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China's Inter-Regional Trade of Virtual Water: A Multi-Regional Input–Output Table Based Analysis

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The success of China's economic development has brought increasing pressures on its water resources, motivating it to better understand water use characteristics and how scarce water resources are transferred among regions. Virtual water is a term used to refer to the volume of freshwater consumed for producing traded goods and services. It reflects the actual human consumption of water resources and therefore is important for water resources management. The goal of this paper is to evaluate the current inter-regional virtual water trade (VWT) structure and to assess the implications of these trade patterns for water use and water conservation strategies in China. Based on the most recently available multi-regional input–output (MRIO) data, we have developed an extended inter-regional input–output (IRIO) model for eight economic regions in China to account for virtual water flows. The findings show that water use efficiency has increased over the years, but it is still unbalanced among the regions. The total amount of VWT has increased, and the major source of the trade is domestic inter-regional trade, especially intermediate products trade. Moreover, the main direction of virtual water transfer is from water-poor inland regions to water-rich regions, which is unfavorable for water resource allocation and efficiency. Therefore, in addition to enhancing water use efficiency and encouraging water-saving production alternatives, we suggest that China's government should also adopt a market-based water pricing system.

Keywords: Virtual water; inter-regional input–output (IRIO) model; China.

1. Introduction

China has been experiencing astonishing economic growth during the last three decades. However, China also has been facing a fast growing water demand because of its vigorous economic growth, population expansion, urbanization and industrialization. China ranks No. 4 for total water resources in the world, with access to about 6% of the world's fresh water resources. However, the per capita water availability in China is only about 2,200 cu m, which is about a quarter of the global average. According to the international standards (WWAP 2012), people face "water scarcity" when annual water supplies drop below 1,000 cu m/person and "absolute water scarcity" when the value drop below 500 cu m/person. Figure 1 shows the per capita water resource distributions in China for 2002 and 2007. A total of 12 provinces faced water scarcity in 2002, 10 of which faced absolute water scarcity. This number decreased to 11 provinces in 2007, including eight that faced absolute water scarcity. In both of these years, the water-scarce provinces were mainly located in arid northern China areas where water resources are only 5% of the national total. However, these regions had the largest water demands and represented one-third of the total area in China, provided more than one-half of China's wheat and one-third of its maize (Aeschbach-Hertig and Gleeson 2012). This geographical mismatch between water demands and water resources has become one of the largest threats to sustainable water supply in China.

Recognizing this mismatch, the Chinese government has proposed several physical water transfer projects to satisfy the water demands in water-scarce regions, including the world's largest — South-to-North Water Diversion Project (SNWDP). However, these physical water transfer projects are costly and unsustainable, thus they cannot be expected to play a sufficient role in a permanent solution to the water scarcity problem. In addition to the physical water transfer methods, virtual water is another solution to remedy regional water scarcity. By definition, virtual water is the freshwater consumed for producing traded goods and services (Allan 1994). Linking water use to consuming behavior can reveal evidence of a region's resource disadvantage when water withdrawal from one region is consumed virtually by other regions through water embodied in consumed products and direct use. On the other hand, regions that consume the products that are produced in the other regions may well gain in its own water resource balance. Therefore, importing and exporting goods and services is virtually equivalent to importing and exporting water. Based on this concept, water-scarce regions can and do import water-intensive products instead of producing them locally, thus conserving local water resources.

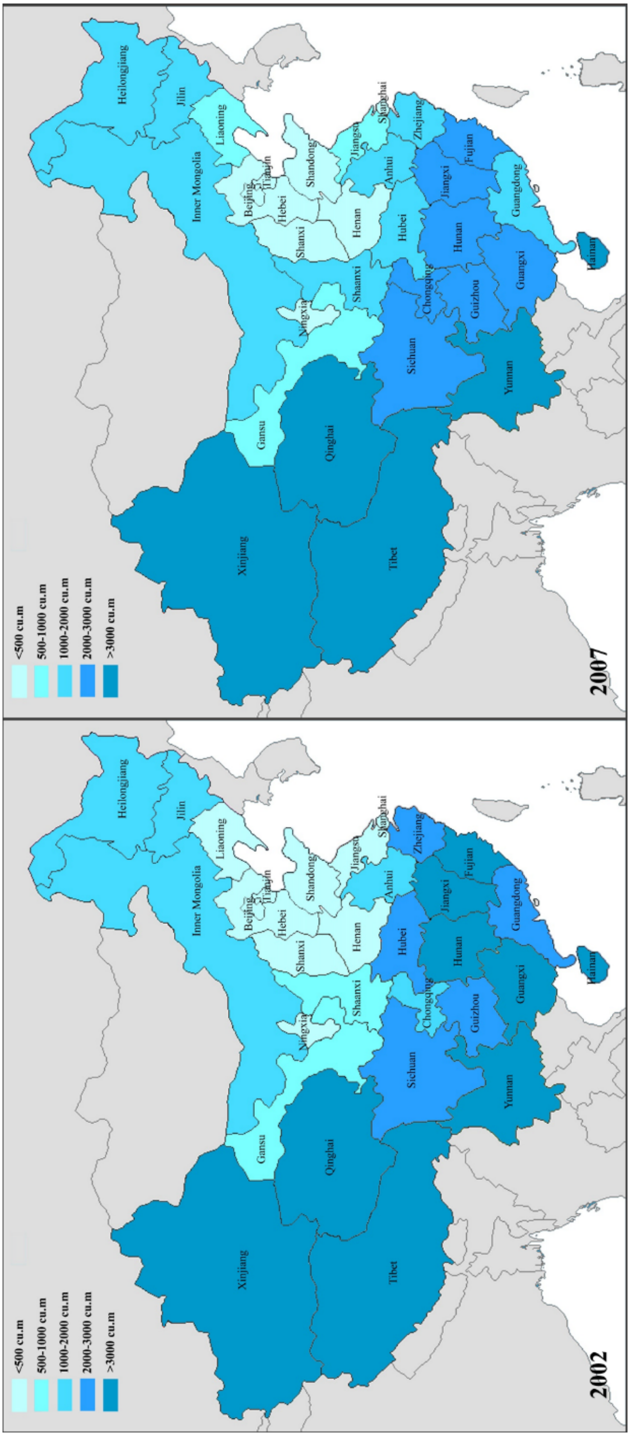

Figure 1. Per Capita Water Resource Distribution in China (2002, 2007)

Hoekstra and Hung (2002) introduced the concept of virtual water trade (VWT) to refer to the hidden flow of embodied water in products that are transported from one place to another. Although water usage primarily occurs in local production processes, it is also shaped dramatically by trading among regions. Therefore, dealing with the water scarcity problem by only focusing on local production processes is insufficient. Optimizing the VWT nexus is a more appropriate objective, and one worthy of increased attention. VWT can help an economic region relieve its water deficiencies by importing virtual water — water embodied in trade — from water-abundant regions. Consequently, we contribute to this objective by analyzing the VWT nexus as it relates to regional water policy in China.

This study assesses the current inter-regional VWT structure and the implications of trade patterns in China for water use and water conservation strategies. We investigate China's regional virtual water embodied in export, outflow (of both intermediate products and final products), and the domestic trade of virtual water by applying an inter-regional input–output (IRIO) model based on the most recently available multi-regional input–output (MRIO) data. IRIO models can provide an accurate accounting of trade, and in this way identify the places where water uses actually occur and reveal the linkages between regional direct water use and embodied water requirements. The results of this study show that water use efficiency has increased over the years in China, but is still unbalanced among the regions. The total amount of VWT has increased, and the major source of the trade is domestic inter-regional trade, especially intermediate products trade. Moreover, the main direction of virtual water transfer is from water-poor inland regions to water-rich regions, which is unfavorable for water resource allocation and efficiency. The rest of this paper is organized as follows: Section 2 gives a brief review of previous works, Section 3 introduces the methodology and data, Section 4 presents the results, and Section 5 provides the conclusions.

