an example and using input–output analysis, this paper analyzes the macroeconomic impact of the increased water supply on the affected areas in the industrial sector. Our empirical results show that the increased water supply has brought about direct economic benefits to Beijing, which had increased from RMB 4.39 billion in 2008 to RMB 55.99 billion in 2013. The estimated full value of economic benefits had increased from RMB 14.07 billion in 2008 to RMB 231.86 billion in 2013. In addition, management of water conservancy, environment and public facilities, and public management, social security and social organization are the two main industrial sectors which drive the most direct economical benefits. This paper also forecasts the impact of the South-to-North Water Division Project on Beijing's various industrial sectors by 2020. Based on our analysis, this paper puts forward policy recommendations to further improve the efficiency of water usage in Beijing.

**Keywords:** South-to-North Water Diversion, Input–output analysis, Water resources, Economic impact

## 1 Background

Beijing is a city with a shortage of water resources, and the water resource per capita is far below that of the lower limit of international water shortage. With rapid economic development and the improvement in living standards, the contradiction between the increasing demand for water and the shortage of water resources becomes increasingly pointed. It also becomes the main factor restricting the socioeconomic development of Beijing. Figure 1 shows the total water supply and structure of Beijing in 2008–2013. Since the beginning of South-to-North Water Diversion in 2008, the total volume of the South-to-North Water has grown to 0.32 billion cubic meters in 2013. Water diverted from the south to Beijing is mainly used for industrial and domestic purposes and to substitute the previously overexploited underground water. 0.3 billion cubic meters per year is being used as domestic water in the city center, substituting 0.2 billion cubic meters of water supplied by the Miyun reservoir and reducing the exploitation of underground water by 0.1 billion cubic meters. According to the General Plan for Beijing

Springer Open

© The Author(s) 2018. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

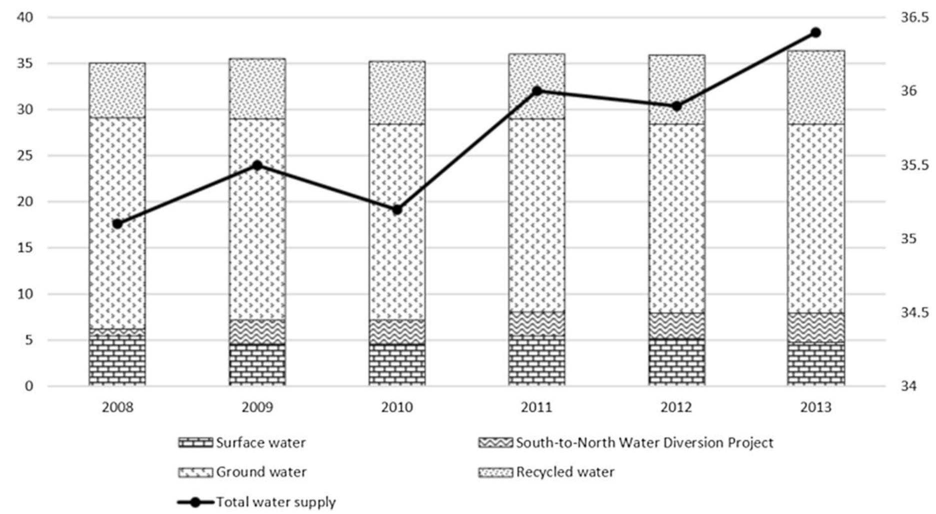


**Fig. 1** Total water supply and structure of Beijing in 2008–2013 (billion cubic meters). Data source, Statistical Yearbook of Beijing Water Affairs (2013)

South-to-North Water Diversion Auxiliary Project, it is estimated that 1.4 billion cubic meters of water will be diverted from the south to the north per annum after 2020, of which 1.256 billion cubic meters is for residential and industrial purposes, while 0.145 billion cubic meters is for the ecological environment. The aim is to reduce the exploitation of underground water by 0.4 billion cubic meters.

However, the macro-influence of increased water supply on the benefitting areas needs to be further analyzed. Analysis on the industrial sector, in particular, had been relatively weak and should be an area of focus. Using Beijing as an example, although the total water consumption of Beijing in recent years is basically unchanged, the South-to-North Water Project mainly substitutes the previously overexploited underground water and potentially increases the water level for the entire Beijing water system. How much economic benefit does the increased water volume bring? If the current industrial structure is maintained, how much economic benefit can 1.4 billion cubic meters of water bring by 2020? The following analysis tries to answer these questions.

One of the objectives of the South-to-North Water Diversion Project is to solve the unbalanced distribution of water resource spatially and regionally. The key to the problem is to resolve the water shortage of Beijing and Tianjin area, Hebei and Henan. The economic, social and environmental benefits of the South-to-North Water Diversion Project in the benefitting areas are the subject of concern for many researchers. There are a number of studies analyzing the rationale, economic, environmental and social implications of South-to-North Water Division (SNWD) Project (Ma et al. 2006; Shang et al. 2003; Shao and Wang 2003; Yang and Zehnder 2001). An important reason for the implementation of this project is the resulting environmental benefits (Yang and Zehnder 2005). Many studies have researched the economic impacts (Berkoff 2003; Berrittella et al. 2006; Fang et al. 2015; Hu et al. 2013; Lin et al. 2012; Moore 2014; the World Bank 2001), social impacts (Chang et al. 2011; Huang et al. 2011; Webber et al. 2017; Crow-Miller and Webber 2017) and environmental impacts (Liu 1998; Chen et al. 2013; Zhang 2009) of the SNWD project. Li and Xu (2004) established the macro-influence evaluation index system of South-to-North Water

Diversion and conducted quantitative and qualitative analyses on the macro-influence of South-to-North Water Diversion through the system using four dimensions, namely economy, society, environment and system. However, Wilson et al. (2017) pointed out that whether the SNWD project is economically beneficial depends largely on model assumptions, meaning that economic gains at the regional and national level are uncertain. To our best knowledge, most of these papers have focused on the economic impact of the SNWD project on the country as a whole. Feng et al. (2007) used water computable general equilibrium model to analysis the impacts of SNWD project. They found that the project will not only drive Beijing's sustainable development but also preserve Beijing's ecological vulnerability. However, during the operational period of the South-to-North Water Diversion Project, the macro-influence of increased water supply on the benefitting areas needs to be further analyzed. Analysis on the industrial sector, in particular, is relatively weak and should be an area of focus. The post-water transfer economic effects of the South-to-North Water Diversion Project will influence the local economic development that results from increased water resources in the benefitting area, that is, the contribution and function of the transferred water for the economic activities in the benefitting areas. The social production output of water-dependent industries in the benefitting areas will be altered due to the increased supply of available water. This will result in the alteration of production achievement and will be directly reflected in regional GDP changes. To evaluate the effect of the South-to-North Water on the economic benefit of Beijing, it is necessary to discuss the change in Beijing's total water supply change due to the South-to-North Water Diversion Project, the economic influence on the regional economy and subdivision industrial sectors, as well as the distribution method of water diversion economic effect in sectors.

At present, the research on water resources with input–output technique has become an important research direction, and this is also the research method in this paper. Stoevener and Castle (1965) were the first to apply the input–output model and benefit–cost analytical method to water resource research. Carter and Ireri (1970) proposed to study river water utilization and distribution of Colorado in California and Arizona through the inter-regional input–output model. Thoss and Wiik (1974) proposed to study the economic development and pollution management with the general input–output model, combine the input–output technique with mathematical programming and calculate the shadow price for discharge and governance of water resources and wastewater. Bouhia (1998) proposed to fuse water resources in the input–output model. Sánchez-Chóliz and Duarte (2000) analyzed the economic influence of increased irrigation areas in the Spanish Ebro drainage basin using the input–output technique. Velazquez (2006) put forward a water resource consumption input–output model based on the extended input–output model, productivity variables and water consumption. The model distinguishes the direct consumption areas from the indirect consumption areas of water resources in the economic system for the analyses of production potential and water resource consumption within the economic system. Guan and Hubacek (2007) established the optimization model of regional water environment economic system and provided quantitative descriptions of each of the relationships between economic development and water resources, water pollution and water pollution governance investment. Wang et al. (2009) studied cases of water shortage in drought regions and having found that Zhangye had been confronted with severe water shortage, suggested to distinguish between industrial direct and indirect water deprivation. Wang then provided the quantitative relationship between water resources and other industries and explained the leading position of water resources through theoretical and quantity indexes. Results from the recent studies above indicated that the distinction of industrial direct water deprivation and total water deprivation is the precondition for the optimization management of water resources. Furthermore, the estimation in the current literature of the water output elasticity in China is rarely seen. Wang and Lall (2002) estimated the water consumption output elasticity of different industries through Chinese enterprise data. This paper also estimates the water consumption output elasticity in Beijing and enriches the research in this aspect. The remaining content of this paper is as follows: Sect. 2 introduces the research model and parameter estimation method in this paper, Sect. 3 introduces the economic benefit evaluation of South-to-North Water Diversion in Beijing and Sect. 4 introduces the main conclusion and policy suggestions in this paper.

## 2 Research model

### 2.1 Model building

To understand the influence of increased water resources on Beijing's economic development, we will first calculate the water consumption input–output table of all sectors using the input–output table of Beijing. This is followed by an analysis of the additional output of all key industrial sectors in Beijing resulting from the increased water volume, by calculating the direct value-added output coefficient and total value-added output coefficient of water consumption in all sectors. Lastly, we summarize the total benefit of South-to-North Water Diversion on Beijing's economy.

Based on the above consideration, the direct economic influence ($\mathrm{GDP_D}$) of South-to-North Water Diversion on Beijing is calculated in the following ways:

$$\mathbf{GDP}_{\boldsymbol{D}} = \mu\mathbf{W} \tag{1}$$

where $\boldsymbol{\mu} = \rho\boldsymbol{\theta}\mathbf{A}/2$ refers to the row vector of water consumption direct value-added output coefficient. Element $\mu_i$ refers to the value-added per unit water usage of sector $i$ and reflects the direct economic benefit of sectional production. $\rho$ refers to the water production elasticity, that is, the quantitative increment correlated with the increase of 1 $\mathrm{m}^3$ total output of water consumption. $\boldsymbol{\theta}$ is the row vector of water consumption value-added of all sectors, wherein the element $\theta_i$ refers to the unit water consumption value-added of sector $i$ and $\mathbf{A}$ refers to the direct consumption coefficient matrix of water resources. $\mathbf{W}$ refers to the column vector of water consumption of South-to-North Water diverted to all industrial sectors.

When considering the economic relation between sectors, the contribution made by increased water supply to GDP from the perspective of the whole economic system needs to be examined, or the total economic influence ($\mathrm{GDP_T}$) of the South-to-North Diversion Water needs to be calculated, as shown in Eq. (2):

$$\mathbf{GDP}_{\boldsymbol{T}} = \boldsymbol{\gamma}\mathbf{W} \tag{2}$$

where $\boldsymbol{\gamma} = \rho\boldsymbol{\theta}\mathbf{B}/2$ refers to the row vector of the water consumption total value-added output coefficient and the element $\gamma_i$ is the quantitative change value of the whole system value-added correlated with an increase or decrease of 1-unit water consumption in a certain sector. The definitions of $\rho$, $\boldsymbol{\theta}$ and $\mathbf{W}$ are the same as above, and $\mathbf{B}$ refers to the complete consumption coefficient matrix of water resources.

### 2.2 Parameter estimation

Next, we calculate the water consumption of all sectors in Beijing and the values of $\rho$, $\boldsymbol{\theta}$, $\mathbf{A}$ and $\mathbf{B}$ based on the actual situation in Beijing. This is followed by the calculation of water consumption direct value-added output coefficient and complete value-added output coefficient of Beijing.

Firstly, to calculate the water consumption of all sectors in Beijing, this paper considers the water consumption of all sectors and the availability of water consumption data based on the sector category in Beijing 42 * 42 input–output table in 2007 and 2010. All related sectors are merged and the total value of the industrial sectors after treatment is 30. The principles for the merger of all sectors are as follows: (1) Primary industries are merged into one sector. (2) For secondary industries, handiwork and other manufacturing industries as well as waste products and materials are integrated into "other industries," with 23 sectors in total. (3) For tertiary industries, this research divides the service sector into the following categories: transportation, storage and post, wholesale and retail, hotels and catering services, renting and leasing business services, management of water conservancy, environment and public facilities, education, health, social security and social welfare, culture, sports and entertainment, public management and social organization and other service industries (including postal services, information transmission, computer service and software industry, financial industry, real estate, research and development industry, synthesis technique service industry, neighborhood services and other service industries). Classification is based on the water consumption data of the tertiary industrial sectors provided by the Beijing Water Authority.