2. Literature Review

Evaluating virtual water has become a mainstream approach for understanding how water resources are transferred among regions. VWT is one of the powerful accounting tools used to map the linkages among consumption behavior, trade activities, and water use. Many studies have revealed the relationship between the local economic patterns and VWT in specific countries, e.g., United Kingdom (Yu *et al.* 2010), Netherlands (Oel *et al.* 2009) and France (Ercin *et al.* 2013). In recent years, a growing number of virtual water studies have been conducted in China. Guan and Hubacek (2007) and Zhang and Anadon (2014) assessed the domestic VWT in China. They found that virtual water was traded from North to South, from arid regions to wet regions, which is roughly the opposite of the distribution of China's water resources. Wang *et al.* (2013) and Zhang *et al.* (2011) evaluated the water footprint (WF) and VWT of Beijing. They found that Beijing is advanced in water use efficiency compared to the other provinces in China; however, it is a net virtual water importer and it primarily relied on external water supplies. Dong *et al.* (2013) evaluated the regional WF of Liaoning province. They found that Liaoning was a net virtual water exporter, although water shortage is a serious concern in this region. In addition, Zhao *et al.* (2010) and Okadera *et al.* (2014) estimated the WF and VWT of Haihe River basin and Yangtze River basin, respectively. They found that these basins were small net importers of virtual water through the trade of raw and processed food products.

The most popular methods used for estimating the VWT are WF and input–output analysis (IOA). The WF method for virtual water estimation was first introduced by Hoekstra in regard to the concept of ecological footprint, which is defined as the sum of domestic water use and net virtual water imported into a country (Hoekstra and Hung 2002). The current calculation of virtual water through the WF method mainly concentrates on the agricultural and animal husbandry products but excludes industrial products, primarily because industrial products contain relatively less virtual water and the calculation process is complex. Therefore, the WF method is only a partial accounting because it falls short of accounting for the total virtual water among various products.

The IOA method provides a technique to study the interconnections and interdependencies of different sectors quantitatively in an economic system. It was first proposed by Leontief in the 1930s. IOA uses straightforward mathematic routines to track all direct and indirect resource use embodied within consumption (Leontief 1970). The IOA framework has been widely applied to studies of resources embodied in the products, e.g., embodied land with ecological footprint (Bicknell *et al.* 1998; Wiedmann *et al.* 2006), embodied carbon dioxide emissions concerning global warming (Gale 1995; Meng *et al.* 2013), embodied energy use (Zhang *et al.* 2013), and embodied water use with the WF (Zhang and Anadon 2014). An extended IRIO model can be generated by incorporating the sectoral water use within a traditional IO table. In the IRIO framework, different regions are connected through the inter-regional trade, and virtual water flows can be calculated and analyzed. Unlike the WF method, the IOA method estimates the virtual water in all economic sectors, and can explicitly quantify the water embodied in trade.

This study contributes to the literature in four unique ways: (1) evaluating the current VWT structure of China by applying both the traditional IO-based measure of regional virtual water in trade (VWiT) and the newly developed measure of domestic trade in virtual water (TiVW); (2) analyzing the driving forces to derive more details behind the VWT; (3) offering meaningful policy suggestions aimed at relieving the inter-regional water imbalance; and (4) capturing the change and development of regional VWT in China by comparing the results between 2002 and 2007.

3. Methodology and Data

3.1. *Inter-regional input–output model*

The IRIO model is established based on the MRIO tables of China for the years of 2002 and 2007. Assuming that there are R regions and each region includes N sectors in the model, the basic row balance of the MRIO table could be expressed as

$$x_i^r = \sum_{s=1}^{R}\sum_{j=1}^{N} z_{ij}^{rs} + y_i^r, \tag{1}$$

where x_i^r stands for the total economic output of sector i in region r; z_{ij}^{rs} represents the inter-sector monetary flow from sector i in region r to sector j in region s, and y_i^r is the total final use supplied by sector i in region r. Given a technical coefficient matrix $A^{rs} = [a_{ij}^{rs}]$ given by $a_{ij}^{rs} = z_{ij}^{rs}/x_j^s$, Eq. (1) can be reformulated as

$$x_i^r = \sum_{s=1}^{R}\sum_{j=1}^{N} a_{ij}^{rs} x_j^s + y_i^r. \tag{2}$$

Further, Eq. (2) for all i and r can be expressed in matrix form as

$$X = AX + Y, \tag{3}$$

where $X = \begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^R \end{bmatrix}$ is the aggregate output for all regions, $A = \begin{bmatrix} A^{11} & A^{12} & \cdots & A^{1R} \\ A^{21} & A^{22} & \cdots & A^{2R} \\ \vdots & \vdots & \ddots & \vdots \\ A^{R1} & A^{R2} & \cdots & A^{RR} \end{bmatrix}$ is the aggregate cross-regional direct technical coefficient matrix, and $Y = \begin{bmatrix} y^1 \\ y^2 \\ \vdots \\ y^R \end{bmatrix}$ is the aggregate final demand, which is the sum of consumption (rural household, urban household and government consumption), investment (fixed capital formation and stock consumption), the international exports and the other balanced items.

The Leontief inverse matrix $L = (I - A)^{-1}$ is obtained when solving Eq. (3) for sectoral output as a function of final demand

$$X = (I - A)^{-1}Y. \tag{4}$$

3.2. *Indicators of water use in input–output framework*

The direct water use coefficient of each sector could be calculated by incorporating water use quantity as:

$$\alpha_j = w_j/x_j, \tag{5}$$

where α_j is the amount of water directly used by sector j to increase one monetary unit output and w_j is the water use of sector j, x_j is the aggregate output of sector j.

By combining Eq. (4), the matrix form of Eq. (5) could be rewritten as

$$W = \alpha X = \alpha(I - A)^{-1}Y, \tag{6}$$

where $W = [w_j]$ is the water use vector, $\alpha = [\alpha_j]$ denotes the direct water use coefficient vector.

The cumulative water use coefficient β can be defined from Eq. (6)

$$\beta = \alpha(I - A)^{-1} = [\beta_j], \tag{7}$$

where β_j represents the cumulative amount of water used, including both direct and indirect water use, to generate one monetary unit of output in sector j.

The water multiplier γ represents the total amount of water consumed to produce a monetary unit of output relative to the amount of water consumed directly per monetary unit produced. It is defined as cumulative water use coefficient divided by direct water use coefficient

$$\gamma_j = \beta_j/\alpha_j, \tag{8}$$

where γ_j measures the water intensity of final use relative to production for sector j. Values of γ_j range from 1 to ∞, with larger γ_j values indicating larger indirect water use for producing sector j.

3.3. *Virtual water trade*

The water that is used in the production process of goods and services is called the "virtual water" contained in the goods and services. International or inter-regional trade of these goods and services brings along trade of virtual water. To explain VWT from the perspective of inter-regional production networks, we apply both the regional VWiT and the domestic TiVW to China's inter-regional (eight regions) frameworks. The critical difference between VWiT and TiVW is that the former is based on a single IO table in which the inter-regional trade is treated as exogenous variable, and the latter is based on an inter-regional IO framework in which the inter-regional trade is determined endogenously. These distinctions become clear in detailed definitions that follow.

3.3.1. *Regional virtual water in trade*

VWiT measures the embodied water in trade, including both the international trade and inter-regional trade in goods and services. This measure is based on a single national or regional IO table in which the international or inter-regional trade in intermediate and final goods and services is treated as an exogenous variable. To assess the virtual water embodied in a region's export (international trade with the rest of the world) and outflow (domestic trade with the rest of the nation), the regional IO-based VWiT could be written as follows.

Water embodied in the exports of region r:

$$\mathrm{WE}^r = \beta^r \mathrm{ex}^r = \alpha^r (I - A^r)^{-1} \mathrm{ex}^r, \tag{9}$$

where β^r is region r's cumulative water use coefficients, α^r is region r's direct water use coefficients, A^s is the intra-regional coefficient matrix of region r, and ex^r is region r's exports.

Water embodied in the outflow of region r:

$$\mathrm{WO}^r = \beta^r \mathrm{ou}^r = \alpha^r (I - A^r)^{-1} \mathrm{ou}^r, \tag{10}$$

where ou^r is region r's outflow.

The outflow could be separated into outflow of intermediate products and outflow of final products. Water embodied in the outflow of intermediate products of region r can be written as

$$\mathrm{WI}^r = \beta^r \mathrm{imd}^r = \alpha^r (I - A^r)^{-1} \mathrm{imd}^r. \tag{11}$$

Water embodied in the outflow of final products of region r can be written as

$$\mathrm{WF}^r = \beta^r \mathrm{fd}^r = \alpha^r (I - A^r)^{-1} \mathrm{fd}^r, \tag{12}$$

where imd^r is region r's outflow in intermediate products, and fd^r is region r's outflow in final products.