Using the total water consumption of Beijing and the water consumption of all sectors as control data, and with the assumption that the water consumption structure of Beijing industrial sectors is identical to that of the whole country, we adjust and calculate the water consumption of industrial sectors in Beijing from 2008 to 2013 based on the *China's Statistic Yearbook*, *Beijing Water Resources Bulletin* (2008–2013), Research Group of China Input–Output Association (2007) and the data and research conclusion of Wang et al. (2008). Based on the water consumption of all industrial sectors in Beijing, we find that water consumption differs greatly for different industrial sectors. In particular, the water consumption of the agricultural sector, which had been consistently high, now shows a downwards trend (reduced from 1.2 billion cubic meters in 2008 to 0.909 billion cubic meters in 2013). The increment of the agricultural production value shows the increased water consumption efficiency of the agricultural sector. The total water consumption of industrial sector is reduced year on year, since Beijing readjusts the industrial structure every year and shuts down industries which consume a lot of water and energy. The annual water consumption of the service sector is relatively stable and water consumption efficiency is increasing year on year. Sectors can be categorized into high-water-consumption sectors (direct water consumption of more than 30 million tons), medium-water-consumption sectors (direct water consumption between 8 and 30 million tons) and low-water-consumption sectors (direct water consumption below 8 million tons) according to the actual water consumption of the sector; see Table 1.

**Table 1 Categorization of water consumption sector (take 2013 as the example)**

| Category | Sectors |
|---|---|
| High-water-consumption sector | Agriculture, manufacture of foods and tobacco, processing of petroleum, coking, processing of nuclear fuel, chemical industry, smelting and rolling of metals, production and processing industry of electric and thermal power, construction, wholesale and retail trades, hotels and catering services, management of water conservancy, environment and public facilities, education and public management and social organization |
| Medium-water-consumption sector | Coal mining and washing, metal separation, manufacture of textile, papermaking and stationery manufacturing, manufacture of communication equipment, computer and other electronic equipment, culture, sports and entertainment, renting and leasing business services, health, social security and social welfare |
| Low-water-consumption sector | Extraction of petroleum and natural gas, mining of nonmetal ores, manufacture of garment/feather/down feather and other fiber products, processing of timbers and manufacture of furniture, manufacture of nonmetallic mineral products, manufacture of metal products, manufacture of general purpose and special purpose machinery, manufacture of transport equipment, manufacture of electrical machinery and equipment, manufacture of measuring instruments and machinery for cultural activity and office work, production and distribution of gas, production and distribution of water, other industries, transport, storage and post |

Secondly, the decomposition of inputs into capital ($K$), labor ($L$), energy ($E$) and intermediate materials ($M$) was applied by Jorgenson et al. (1987). In this paper, in order to calculate the output elasticity $\rho$ of water, we use water as an intermediate material, which as the capital and the labor force of the Cobb–Douglas production function, so as to calculate the output elasticity of water. To be specific, the three-element production function can be calculated as follows:

$$Z = AK^{\alpha}L^{\beta}W^{1-\alpha-\beta} \tag{3}$$

where $Z$, $L$ and $K$ represent output, labor force and capital, respectively. $W$ represents water resource and $A$ represents coefficient of technical efficiency. $\alpha$ and $\beta$ represent output elasticity of the labor force and that of the capital, respectively. After linearization to the above equation through natural logarithm, we attain:

$$\ln\left(\frac{Z}{W}\right) = \ln A + \alpha \cdot \ln\left(\frac{K}{W}\right) + \beta \cdot \ln\left(\frac{L}{W}\right) \tag{4}$$

Using Eq. (4), we conduct regressive calculation of Beijing's data from 2002 to 2013 and estimate $\alpha$ and $\beta$.[1] The data are sourced from the *Statistical Yearbook of Beijing* over the years.

Water output elasticity $\rho$ over the years can be determined using Eq. (5), the results of which is shown in Table 2:

$$\rho_t = \left\{\ln(Z_t) - \ln A - \alpha \ln(K_t) - \beta \ln(L_t)\right\} \Big/ \ln(W_t) \tag{5}$$

[1] After verification of the steadiness of by ADF, the regression result is that the labor output elasticity $\alpha = 0.772$, the capital output elasticity $\beta = 0.119$ and the model's overall verification $= 0.998$, $D.W. = 0.924$; $F = 1905.399$, sig $= 0.000$.

**Table 2 Water output elasticity over the years**

| 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| 8.2% | 8.8% | 9.3% | 9.3% | 9.1% | 8.9% |

Thirdly, we calculate the unit water output coefficient $\theta_{it}$ of industrial departments. Coefficients of various industrial departments' water output are their unit water outputs, which can be considered as the reciprocal of the water consumption volume per RMB 10,000 GDP. This can be calculated by dividing various industrial departments' water consumption volumes using their added value through the input–output table, as shown in Eq. (6):

$$\theta_{it} = \overline{\mathrm{GDP}_{it}} \Big/ \overline{\mathrm{TW}_{it}^{\mathrm{Beijing}}} \tag{6}$$

As the government of Beijing only published the input–output table for the year of 2007 and 2010, various departments' added value in other years can be derived using the following method: (1) For the year of 2007 and 2010, the data in the input–output table are used directly. (2) Various departments' added value in 2008, 2009, 2011, 2012 and 2013 are derived through adjustment from relevant data in the *Statistical Yearbook of Beijing*. Unit water output coefficients of various departments can be derived with the help of their individual water consumption volumes.

In addition, the water's direct consumption coefficient matrix is derived on the basis of the ordinary value type input–output table. Sector $j$ produces the unit product by direct consumption of sector $i$'s product volume, which is referred to as sector $j$'s direct consumption coefficient to sector $i$, represented by $a_{ij}$:

$$\boldsymbol{a_{ij}} = \frac{\boldsymbol{X_{ij}}}{\boldsymbol{X_j}} \quad \left(i, j = 1,\ 2,\ 3, \ldots, 30\right) \tag{7}$$

where $\boldsymbol{X_j}$ is sector $j$'s added value and $\boldsymbol{X_{ij}}$ is sector $i$'s input of added value to sector $j$. Direct consumption coefficient matrix **A** is the 30-order matrix comprised of various departments' direct consumption coefficients. The water's complete consumption coefficient is the sum of the total direct consumption coefficient and the total indirect consumption coefficient. Based on the direct consumption coefficient matrix, the water's complete consumption coefficient matrix **B** is calculated through the Leontief matrix.