3.3.2. *Domestic trade in virtual water*

To investigate domestic TiVW, we apply the concept of domestic TiVA (Johnson and Noguera 2011) and TiCE (Meng *et al.* 2013) to measure the inter-regional trade of virtual water. TiVW measures a region's virtual water used by the other region's final demand and export through inter-regional supply chains. This measure is based on an inter-regional IO framework in which the inter-regional trade in intermediate goods and services is treated as endogenous variables.

Virtual water use in region r caused by the other region's final demand can be expressed as

$$\mathrm{WFD}^{r\cdot} = (u, u)\mathrm{diag}(\alpha^r, 0)\begin{pmatrix} L^{rr} & L^{r\cdot} \\ L^{\cdot r} & L^{\cdot\cdot} \end{pmatrix}\begin{pmatrix} \mathrm{fd}^{r\cdot} \\ \mathrm{fd}^{\cdot\cdot} \end{pmatrix}, \quad (13)$$

where u is the unity vector, $L^{r\cdot}$ is the total input in region r to satisfy one unit increase of final demand in any other region, and $\begin{pmatrix} L^{rr} & L^{r\cdot} \\ L^{\cdot r} & L^{\cdot\cdot} \end{pmatrix} = \left[I - \begin{pmatrix} A^{rr} & A^{r\cdot} \\ A^{\cdot r} & A^{\cdot\cdot} \end{pmatrix}\right]^{-1}$, $A^{r\cdot}$ is the inter-regional input coefficients from region r to any other region, $\mathrm{fd}^{r\cdot}$ is region r's final demand for goods and services produced in any other region.

Virtual water use in region r caused by the other region's exports can be expressed as

$$\mathrm{WEX}^{r\cdot} = (u, u)\mathrm{diag}(\alpha^r, 0)\begin{pmatrix} L^{rr} & L^{r\cdot} \\ L^{\cdot r} & L^{\cdot\cdot} \end{pmatrix}\begin{pmatrix} 0 \\ \mathrm{ex}^{\cdot} \end{pmatrix}, \quad (14)$$

where $\mathrm{ex}^{\cdot}$ is any other region's exports.

3.4. *Data sources*

The main data foundation of this study is the set of China MRIO tables of 2002 and 2007. The MRIO tables are constructed by China's State Information Center (SIC 2011), and include 8 regions, reflecting the similarity of economic structure and spatial location of provinces in China. The 8 regions contain 30 jurisdictions, including 22 provinces, 4 municipalities and 4 autonomous regions in mainland China. Each region includes 17 sectors (1 agricultural sector, 13 industrial sectors, and 3 tertiary sectors). The regional classification is displayed in Appendix A.

The sectoral water data in this study are targeted at every sector in all provinces. The water data are collected from China Environmental Statistical Yearbook (CESY 2003, 2008), including the water use of the agricultural sector, industrial sector and household and service sector. The water use in each region is equal to the summation of the corresponding provinces. In this study, only the blue water (surface and ground water) use is included, not the green water (rainwater and the water stored in soil). Two assumptions are used in this study: (1) water intensity (water use per unit economic output) across the industrial sectors and the service sectors is assumed uniform respectively; and (2) disaggregation of the total water use is according to the proportion of the intermediate input from the "water production and supply" sector to the other sectors.

4. Results

4.1. *China's regional water use*[1]

The national total amount of water use in China has increased from 5,497.30 hundred million cu m in 2002 to 5,818.66 hundred million cu m in 2007, which is only a 5.85% increase. However, the national GDP has increased from 11,735.78 billion Chinese Yuan in 2002 to 21,327.85 billion Chinese Yuan in 2007, which is almost double. Therefore, the water use intensity (water use divided by GDP) has decreased from 4.68 cu m/Yuan in 2002 to 2.73 cu m/Yuan in 2007, which indicates that the water use efficiency has increased greatly from 2002 to 2007 in China.

Figure 2 shows the sector structure of per capita direct water use of each region. Among the 8 regions, northwest has the largest per capita direct water uses in both 2002 and 2007, which were more than 800 cu m; and north municipalities have the lowest per capita direct water uses, which were approximately 200 cu m. The highest per capita direct water use is about four times more than the lowest one. Among the economic sectors, the agricultural sector has the most direct water use. Direct water use in the agricultural sector accounts for half of the total direct water use in all the regions; particularly, this value is up to 90% in the northwest.

The direct water use coefficient α represents the water that is used to generate one unit of monetary output. The results of the regional direct water use coefficients of 2002 and 2007 are shown in Table 1. From 2002 to 2007, the direct water use coefficients have decreased in most of the sectors, which indicates that less water is used to generate the same unit monetary output. The direct water use coefficient for the electricity, gas and water supply sector in the northwest, for example, decreased from 13.83 cu m/thousand Yuan in 2002 to 5.3 cu m/thousand Yuan in 2007, which indicates that in order to generate the same unit monetary output, the direct water use in 2007 is about three times less than in 2002. Similar to the per capita direct water use, the agricultural sector also has the largest direct water use coefficient, which were 384.81 cu m/thousand Yuan in 2002 and 198.64 cu m/thousand Yuan in 2007. Compared with the electricity, gas and water supply sector, these values show more than a 30 to 40 times increase, which indicates that in order to generate the same unit monetary output, the direct water used in the

[1]In order to eliminate the effects of inflation, all the monetary units are in the constant Year 2000 Chinese Yuan.

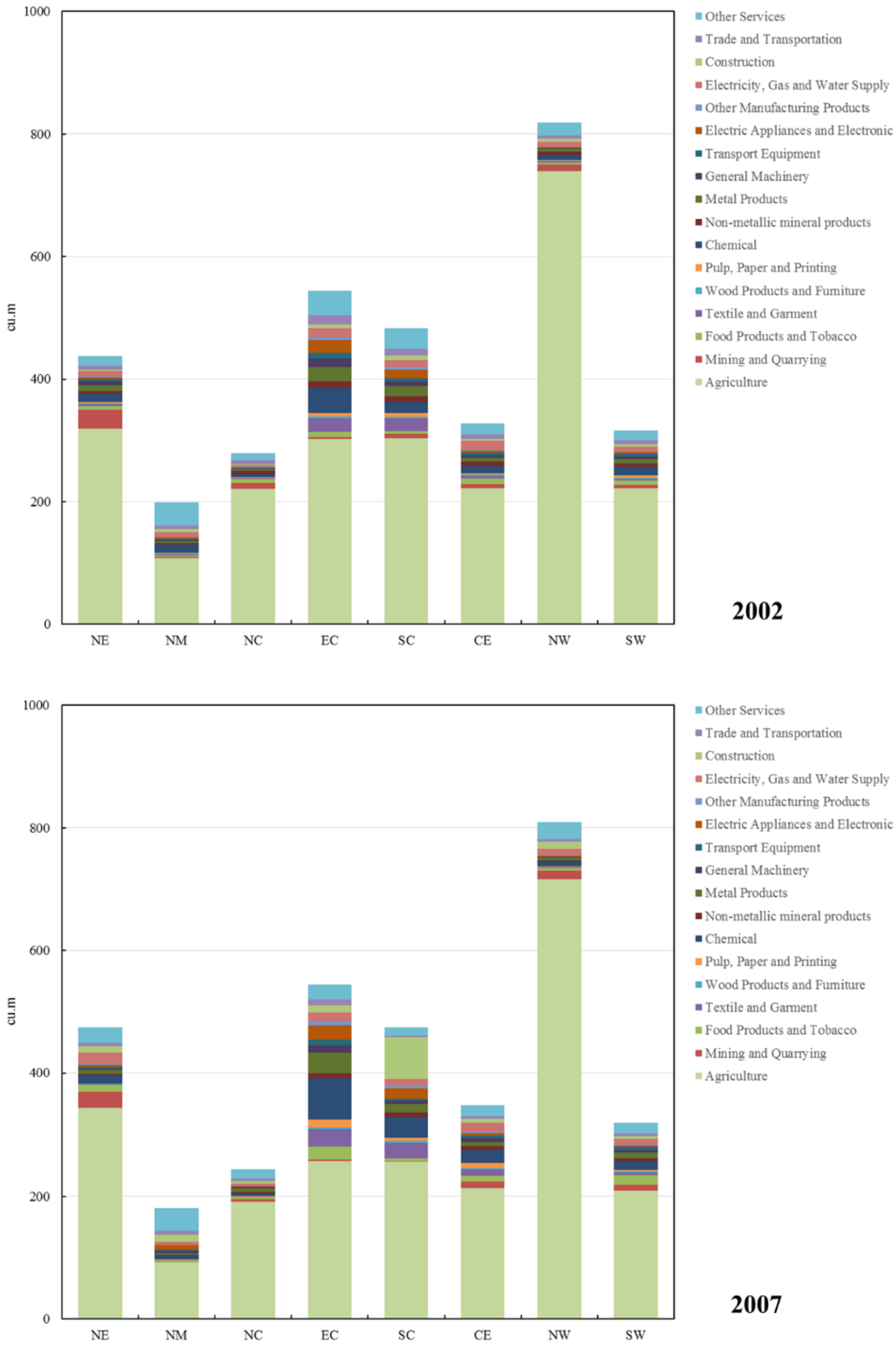

Figure 2. Sector Structure of Per Capita Direct Water Use by Regions (2002, 2007)

Table 1. China Regional Direct Water Use Coefficient (2002, 2007)

Direct Water Use Coefficient (cu m/10^3 Yuan)		Agriculture	Mining and Quarrying	Food Products and Tobacco	Textile and Garment	Wood Products and Furniture	Pulp, Paper and Printing	Chemical	Non-metallic Mineral Products	Metal Products	General Machinery	Transport Equipment	Electric Appliances and Electronic	Other Manufacturing Products	Electricity, Gas and Water Supply	Construction	Trade and Transportation	Other Services
2002	NE	124.71	18.31	5.23	5.78	1.48	9.64	4.79	11.48	5.16	4.96	3.80	3.25	3.44	12.80	0.82	2.36	3.07
	NM	59.15	1.37	1.55	1.76	1.32	1.51	2.36	3.34	0.89	1.10	0.86	0.29	0.54	9.09	0.95	0.60	1.42
	NC	79.41	6.82	2.74	1.50	1.28	1.62	1.80	7.64	1.59	0.70	2.41	0.64	1.41	5.57	0.48	2.38	2.59
	EC	111.21	11.49	5.30	4.39	5.30	3.91	7.10	13.27	5.64	4.39	4.99	4.56	4.10	11.87	1.74	3.42	4.41
	SC	120.19	10.70	3.99	8.82	3.45	3.87	5.25	19.04	8.73	6.58	7.33	2.49	4.81	7.34	2.92	2.78	4.33
	CE	107.06	8.58	10.09	8.65	6.38	9.96	11.62	15.30	5.44	8.33	8.18	10.63	9.19	29.29	2.00	4.49	6.00
	NW	384.81	11.62	5.59	9.19	1.77	6.33	8.31	19.74	4.40	4.92	4.36	2.80	6.29	13.83	2.48	2.98	6.07
	SW	123.49	15.41	9.84	15.67	20.15	21.81	20.51	20.29	9.84	13.43	6.58	13.01	11.39	20.77	2.18	5.17	5.78
2007	NE	70.18	7.11	2.72	1.50	1.02	1.78	1.78	1.59	1.24	0.87	0.62	1.91	0.68	6.93	2.04	1.15	2.84
	NM	51.48	0.22	0.72	0.54	0.85	0.82	0.55	0.59	0.19	0.72	0.22	0.37	0.29	0.83	0.88	0.41	0.72
	NC	40.15	1.08	0.34	0.31	0.13	0.29	0.51	0.69	0.65	0.31	0.15	0.22	0.26	1.51	1.04	0.75	1.58
	EC	78.94	5.02	6.26	2.35	1.86	5.02	4.14	3.56	2.55	1.31	1.55	1.49	1.86	3.36	1.26	1.11	1.25
	SC	74.08	1.32	1.50	4.22	1.63	2.15	3.84	3.09	2.41	2.39	1.09	0.95	1.15	2.74	14.55	0.26	1.03
	CE	57.65	5.26	3.52	6.73	4.39	11.50	6.27	3.29	1.63	3.62	3.75	3.42	2.96	8.35	2.08	1.14	2.92
	NW	198.64	3.04	2.49	2.32	2.42	4.37	2.17	1.98	0.95	1.23	0.89	1.05	1.62	5.30	2.41	1.08	4.10
	SW	61.25	10.19	7.31	9.24	9.05	7.39	7.24	6.65	3.45	4.81	2.40	3.68	3.89	5.39	1.25	1.70	3.23
Growth Rate	NE	−43.73%	−61.14%	−48.07%	−74.04%	−31.43%	−81.52%	−62.87%	−86.16%	−75.93%	−82.39%	−83.66%	−41.24%	−80.15%	−45.85%	147.50%	−51.17%	−7.51%
	NM	−12.97%	−83.60%	−53.22%	−69.21%	−35.95%	−45.86%	−76.79%	−82.25%	−78.41%	−34.68%	−74.78%	27.89%	−46.12%	−90.89%	−8.25%	−31.49%	−49.15%
	NC	−49.44%	−84.13%	−87.45%	−79.41%	−89.66%	−82.08%	−71.53%	−90.99%	−59.29%	−56.15%	−93.62%	−64.87%	−81.85%	−72.89%	114.91%	−68.40%	−39.13%
	EC	−29.02%	−56.30%	18.00%	−46.54%	−64.90%	28.55%	−41.70%	−73.15%	−54.81%	−70.26%	−68.94%	−67.26%	−54.61%	−71.73%	−27.33%	−67.52%	−71.55%
	SC	−38.36%	−87.63%	−62.31%	−52.13%	−52.81%	−44.52%	−26.94%	−83.78%	−72.39%	−63.76%	−85.16%	−61.93%	−76.03%	−62.69%	398.00%	−90.71%	−76.32%
	CE	−46.15%	−38.71%	−65.09%	−22.17%	−31.28%	15.48%	−46.08%	−78.48%	−70.07%	−56.58%	−54.15%	−67.87%	−67.79%	−71.50%	4.19%	−74.62%	−51.37%
	NW	−48.38%	−73.87%	−55.45%	−74.80%	36.98%	−30.91%	−73.90%	−89.99%	−78.32%	−75.05%	−79.69%	−62.70%	−74.18%	−61.65%	−3.00%	−63.60%	−32.47%
	SW	−50.40%	−33.89%	−25.72%	−41.02%	−55.09%	−66.12%	−64.68%	−67.22%	−64.93%	−64.20%	−63.57%	−71.71%	−65.83%	−74.05%	−42.77%	−67.12%	−44.16%

agricultural sector is about 30 to 40 times more than the water used in electricity, gas and water supply sector.

Water multiplier implies the indirect effects on the local water use in the production process. Figure 3 gives the regional water multiplier by sectors for both 2002 and 2007. The results in Table 1 and Fig. 3 show that the upstream sectors in the supply chain, such as agriculture, mining and quarrying, electricity, gas and water supply have relatively larger water use coefficients and smaller water multipliers. Conversely, the downstream sectors, such as food products and tobacco, textile and garment, wood products and furniture have much larger water multipliers than the upstream sectors, but lower water use coefficients. This indicates that the upstream sectors depend primarily on the direct water use and the downstream sectors depend mainly on consuming the other sectors' goods and services to satisfy their water demand.

4.2. *Regional virtual water in trade*

Figure 4 illustrates China's regional VWiT for both 2002 and 2007. At the absolute level, the three developed coastal regions (north coast, east coast and south coast) have a higher embodied water use in export than the other inland regions for both years. The main reason is that these coastal regions are manufacturing-oriented export economies with a large part of their total products exported internationally. North municipalities have the lowest VWiT among the regions given their services-oriented export economies. When analyzing the changing export pattern of VWiT, the northwest shows a significant increasing trend, largely resulting from its increasing export dependency. The main contribution of this export from the northwest is from the electricity, gas and water supply sector, whose export has increased about 200 times from 2002 to 2007.