Lastly, based on the foregoing built model, the water direct value-added output coefficient and the water complete value-added output coefficient of Beijing's various industrial departments are derived as shown in Table 3.

Based on the water direct value-added output coefficients of Beijing's various industrial departments, the water output effect of different industrial departments varies significantly. If the water direct value-added output coefficient is used as a basis for classification, then we can categories the industrial departments into: high-output departments (output coefficient above 200 yuan/$m^3$), medium-output departments (output coefficient between RMB 100–200/$m^3$) and low-output departments (output coefficient below RMB 100/$m^3$). The categories reflect the efficiency of various industrial

**Table 3 Water direct and water complete value-added output coefficients (RMB/m$^3$)**

| Sectors | Water direct value-added output coefficient | | Water complete value-added output coefficient | |
|---|---|---|---|---|
| | 2008 | 2013 | 2008 | 2013 |
| AFA | 27.56 | 103.55 | 133.54 | 519.74 |
| MWC | 42.78 | 161.43 | 229.29 | 946.33 |
| PNG | 91.54 | 120.03 | 225.46 | 507.62 |
| MMO | 44.44 | 79.27 | 137.13 | 691.85 |
| MNO | 85.24 | 334.74 | 267.51 | 1018.79 |
| MFT | 51.37 | 136.36 | 191.18 | 663.34 |
| MAT | 40.35 | 96.4 | 159.62 | 582.65 |
| TFC | 41.66 | 101.75 | 148.13 | 564.2 |
| TMF | 76.29 | 164.72 | 252.84 | 745.3 |
| PPA | 48.97 | 106.93 | 190.09 | 552.72 |
| PCN | 85.96 | 183.17 | 316.48 | 719.51 |
| CHI | 38.19 | 127.03 | 161.48 | 658.81 |
| NMP | 65.47 | 215.39 | 254.73 | 892.11 |
| SRM | 29.6 | 109.83 | 191.58 | 813.92 |
| MMP | 45.36 | 110.79 | 209.62 | 725.8 |
| GSM | 160.19 | 237.83 | 369.02 | 822.06 |
| MTE | 157.46 | 379.79 | 454.27 | 1237.95 |
| EME | 136 | 247.17 | 350.35 | 859.63 |
| CCO | 171.59 | 164.61 | 545.74 | 864.8 |
| MCO | 243.32 | 254.76 | 526.91 | 816.43 |
| PEH | 20.22 | 114.8 | 116.84 | 725.89 |
| PDG | 26.28 | 313.87 | 73.76 | 892.56 |
| PDW | 95.88 | 193.11 | 259.57 | 810.98 |
| OTI | 35.11 | 124.98 | 195.15 | 726.01 |
| CON | 67.67 | 187.36 | 242.69 | 825.63 |
| TSP | 94.29 | 381.09 | 265.63 | 1081.56 |
| WRT | 57.33 | 187.98 | 163.23 | 573.46 |
| HCS | 37.74 | 129.44 | 144.38 | 607.38 |
| RLB | 89.77 | 231.42 | 257.52 | 790.51 |
| WEP | 45.4 | 143.78 | 172.88 | 655.91 |
| EDU | 41.76 | 91.05 | 142.34 | 380.57 |
| HSS | 34.15 | 79.96 | 156.98 | 544.21 |
| CSE | 61.9 | 155.41 | 193.21 | 584.71 |
| PMS | 58.88 | 173.1 | 173.7 | 661.86 |
| OTS | 82.65 | 186.36 | 244.65 | 619.55 |

departments in terms of direct water consumption. Table 4 describes the direct water consumption efficiency of various industrial departments in 2013.

## 3 Evaluation of economic benefits of South-to-North Water Diversion Project to Beijing

### 3.1 Economic benefit of South-to-North Water Diversion to Beijing during 2008–2013

Annual volume of water distributed to Beijing by the South-to-North Water Diversion during 2008–2013 is 70 million tons, 260 million tons, 255 million tons, 260 million tons, 280 million tons and 351 million tons, respectively. Distributed water was mainly

**Table 4 Various industrial departments' direct water consumption efficiency (for the year 2013 as an example)**

| Category | Departments |
|---|---|
| High-output departments | Mining and separating of nonmetal ores and other ores, manufacturing of nonmetallic mineral products, manufacturing of general purpose and special purpose machinery, manufacturing of transport equipment, manufacturing of electronic machinery and apparatus, manufacturing of measuring instruments and machinery for cultural activity and office work, production and distribution of gas, other industrial, scientific and technical services |
| Medium-output departments | Mining and washing of coal, extraction of petroleum and natural gas, mining of metal ores, manufacturing of foods and tobacco, processing of timbers and manufacturing of furniture, processing of petroleum, coking, processing of nuclear fuel, chemical industry, smelting and rolling of metals, manufacturing of metal products, manufacturing of communication equipment, computer and other electronic equipment, production and supply of electric power and heat power, production and distribution of water, construction, commercial services, hotels and catering services, public management, other services |
| Low-output departments | Agriculture, manufacture of textile, textile/garment/shoe/hat/feather and their manufacture, papermaking, printing and manufacture of articles for culture, education and sports activities, education and sport activities |

introduced to the domestic sector, and their GDP output effect is mainly reflected in the domestic sector. Although the water of South-to-North project is mainly supplied to urban residents as drinking water according to the principle of "Drinking, Supplement and Storage," it actually indirectly increases the volume of domestic water if we were to consider the water supply of Beijing as a whole. Therefore, the economic benefit of increased water supply in the construction industry and the service industry can be used to estimate the economic benefit of South-to-North Water Diversion during this period.

According to Eqs. (1) and (2), direct economic benefit and comprehensive economic benefit of South-to-North Water Diversion during 2008–2013 to Beijing GDP can be derived, as shown in Table 5.