The VWiT regional outflow values (export to other regions) are much larger than their corresponding regional foreign exports values for all regions. This indicates that the major source of the regional VWiT is domestic inter-regional trade. By separating the outflow by intermediate products and final products (see the bottom part of Fig. 4), we see that intermediate products play a dominant role in VWiT. This is because the inland regions have been deeply involved in domestic supply chains by providing more intermediate products to other regions. For the VWiT in regional outflow of either intermediate products or final products, the east coast and central regions have the largest absolute values, because these regions are located in the upstream of inter-regional supply chains, providing a large proportion of both intermediate products and final products to the other regions. When analyzing the change patterns of the regional outflow, the northeast has the largest

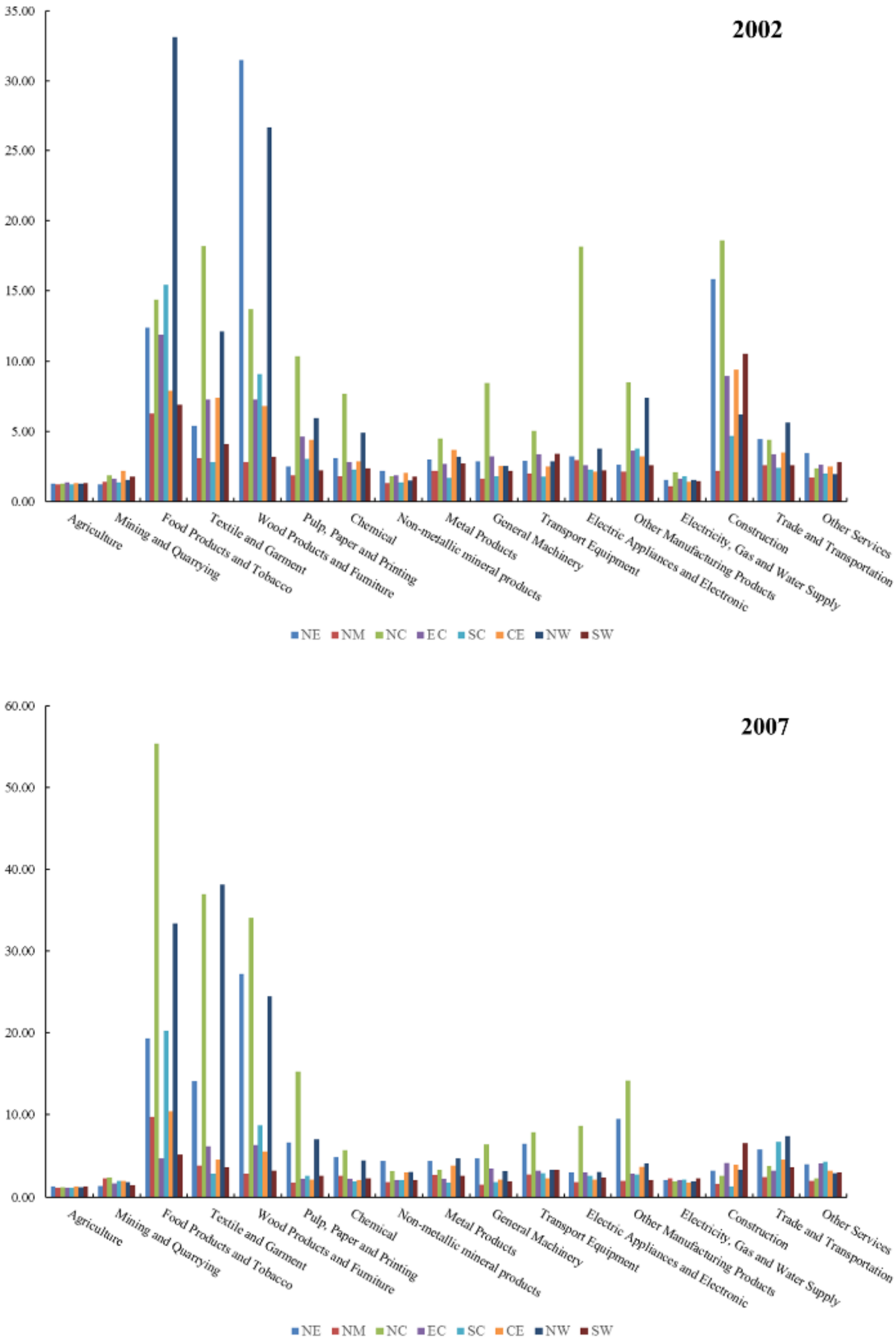

Figure 3. Regional Water Multiplier by Sectors (2002, 2007)

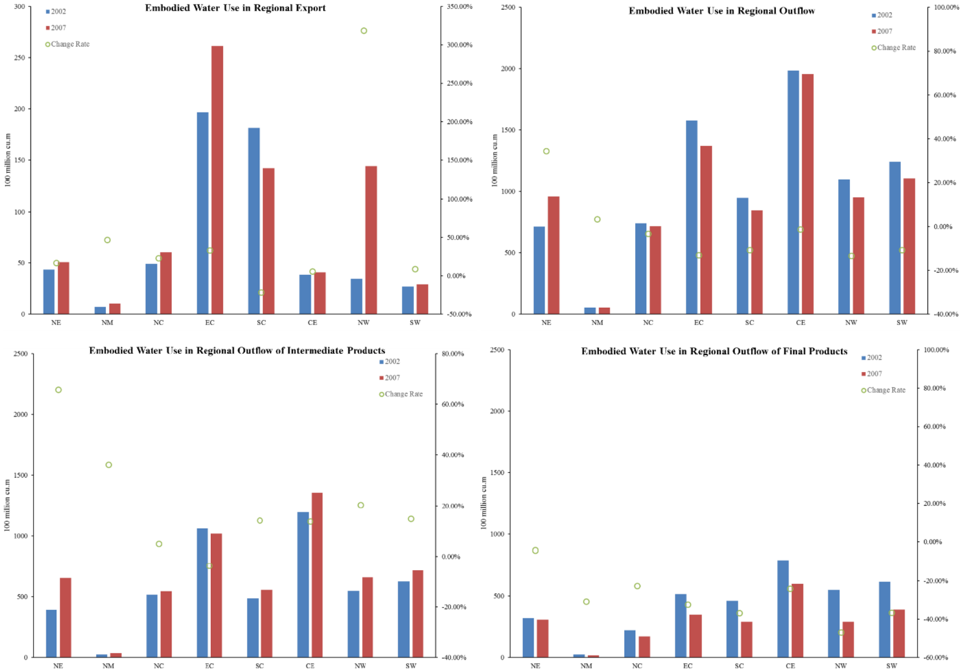

Figure 4. China's Regional Virtual Water in Trade (2002, 2007)

change rate for both intermediate products and final products. This is because the northeast's production process is more water-intensive and its status has changed from the downstream to the upstream of inter-regional trade from 2002 to 2007.

4.3. *Domestic trade in virtual water*

To capture the structure and the origin and distribution of virtual water, we applied the concept of domestic TiVW to China's MRIO tables for 2002 and 2007. The results of TiVW can explain further how the water is used and distributed across the regions through the inter-regional supply chains. The results of China's inter-regional TiVW use by final demand and the trade balance are displayed in Table 2. The results show that the total national TiVW has been increased from 717.1084 hundred million cu m in 2002 to 1,171.1147 hundred million cu m in 2007, revealing a dramatic change in magnitude. In 2002, the central region was the largest exporter of virtual water, which accounts for 26.14% of the total VWT, followed by the northwest (18.36%). The central region was also the largest importer of virtual water, which accounts for 18.09%, followed by the coastal regions (north coast 16.14%, and east coast 16.10%). These results indicate that the central region

Table 2. Domestic Inter-Regional Trade in Virtual Water Use by Final Demand and the Trade Balance (2002, 2007)

		2002									2007								
(100 million cu m)		NE	NM	NC	EC	SC	CE	NW	SW	Total	NE	NM	NC	EC	SC	CE	NW	SW	Total
Inter-regional trade	NE		9.3516	10.0340	2.8165	2.4876	5.9714	11.0080	3.3528	45.0218		8.7111	35.6095	27.1727	16.3451	29.1157	8.0671	15.1072	140.1285
	NM	0.4997		2.8584	0.2032	0.1282	0.3700	0.5138	0.2315	4.8047	1.2926		11.0074	1.7684	0.8740	2.6533	0.9705	1.1351	19.7013
	NC	6.1997	20.5109		5.8289	2.2006	10.6038	8.8588	1.4528	55.6556	4.1052	11.6902		14.2493	8.5312	37.9276	7.2176	6.3679	90.0889
	EC	3.5584	6.0404	17.1767		10.8198	43.0561	8.5382	7.0254	96.2150	2.2805	1.3933	7.9423		18.6511	28.5789	3.8810	5.6095	68.3367
	SC	5.9735	5.2229	10.8295	14.5745		20.3155	13.5613	14.8414	85.3187	6.5079	1.9774	6.1714	11.3129		25.2640	8.0810	29.0851	88.3996
	CE	12.4916	15.6115	38.4100	60.5517	22.3230		25.8977	12.1981	187.4836	4.4983	3.6738	34.7277	103.5473	32.6155		9.3595	12.2792	200.7014
	NW	25.0387	15.6284	23.0116	19.7780	7.1917	31.1008		9.9454	131.6946	14.0090	10.5381	97.7713	107.2828	43.8150	98.9442		55.8362	428.1966
	SW	10.6905	6.7371	13.3891	11.6834	18.6862	18.3346	31.3936		110.9145	5.9774	2.0127	14.1601	21.2920	44.0139	34.6151	13.4904		135.5616
	Total	64.4520	79.1027	115.7093	115.4363	63.8371	129.7521	99.7715	49.0473	717.1084	38.6709	39.9967	207.3897	286.6254	164.8459	257.0988	51.0671	125.4201	1171.1147
Share in total inter-regional trade in water	NE		1.30%	1.40%	0.39%	0.35%	0.83%	1.54%	0.47%	6.28%		0.74%	3.04%	2.32%	1.40%	2.49%	0.69%	1.29%	11.97%
	NM	0.07%		0.40%	0.03%	0.02%	0.05%	0.07%	0.03%	0.67%	0.11%		0.94%	0.15%	0.07%	0.23%	0.08%	0.10%	1.68%
	NC	0.86%	2.86%		0.81%	0.31%	1.48%	1.24%	0.20%	7.76%	0.35%	1.00%		1.22%	0.73%	3.24%	0.62%	0.54%	7.69%
	EC	0.50%	0.84%	2.40%		1.51%	6.00%	1.19%	0.98%	13.42%	0.19%	0.12%	0.68%		1.59%	2.44%	0.33%	0.48%	5.84%
	SC	0.83%	0.73%	1.51%	2.03%		2.83%	1.89%	2.07%	11.90%	0.56%	0.17%	0.53%	0.97%		2.16%	0.69%	2.48%	7.55%
	CE	1.74%	2.18%	5.36%	8.44%	3.11%		3.61%	1.70%	26.14%	0.38%	0.31%	2.97%	8.84%	2.79%		0.80%	1.05%	17.14%
	NW	3.49%	2.18%	3.21%	2.76%	1.00%	4.34%		1.39%	18.36%	1.20%	0.90%	8.35%	9.16%	3.74%	8.45%		4.77%	36.56%
	SW	1.49%	0.94%	1.87%	1.63%	2.61%	2.56%	4.38%		15.47%	0.51%	0.17%	1.21%	1.82%	3.76%	2.96%	1.15%		11.58%
	Total	8.99%	11.03%	16.14%	16.10%	8.90%	18.09%	13.91%	6.84%	100.00%	3.30%	3.42%	17.71%	24.47%	14.08%	21.95%	4.36%	10.71%	100.00%
Trade balance	NE		8.8519	3.8343	−0.7419	−3.4859	−6.5202	−14.0307	−7.3377	−19.4303		7.4185	31.5044	24.8922	9.8372	24.6174	−5.9419	9.1298	101.4576
	NM	−8.8519		−17.6525	−5.8372	−5.0947	−15.2414	−15.1146	−6.5056	−74.2980	−7.4185		−0.6829	0.3751	−1.1033	−1.0205	−9.5676	−0.8777	−20.2954
	NC	−3.8343	17.6525		−11.3478	−8.6288	−27.8062	−14.1528	−11.9363	−60.0537	−31.5044	0.6829		6.3070	2.3598	3.1999	−90.5538	−7.7923	−117.3009
	EC	0.7419	5.8372	11.3478		−3.7547	−17.4957	−11.2398	4.6581	−19.2213	−24.8922	−0.3751	−6.3070		7.3382	−74.9684	−103.4018	−15.6825	−218.2887
	SC	3.4859	5.0947	8.6288	3.7547		−2.0075	6.3697	−3.8448	21.4816	−9.8372	1.1033	−2.3598	−7.3382		−7.3516	−35.7340	−14.9289	−76.4464
	CE	6.5202	15.2414	27.8062	17.4957	2.0075		−5.2031	−6.1365	57.7315	−24.6174	1.0205	−3.1999	74.9684	7.3516		−89.5847	−22.3359	−56.3974
	NW	14.0307	15.1146	14.1528	11.2398	−6.3697	5.2031		−21.4482	31.9231	5.9419	9.5676	90.5538	103.4018	35.7340	89.5847		42.3458	377.1295
	SW	7.3377	6.5056	11.9363	4.6581	3.8448	6.1365	21.4482		61.8672	−9.1298	0.8777	7.7923	15.6825	14.9289	22.3359	−42.3458		10.1416
	Total	19.4303	74.2980	60.0537	19.2213	−21.4816	−57.7315	−31.9231	−61.8672	0.0000	−101.4576	20.2954	117.3009	218.2887	76.4464	56.3974	−377.1295	−10.1416	0.0000

plays an important water transfer role, importing it from the west inland regions (northwest and southwest) and exporting it to the coastal regions. This is largely due to its geographic centrality and well-developed transportation infrastructure, placing it in a prime position to be both an important consumer and supplier of intermediate products in China's domestic supply chains.

By 2007, significant changes had occurred. The largest exporter has changed from the central region to the northwest (36.56%), the trade balance of which has increased from 31.9231 to 377.1295 hundred million cu m. The northeast has changed from net virtual water importer to the second largest exporter in the domestic TiVW framework. The trade balance for the northeast has changed from −19.4303 to 101.4565 hundred million cu m. The coastal regions are still the largest importers (east coast 24.47%, north coast 17.17%, and south coast 14.08%). These results indicate that the direction of the VWT was from the water-poor inland regions (northwest and northeast) to the water-rich regions (coastal regions) in China, which is consistent with the results that Guan and Hubacek (2007) and Jiang *et al.* (2014) found.

Figures 5 and 6 further confirm the results and show the detail inflow and outflow of virtual water by regions for both 2002 and 2007. In 2002, the north municipalities and the north coast had the largest trade deficit while the southwest and the central regions had the largest trade surplus. In 2007, the east coast and north coast regions had the largest trade deficit while the northwest and northeast regions had the largest trade surplus. There are clear structural changes that occurred between 2002 and 2007 for some of the regions. The central and the coastal regions have tended to purchase considerably more final goods from the inland regions rather than to produce them locally. On the contrary, the northeast and northwest, as the important water base regions, have been able to provide more highly processed water-intensive intermediate goods to support other regions' supply chains rather than providing only water-oriented materials.