This shows that, although the annual water supply from the South-to-North Water Diversion during 2008–2013 is less than 300 million $m^3$, it has a significant contribution

**Table 5 Direct and comprehensive economic benefits of South-to-North Water Diversion to Beijing (unit RMB 100 million)**

| Sectors | Direct economic benefit | | Comprehensive economic benefit | |
|---|---|---|---|---|
| | 2008 | 2013 | 2008 | 2013 |
| CON | 2.68 | 36.49 | 9.6 | 160.8 |
| TSP | 0.69 | 9.82 | 1.94 | 27.88 |
| WRT | 1.11 | 35.52 | 3.16 | 108.37 |
| HCS | 2.21 | 51.84 | 8.46 | 243.29 |
| RLB | 1.43 | 35.32 | 4.11 | 120.66 |
| WEP | 6.26 | 194.6 | 23.82 | 887.77 |
| EDU | 2.29 | 31.88 | 7.8 | 133.26 |
| HSS | 0.73 | 12.25 | 3.35 | 83.34 |
| CSE | 0.46 | 7.1 | 1.45 | 26.73 |
| PMS | 4.65 | 88.85 | 13.73 | 339.74 |
| OTS | 21.38 | 56.18 | 63.29 | 186.78 |
| Total | 43.89 | 559.88 | 140.72 | 2318.62 |

to the economy of Beijing. (1) During this period, according to the principle of "Drinking, Supplement and Storage," South-to-North Water Diversion was mainly supplied to the construction industry and the service industry, and the direct economic benefits brought about by the increased water supply to Beijing are RMB 4.389 billion (2008), RMB 18.697 billion (2009), RMB 30.056 billion (2010), RMB 37.519 billion (2011), RMB 39.661 billion (2012) and RMB 55.988 billion (2013), respectively, of which two industries [(i) management of water conservancy, environment and public facilities, and (ii) public management and social organizations] have the largest driving effect to the economy. (2) During this period, the comprehensive benefits generated by South-to-North Water Diversion are estimated to be RMB 14.072 billion (2008), RMB 58.767 billion (2009), RMB 129.377 billion (2010), RMB 160.718 billion (2011), RMB 159.635 billion (2012) and RMB 231.862 billion (2013), respectively.

### 3.2 Economic benefit of South-to-North Water Diversion to Beijing in 2020

With increased water supply from the South-to-North Water Diversion Project, there will be a gradual increase in volume of redistributed water supplied to industrial production departments rather than to urban residents. Therefore, it is necessary to estimate the economic benefits of South-to-North Water Diversion to all of Beijing's industrial departments up to the year of 2020. This requires estimation of Beijing's population and economic aggregate in 2020.

Based on the *Overall Urban Planning of Beijing* (2004–2020), the predicted per capita GDP of Beijing in 2020 is USD 10,000, and the population in 2020 is 18 million. However, Beijing had exceeded these planned objectives as early as in 2009. Apparently, these figures cannot be used as a basis for the prediction of Beijing's economy scale in 2020. In order to predict the economic volume of Beijing in 2020, this article provides estimation on the basis of publicly released government papers and research results. This article predicts that the per capita GDP of Beijing in 2020 will be up to USD 20,000.[2] *Investigation Report of Promoting Coordinated Development of Capital Population and Resource Environment* (2010) completed by the CPPCC organization of Beijing, estimates based on Beijing's permanent resident population at the end of 2009 and annual population growth rate during the period of 11th Five-year Plan that the permanent resident population of Beijing in 2020 will be 25 million. Based on above two predicted figures, and according to the current exchange rate (USD 1 = RMB 6.19), we estimate that the GDP of Beijing in 2020 will be RMB 3095 billion.

In recent years, the proportion of Beijing's primary industry has minor variations, at approximately 1%. Therefore, we assume that the proportion of Beijing's primary industry will remain at 1% in 2020. For the secondary industry, we apply the proportion data during 2008–2014 which has minor variation and is in the closest period to 2020. Using the linear trend extrapolation method, we calculate that the proportion of the secondary industry in 2020 is 19.63%, while that of the tertiary industry is 79.37%. It is further calculated that the added value of the primary, secondary and tertiary industries in 2020 is RMB 30.95 billion, RMB 607.55 billion and 2456.5 billion, respectively. In order to simplify the calculation result, we assume that the departmental structure across these

[2] In 2013, Wang Anshun, the acting mayor of Beijing at that time, announced in the 14th People's Congress of Beijing that the per capita GDP of Beijing will reach USD 20,000 by 2020.

industries remains constant from 2013 to 2020. As Beijing's industrial structure is being constantly adjusted to improve the proportion of high-end services, the water consumption per RMB 10,000 GDP is dropping at 4% substantially. Therefore, it is reasonable to believe that this assumption has underestimated the contribution of water to GDP to a certain extent. Estimation and calculation of the added value of Beijing's various industrial departments are shown in the first column of Table 6.

In order to simulate the water demand structure of 2020, this article estimates water consumption volume of various industrial departments based on Beijing's water consumption trend and currently available data. In 2012, the government of Beijing released the *Opinion about Implementing the Strictest Water Resource Management System*, in which it plans to control the total water consumption of Beijing below 4.658 billion $m^3$ by 2020, reduce the water consumption per RMB 10,000 industrial added value to below 10 $m^3$, and increase the efficient utilization rate of agricultural irrigation water to above 0.71. The estimation process of agricultural water, industrial water and service water is as follows: (1) Estimated value of agricultural water: Beijing Agricultural Water Conservation Working Conference convened on May 16, 2014, and announced that Beijing plans to reduce agricultural water to 500 million $m^3$ by 2020. This is substantially consistent with the estimated value from linear external expansion of the agricultural water data during 2008–2013. (2) Estimation of industrial water: According to the estimation made above, the total industrial output value by 2020 is estimated to be RMB 607.55 billion, and the industrial departments' water consumption will be 607.6 million $m^3$ according to the high benchmark of 10 $m^3$ water consumption per RMB 10,000 industrial added value. (3) Estimation of service water: Due to lack of relevant data, in order to simplify analysis, this article assumes that the water consumption per RMB 10,000 added value of the service industry is equal to that of 2013; thus, it is estimated that the water consumption of service departments in 2020 will be 1.115 billion $m^3$ according to the total service output value of RMB 2456.5 billion estimated above. With constant improvement in technology, the water consumption per RMB 10,000 added value of the service industry should be reduced accordingly. Hence this estimated value might have overestimated the service industry's water consumption in 2020 (underestimated its output efficiency). However, in order to simplify the calculation process, we assume that the water consumption structures of various industrial departments of Beijing in 2020 and 2010 are identical; thus, the water consumption of these industries in 2020 is derived as shown in column 2 of Table 6.

In order to calculate the water added value output coefficient, we first calculate that the output elasticity of water resources in 2020 is, on this basis we estimate the unit water added value, water direct added value output coefficient and water comprehensive added value output efficient of Beijing's industrial departments in 2020, as shown in column 3–5 of Table 6.

According to the *Beijing Water Resource Deployment Planning of the South-to-North Water Diversion*, the South-to-North Water Division Project's water supply to Beijing will be up to 1.4 billion $m^3$ by 2020, of which 145 million $m^3$ will be introduced to the environment and the remaining will be introduced to industries, construction and services. Using this water supply as control data and assuming the water consumption structures in 2010 and 2020 are identical, we calculate the water volume supplied by the South-to-North Water Diversion to industries, construction and services, and use these

**Table 6 Data of various departments of Beijing and GDP influence of South-to-North Water Diversion on these departments in 2020**

| Sectors | Added value (100 million $m^3$) | Water consumption of various departments (100 million $m^3$) | Unit water added value ($RMB/m^3$) | Water distributed to various departments from South-to-North Water Diversion (100 million $m^3$) | Water direct added value output coefficient ($RMB/m^3$) | Direct effect of GDP influence value of South-to-North Water Diversion (RMB 100 million) | Water complete added value output coefficient ($RMB/m^3$) | Complete effect of GDP influence value of South-to-North Water Diversion (RMB 100 million) |
|---|---|---|---|---|---|---|---|---|
| MWC | 173.42 | 0.2 | 0.08 | 0.19 | 174.99 | 16.47 | 1030.04 | 96.95 |
| PNG | 130.15 | 0.1 | 0.23 | 0.05 | 132.5 | 3.25 | 556.59 | 13.64 |
| MMO | 70.72 | 0.2 | 0.042 | 0.14 | 88.81 | 6.41 | 762.55 | 55.02 |
| MNO | 115.74 | 0 | 0.82 | 0.01 | 364.73 | 2.23 | 1111.68 | 6.79 |
| MFT | 301.8 | 0.4 | 0.079 | 0.33 | 147.82 | 24.52 | 722.38 | 119.83 |
| MAT | 14.4 | 0.2 | 0.008 | 0.16 | 103.46 | 8.25 | 631.98 | 50.42 |
| TFC | 79.03 | 0 | 0.181 | 0.04 | 109.92 | 2.07 | 612.29 | 11.55 |
| TMF | 30.44 | 0 | 0.454 | 0.01 | 184.25 | 0.53 | 819.83 | 2.37 |
| PPA | 143.78 | 0.3 | 0.052 | 0.24 | 115.79 | 13.9 | 601.93 | 72.28 |
| PCN | 232.75 | 0.9 | 0.027 | 0.74 | 199.5 | 73.78 | 785.51 | 290.5 |
| CHI | 541.78 | 1.4 | 0.038 | 1.23 | 138.08 | 84.58 | 719.1 | 440.48 |
| NMP | 147.88 | 0 | 0.445 | 0.03 | 241.52 | 3.47 | 981.39 | 14.11 |
| SRM | 18.85 | 0.8 | 0.002 | 0.68 | 120.45 | 41.18 | 893.66 | 305.5 |
| MMP | 113.5 | 0 | 0.377 | 0.03 | 121.96 | 1.59 | 796.07 | 10.37 |
| GSM | 407.24 | 0 | 1.523 | 0.02 | 270.38 | 3.13 | 912.87 | 10.55 |
| MTE | 791.53 | 0.1 | 1.508 | 0.05 | 445.76 | 10.12 | 1417.95 | 32.18 |
| EME | 212.47 | 0 | 1.421 | 0.01 | 282.79 | 1.83 | 956.56 | 6.19 |
| CCO | 331.97 | 0.1 | 0.284 | 0.1 | 184.42 | 9.33 | 952.73 | 48.2 |
| MCO | 93.16 | 0 | 1.311 | 0.01 | 290.12 | 0.89 | 907.69 | 2.79 |
| PEH | 874.95 | 1.3 | 0.067 | 1.13 | 129.2 | 73.1 | 801.48 | 453.44 |
| PDG | 57.81 | 0 | 1.167 | 0 | 341.83 | 0.73 | 974.68 | 2.09 |

**Table 6 continued**

| Sectors | Added value (100 million $m^3$) | Water consumption of various departments (100 million $m^3$) | Unit water added value ($RMB/m^3$) | Water distributed to various departments from South-to-North Water Diversion (100 million $m^3$) | Water direct added value output coefficient ($RMB/m^3$) | Direct effect of GDP influence value of South-to-North Water Diversion (RMB 100 million) | Water complete added value output coefficient ($RMB/m^3$) | Complete effect of GDP influence value of South-to-North Water Diversion (RMB 100 million) |
|---|---|---|---|---|---|---|---|---|
| PDW | 13.19 | 0.1 | 0.023 | 0.05 | 213.73 | 5.41 | 891.56 | 22.57 |
| OTI | 40.7 | 0 | 0.552 | 0.01 | 137.92 | 0.44 | 795.14 | 2.54 |
| CON | 1138.24 | 0.6 | 0.193 | 0.39 | 209.74 | 40.5 | 909.8 | 175.66 |
| TSP | 1448.35 | 0.1 | 1.854 | 0.05 | 410.22 | 10.48 | 1177.96 | 30.11 |
| WRT | 3888.7 | 0.6 | 0.679 | 0.37 | 200.23 | 37.51 | 620.85 | 116.31 |
| HCS | 614.35 | 1.2 | 0.051 | 0.79 | 140.27 | 55.7 | 662.41 | 263.03 |
| RLB | 2518.71 | 0.5 | 0.545 | 0.3 | 249.95 | 37.82 | 860.69 | 130.23 |
| WEP | 185.22 | 4.1 | 0.005 | 2.68 | 152.11 | 204.11 | 714.33 | 958.49 |
| EDU | 1242.8 | 1.1 | 0.117 | 0.69 | 98.03 | 34.03 | 414.53 | 143.9 |
| HSS | 682.05 | 0.5 | 0.147 | 0.3 | 88.07 | 13.37 | 595.68 | 90.44 |
| CSE | 729.91 | 0.1 | 0.527 | 0.09 | 168.15 | 7.62 | 637.57 | 28.9 |
| PMS | 979.72 | 1.6 | 0.063 | 1.02 | 185.3 | 94.29 | 719.01 | 365.88 |
| OTS | 12,275.21 | 0.9 | 1.344 | 0.6 | 202.68 | 60.57 | 677.26 | 202.41 |
| Total | 30,640.5 | 17.4 | | 12.55 | | 983.22 | | 4575.72 |

derived values to further calculate water supply's output effect to various departments of Beijing and the overall benefit to Beijing's economy.