The results of the domestic TiVW by regional exports are shown in Table 3, which measured the amount of a region's water use embodied in its partner region's exports. These results facilitate the understanding of how a one region's virtual water uses are triggered by other regions' exports when the region acts as a producer of intermediate products in domestic supply chains. The give-out and gain potential of virtual water use by regional exports for both 2002 and 2007 are shown in Figs. 7 and 8, respectively. The give-out and gain potential of virtual water use are defined as the potential decrease and increase of virtual water use in producing intermediate products. The east coast and south coast regions had the largest give-out potential of virtual water use in both 2002 and 2007, which indicates that they had the largest trade effects on the other regions. One reason is

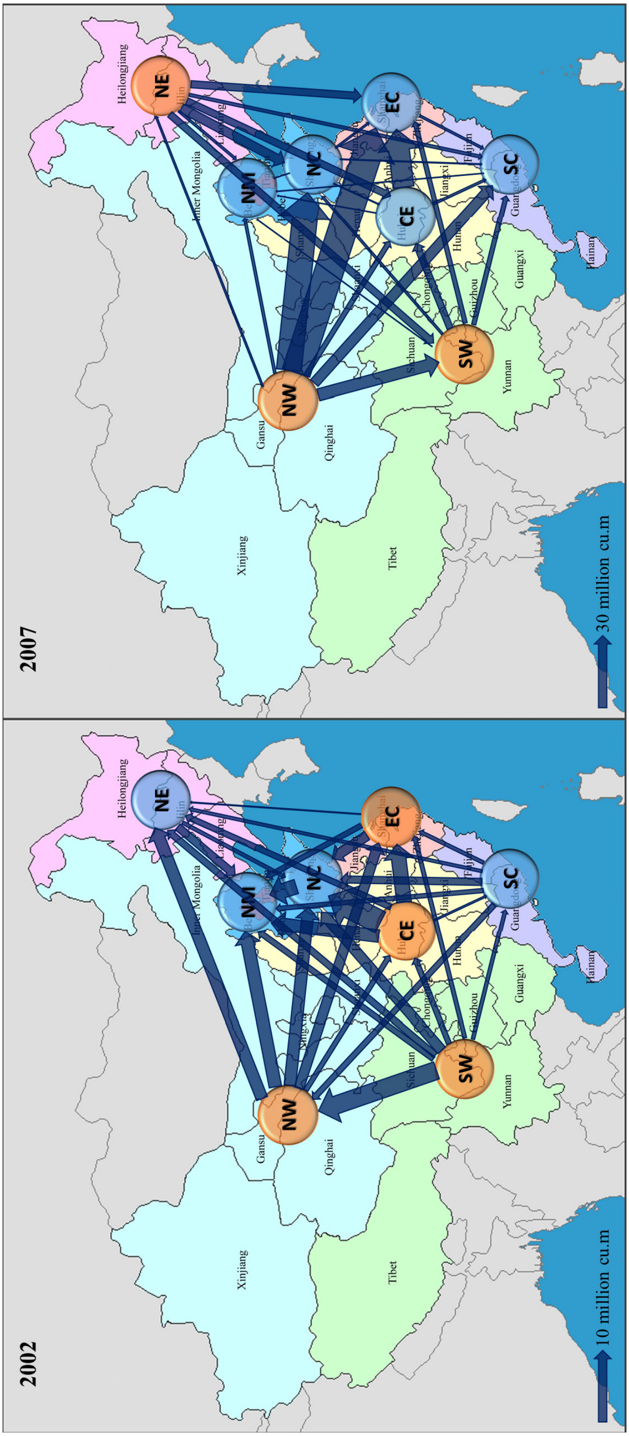

Figure 5. China's Domestic Inter-Regional Trade in Virtual Water (2002, 2007)

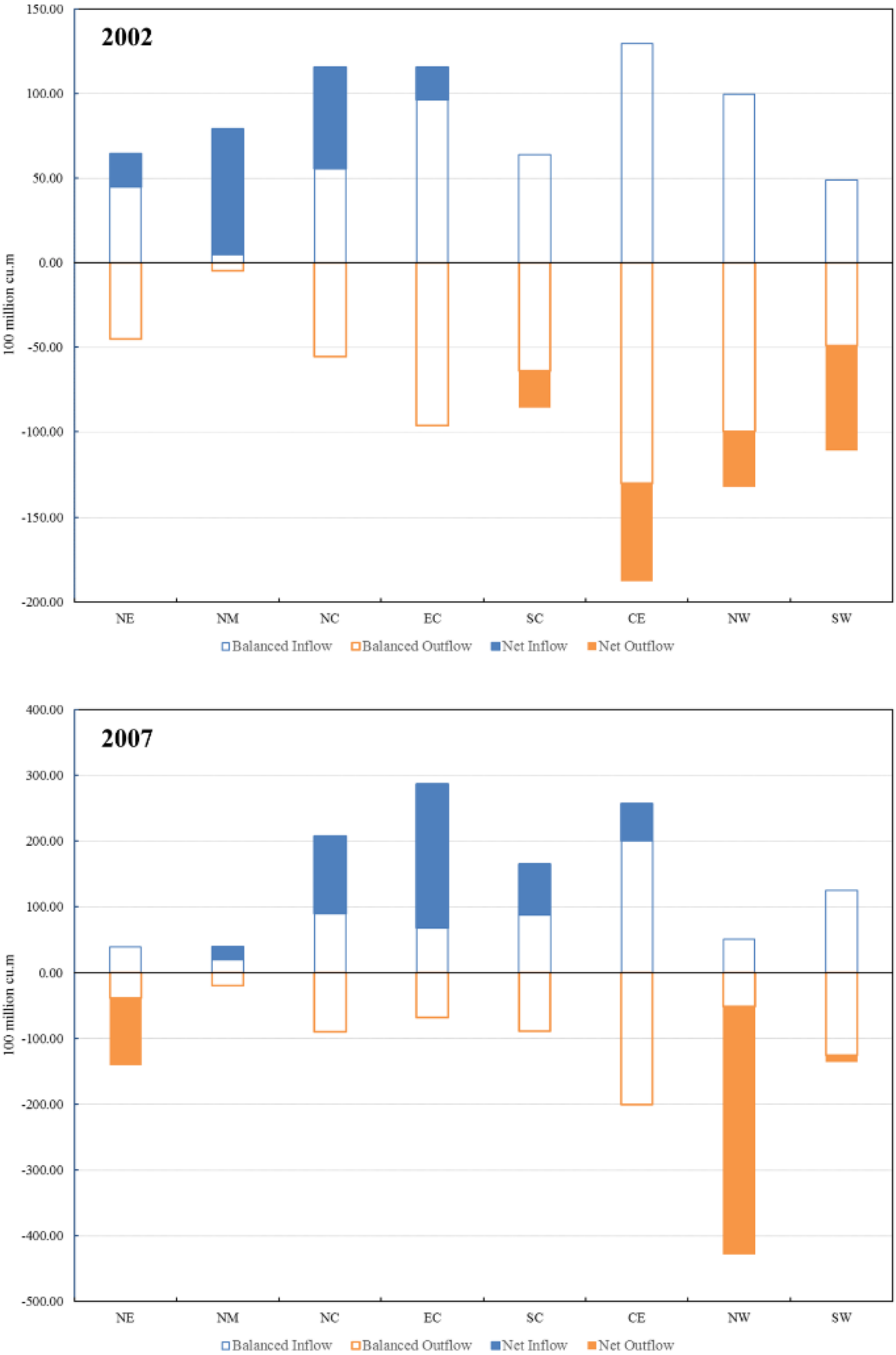

Figure 6. Inflow and Outflow of Virtual Water by Regions (2002, 2007)

Table 3. Domestic Inter-Regional Trade in Virtual Water Use by Regional Exports and Trade Balance (2002, 2007)