As observed from the above table, by 2020:

1. During the water division operation period of the South-to-North Water Diversion middle route project, water distributed to Beijing during Phase I of the project is 1.4 billion $m^3$, in which the water consumption by industries, construction and services after exclusion of environment water consumption is 526 million $m^3$, 39 million $m^3$ and 691 million $m^3$, respectively.
2. Water supply from the South-to-North Water Diversion actually results in increased water consumption of Beijing's total economic system. As estimated, the direct economic benefit of the water supply from South-to-North Water Diversion Project to Beijing will be RMB 38.72 billion by 2020, while the comprehensive economic benefit will be RMB 207.04 billion. Direct economic benefit to the construction industry will be RMB 4.05 billion, while the comprehensive economic benefit will be RMB 17.57 billion. Direct economic benefit to the service industry will be RMB 55.55 billion, while the comprehensive economic benefit will be RMB 232.97 billion.
3. In terms of the industry, industrial departments with major direct economic benefit are chemical industry, production and supply of electric power and heat power, processing of petroleum, coking, processing of nuclear fuel, smelting and rolling of metals, manufacturing of foods and tobacco. The proportion of their total direct economic benefit is 76.74%, and the proportion of their total comprehensive economic benefit is 77.75%, which are basically proportional to the five departments' water consumption. On the other hand, departments with higher-water-output effect of Beijing include manufacturing of transport equipment, mining of nonmetal ores, manufacturing of electrical machinery and instrument, manufacturing of instrument, apparatus and cultural and office work machinery, and production and supply of gas. The proportion of these five departments' total direct economic benefit is only 4.08%, which the proportion of their total comprehensive economic benefit is 2.42%, which are minor proportions.
4. In terms of the services, service departments with major direct economic benefit are management of water conservancy, environment and public facilities, public management and social organization, hotels and catering services, renting and leasing business services. The proportion of these four departments' total direct economic benefit is 70.55%. Two of the above, namely the management of water conservancy, environment and public facilities, and public management and social organization, have higher-water-output effect, and the direct economic benefit of these two departments is RMB 29.84 billion, while the proportion of their total direct economic benefit is 53.72%. However, total water consumption for management of water conservancy, environment and public facilities accounts for 38.8% of the total service industry's water consumption, and the proportion of its direct economic benefit is 36.74%.

## 4 Conclusion and policy recommendation

In this article, we research and find that the direct economic benefit brought about by the increase in South-to-North Water Diversion to Beijing has grown from 4.389 billion in 2008 to RMB 55.988 billion in 2013. The comprehensive economic benefit generated therefrom is estimated to have increased from RMB 14.072 billion in 2008 to RMB 231.862 billion in 2013, in which the management of water conservancy, environment and public facilities, and the public management and social organization have the largest driving effect to the economy. It is also predicted in this article that, by 2020, the direct economic benefit and the comprehensive economic benefit generated by the South-to-North Water Diversion to Beijing's industry will be RMB 38.72 billion and RMB 207.04 billion, respectively. Direct economic benefit to the construction industry will be RMB 4.05 billion, while the comprehensive economic benefit will be RMB 17.57 billion. Direct economic benefit to the service industry will be RMB 55.55 billion, while the comprehensive economic benefit will be RMB 232.97 billion.

The South-to-North Water Diversion middle route project will play a vital role in maintaining Beijing's sustainable economy development. Beijing is in great shortage of water resources and is heavily dependent on the overexploitation of underground water to sustain its economic development. Water resource is increasingly becoming an economic constraint to Beijing. South-to-North Water Diversion Project will lead to significant benefits toward Beijing socio-economy and environment. In particular, without influencing domestic and industrial water consumption of Beijing, the project reduces underground water overexploitation, allowing the gradual restoration of underground water level and underground water reserve.

Based on the research, we propose the following policy recommendations: First of all, governmental departments should strictly enforce various water conservation measures across the entire society, control governmental and enterprise investment and consumption impulses, avoid making blind investments in enterprises or projects with enormous water consumption, and gradually shut down enterprises or projects with major dependence on underground water and even pollution to underground water. Secondly, under the current water consumption trend, comprehensive consideration of departmental water consumption, departmental water output efficiency and departmental water multiplication effect should be given to the industrial structure adjustment and optimization. Thirdly, the industrial structure of services should be optimized when further increasing the proportion of the service industry. As different industries' marginal effect to the economic system varies, increasing water supply to industries with a higher comprehensive added value output coefficient will generate higher benefits to the national economic system. Fourthly, a water consumption monitoring system should be established to introduce statistics and analysis of industrial water consumption to economic census, spot check and statistical work.

**Authors' contributions**
The authors wish to declare that the article was written in collaboration with each author contributing half of the article. Both authors read and approved the final manuscript.

**Competing interests**
The authors declare that they have no competing interests.

**Availability of data and materials**
The dataset supporting the conclusions of this article is available in and bought from *Statistical Yearbook of Beijing*, *Statistical Yearbook of Beijing Water Affairs*, Beijing, 42 * 42 input–output table.

**Consent for publication**
Not applicable.

**Ethics approval and consent to participate**
Not applicable.

**Funding**
Funding was provided by National Natural Science Foundation of China (Grant No. 71733003), Tsinghua University Independent Study Plan (Grant No. 20151080359) and Tsinghua University Humanity and Social Science Revitalization Fund (Grant No. 20145081013).

## Appendix: Abbreviation of sectors of input–output table

| | |
|---|---|
| AFA | Agriculture, forestry, animal husbandry and fishery |
| MWC | Mining and washing of coal |
| PNG | Extraction of petroleum and natural gas |
| MMO | Mining of metal ores |
| MNO | Mining and processing of nonmetal ores and other ores |
| MFT | Manufacture of foods and tobacco |
| MAT | Manufacture of textile |
| TFC | Manufacture of textile wearing apparel, footwear, caps, leather, fur, feather and its products |
| TMF | Processing of timbers and manufacture of furniture |
| PPA | Papermaking, printing and manufacture of articles for culture, education and sports activities |
| PCN | Processing of petroleum, coking, processing of nuclear fuel |
| CHI | Chemical industry |
| NMP | Manufacture of nonmetallic mineral products |
| SRM | Smelting and rolling of metals |
| MMP | Manufacture of metal products |
| GSM | Manufacture of general purpose and special purpose machinery |
| MTE | Manufacture of transport equipment |
| EME | Manufacture of electrical machinery and equipment |
| CCO | Manufacture of communication equipment, computer and other electronic equipment |
| MCO | Manufacture of measuring instrument and machinery for cultural activity and office work |
| PEH | Production and supply of electric power and heat power |
| PDG | Production and distribution of gas |
| PDW | Production and distribution of water |
| OTI | Other industries |
| CON | Construction |
| TSP | Transport, storage and post |
| WRT | Wholesale and retail trades |
| HCS | Hotels and catering services |
| RLB | Renting and leasing, business services |
| WEP | Management of water conservancy, environment and public facilities |
| EDU | Education |
| HSS | Health, social security and social welfare |
| CSE | Culture, sports and entertainment |
| PMS | Public management and social organization |
| OTS | Other services |

## Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 17 October 2017 Accepted: 4 January 2018
Published online: 22 January 2018

## References


Berkoff J (2003) China: the South–North Water Transfer Project—is it justified? Water Policy 5:1–28

Berrittella M, Rehdanz K, Tol RS (2006) The economic impact of the South–North Water Transfer Project in China: a computable general equilibrium analysis. FEEM working paper no. 154.06. Available via DIALOG. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=952938 of subordinate document

Bouhia H (1998) Incorporating water into the input–output table. In: Twelfth international input output conference, New York, May 1998

Carter HO, Ireri D (1970) Linkage of California–Arizona input–output models to analyze water transfer pattern. In: Carter AP, Brody A (eds) Applications of input–output analysis. North-Holland, Amsterdam

Chang J, Wang Y, Huang Q (2011) Water dispatch model for middle route of a South-to-North Water Transfer Project in China. J Am Water Resour Assoc 47:70–80

Chen D, Webber M, Finlayson B et al (2013) The impact of water transfers from the lower Yangtze River on water security in Shanghai. Appl Geogr 45:303–310

Crow-Miller B, Webber M (2017) Of maps and eating bitterness: the politics of scaling in China's South–North Water Transfer Project. Polit Geogr 61:19–30

Fang X, Roe TL, Smith RBW (2015) Water shortages, intersectoral water allocation and economic growth: the case of China. China Agric Econ Rev 7:2–26

Feng S, Li LX, Duan ZG, Zhang JL (2007) Assessing the impacts of South-to-North Water Transfer Project with decision support systems. Decis Support Syst 42:1989–2003

Guan D, Hubacek K (2007) Assessment of regional trade and virtual water flows in China. Ecol Econ 61:159–170

Hu B, Zhou J, Xu S et al (2013) Assessment of hazards and economic losses induced by land subsidence in Tianjin Binhai new area from 2011 to 2020 based on scenario analysis. Nat Hazards 66:873–886

Huang W, Zhang X, Wang J (2011) Multi-agent system computing and simulation of inter-basin water transfer. Intell Autom Soft Comput 17:897–908

Jorgenson DW, Gollop FM, Fraumeni BM (1987) Productivity and U.S. economic growth. Harvard University Press, Cambridge

Li ST, Xu XY (2004) South-to-North Water Transfer Project and China development. Economic Science Press, Beijing **(in Chinese)**

Lin C, Suh S, Pfister S (2012) Does South-to-North water transfer reduce the environmental impact of water consumption in China? J Ind Ecol 16(4):647–654

Liu CM (1998) Environmental issues and the South–North Water Transfer Scheme. China Q 156:899–910

Ma J, Hoekstra AY, Wang H et al (2006) Virtual versus real water transfers within China. Philos Trans R Soc B Biol Sci 361:835–842

Moore SM (2014) Modernisation, authoritarianism, and the environment: the politics of China's South–North Water Transfer Project. Environ Polit 23:947–964

Researching Group of Chinese Input–Output Association (2007) Input–output analysis of water resources consumption and water input coefficient in national economic sectors: the fifth of researching report series on input–output tables of 2002. Stat Res 3(24):21–25 **(in Chinese)**

Sánchez-Chóliz J, Duarte R (2000) The economic impacts of newly irrigated areas in the Ebro Valley. Econ Syst Res 12:96–97

Shang Y, Wang S, Yang Z et al (2003) The cultural relics distribution characteristics along the canal line and appraisal of its influence by the middle route project for water transferring from South to North China. Hum Ecol Risk Assess An Int J 9:403–420

Shao X, Wang Z (2003) Interbasin transfer projects and their implications: a china case study. Int J River Basin Manag 1:5–14

Stoevener HH, Castle EN (1965) Input–output models and benefit-cost analysis in water resources research. J Farm Econ 47:1572–1579

Thoss R, Wiik K (1974) A linear decision model for the management of water quality in the Ruhr. In: Rothenberg J, Heggie IG (eds) The management of water quality and the environment. MacMillan, London

Velazquez E (2006) An input–output model of water consumption: analysing intersectoral water relationships in Andalusia. Ecol Econ 56:226–240

Wang H, Lall S (2002) Valuing water for Chinese industries: a marginal productivity analysis. Appl Econ 34:759–765

Wang Y, Chen YS, Weng JW, Jiang YL (2008) Analysis on characteristics of urban public water use in Beijing. Water Wastewater Eng 34(11):138–143 **(In Chinese)**

Wang Y, Xiao HL, Lu MF (2009) Analysis of water consumption using a regional input–output model: model development and application to Zhangye City, Northwestern China. J Arid Environ 73(10):894–900

Webber M, Crow-Miller B, Rogers S (2017) The South–North Water Transfer Project: remaking the geography of China. Reg Stud 51:370–382

Wilson M, Li X, Ma Y, Smith A, Wu J (2017) A review of the economic, social, and environmental impacts of China's South–North Water Transfer Project: a sustainability perspective. Sustainability 9(8):1489

World Bank (2001) China: agenda for water sector strategy for North China. Report prepared by World Bank, Washington. Available via DIALOG. http://agris.fao.org/agris-search/search.do?recordID=US2014605364 of subordinate document

Yang H, Zehnder A (2001) China's regional water scarcity and implications for grain supply and trade. Environ Plan A 33:79–95

Yang H, Zehnder AJB (2005) The South–North Water Transfer Project in China. Water Int 30:339–349

Zhang Q (2009) The South-to-North Water Transfer Project of China: environmental implications and monitoring strategy. J Am Water Resour Assoc 45:1238–1247