		2002									2007								
(100 million cu m)		NE	NM	NC	EC	SC	CE	NW	SW	Total	NE	NM	NC	EC	SC	CE	NW	SW	Total
Inter-regional trade	NE		1.3684	1.3220	0.7667	1.0158	0.1750	0.3232	0.1124	5.0836		2.9540	5.7311	8.0196	5.1734	0.9344	1.0925	0.3795	24.2846
	NM	0.0416		0.2447	0.0658	0.0962	0.0103	0.0148	0.0048	0.4781	0.0960		0.9065	0.3983	0.1870	0.0403	0.0863	0.0143	1.7287
	NC	0.5408	3.2843		1.8795	1.2497	0.3660	0.3617	0.0645	7.7465	0.8314	4.5692		4.3229	2.3331	0.9593	1.1477	0.1201	14.2836
	EC	0.3593	1.1012	1.8339		6.9255	1.6741	0.3211	0.2391	12.4541	0.3718	0.9256	1.5848		11.8380	1.7087	0.6091	0.2796	17.3176
	SC	0.5239	0.8668	1.1199	5.1781		0.6185	0.4189	0.5395	9.2657	0.6857	1.1156	1.3514	8.2476		0.8736	0.8614	1.0418	14.1771
	CE	1.0266	2.3285	5.5174	15.7239	9.9402		0.9404	0.4575	35.9345	0.7314	1.5389	8.7553	42.0931	16.6947		1.7517	0.5606	72.1256
	NW	1.4389	1.1849	2.7256	3.6896	2.1903	0.7415		0.2922	12.2630	2.5340	3.7450	17.3286	25.8687	10.3727	2.1424		0.9601	62.9515
	SW	0.6284	0.7281	1.1914	2.4380	8.5075	0.3790	0.8070		14.6794	0.5624	0.5372	3.0416	8.4537	14.1364	0.7720	1.6745		29.1779
	Total	4.5594	10.8622	13.9550	29.7417	29.9252	3.9644	3.1871	1.7100	97.9049	5.8126	15.3856	38.6993	97.4038	60.7354	7.4307	7.2231	3.3560	236.0466
Share in total inter-regional trade in water	NE		1.40%	1.35%	0.78%	1.04%	0.18%	0.33%	0.11%	5.19%		1.25%	2.43%	3.40%	2.19%	0.40%	0.46%	0.16%	10.29%
	NM	0.04%		0.25%	0.07%	0.10%	0.01%	0.02%	0.00%	0.49%	0.04%		0.38%	0.17%	0.08%	0.02%	0.04%	0.01%	0.73%
	NC	0.55%	3.35%		1.92%	1.28%	0.37%	0.37%	0.07%	7.91%	0.35%	1.94%		1.83%	0.99%	0.41%	0.49%	0.05%	6.05%
	EC	0.37%	1.12%	1.87%		7.07%	1.71%	0.33%	0.24%	12.72%	0.16%	0.39%	0.67%		5.02%	0.72%	0.26%	0.12%	7.34%
	SC	0.54%	0.89%	1.14%	5.29%		0.63%	0.43%	0.55%	9.46%	0.29%	0.47%	0.57%	3.49%		0.37%	0.36%	0.44%	6.01%
	CE	1.05%	2.38%	5.64%	16.06%	10.15%		0.96%	0.47%	36.70%	0.31%	0.65%	3.71%	17.83%	7.07%		0.74%	0.24%	30.56%
	NW	1.47%	1.21%	2.78%	3.77%	2.24%	0.76%		0.30%	12.53%	1.07%	1.59%	7.34%	10.96%	4.39%	0.91%		0.41%	26.67%
	SW	0.64%	0.74%	1.22%	2.49%	8.69%	0.39%	0.82%		14.99%	0.24%	0.23%	1.29%	3.58%	5.99%	0.33%	0.71%		12.36%
	Total	4.66%	11.09%	14.25%	30.38%	30.57%	4.05%	3.26%	1.75%	100.00%	2.46%	6.52%	16.39%	41.26%	25.73%	3.15%	3.06%	1.42%	100.00%
Trade balance	NE		1.3269	0.7812	0.4075	0.4919	−0.8516	−1.1157	−0.5160	0.5242		2.8580	4.8997	7.6478	4.4877	0.2030	−1.4415	−0.1829	18.4719
	NM	−1.3269		−3.0396	−1.0353	−0.7706	−2.3182	−1.1702	−0.7233	−10.3841	−2.8580		−3.6627	−0.5273	−0.9285	−1.4986	−3.6588	−0.5229	−13.6569
	NC	−0.7812	3.0396		0.0456	0.1298	−5.1515	−2.3639	−1.1269	−6.2085	−4.8997	3.6627		2.7380	0.9816	−7.7960	−16.1809	−2.9216	−24.4157
	EC	−0.4075	1.0353	−0.0456		1.7474	−14.0497	−3.3685	−2.1989	−17.2875	−7.6478	0.5273	−2.7380		3.5904	−40.3844	−25.2597	−8.1741	−80.0862
	SC	−0.4919	0.7706	−0.1298	−1.7474		−9.3217	−1.7714	−7.9680	−20.6596	−4.4877	0.9285	−0.9816	−3.5904		−15.8212	−9.5113	−13.0946	46.5583
	CE	0.8516	2.3182	5.1515	14.0497	9.3217		0.1990	0.0785	31.9702	−0.2030	1.4986	7.7960	40.3844	15.8212		−0.3907	−0.2115	64.6949
	NW	1.1157	1.1702	2.3639	3.3685	1.7714	−0.1990		−0.5148	9.0759	1.4415	3.6588	16.1809	25.2597	9.5113	0.3907		−0.7144	55.7284
	SW	0.5160	0.7233	1.1269	2.1989	7.9680	−0.0785	0.5148		12.9694	0.1829	0.5229	2.9216	8.1741	13.0946	0.2115	0.7144		25.8219
	Total	−0.5242	10.3841	6.2085	17.2875	20.6596	−31.9702	−9.0759	−12.9694	0.0000	−18.4719	13.6569	24.4157	80.0862	46.5583	−64.6949	−55.7284	−25.8219	0.0000

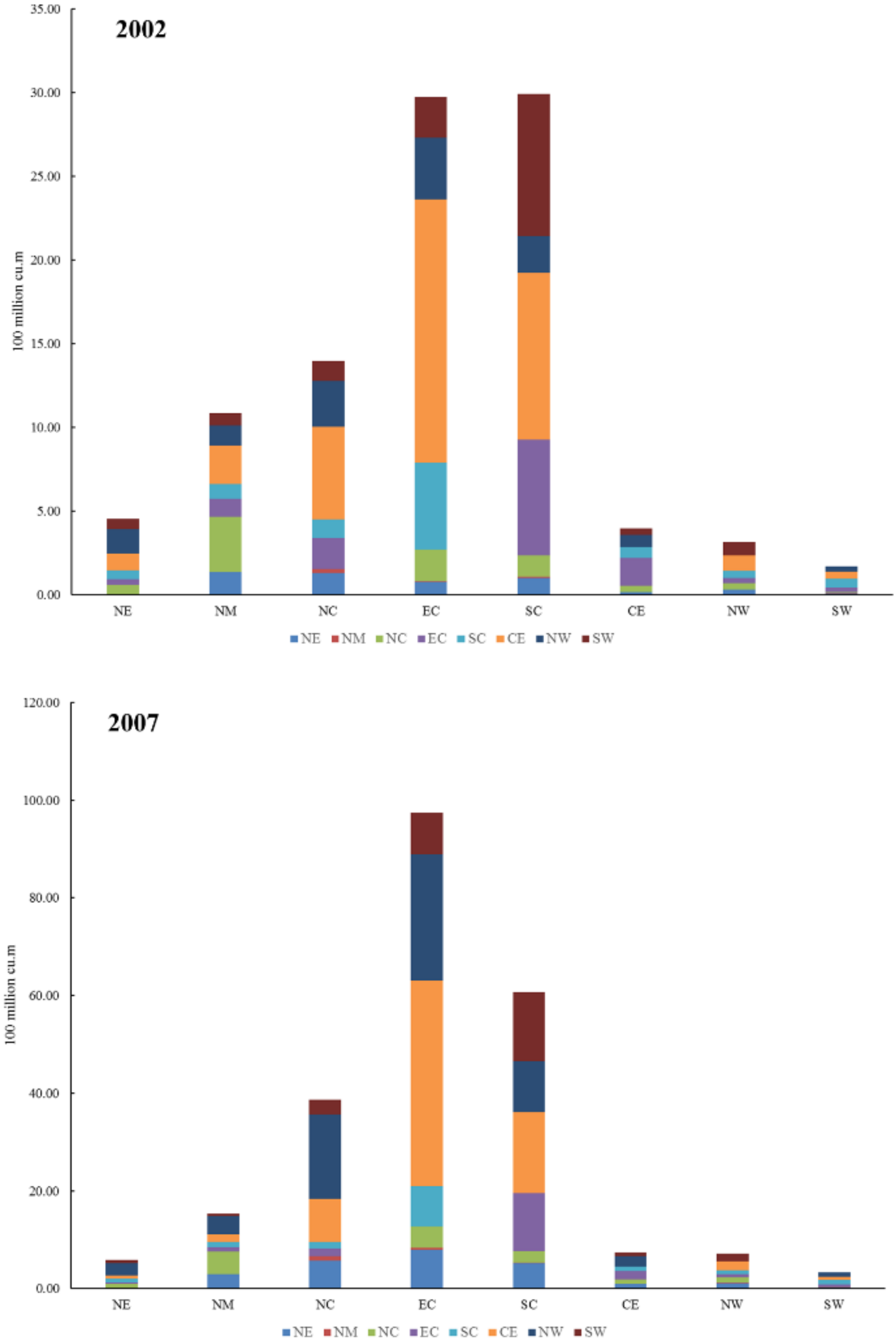

Figure 7. Give-out Potential of Virtual Water Use by Regional Exports (2002, 2007)

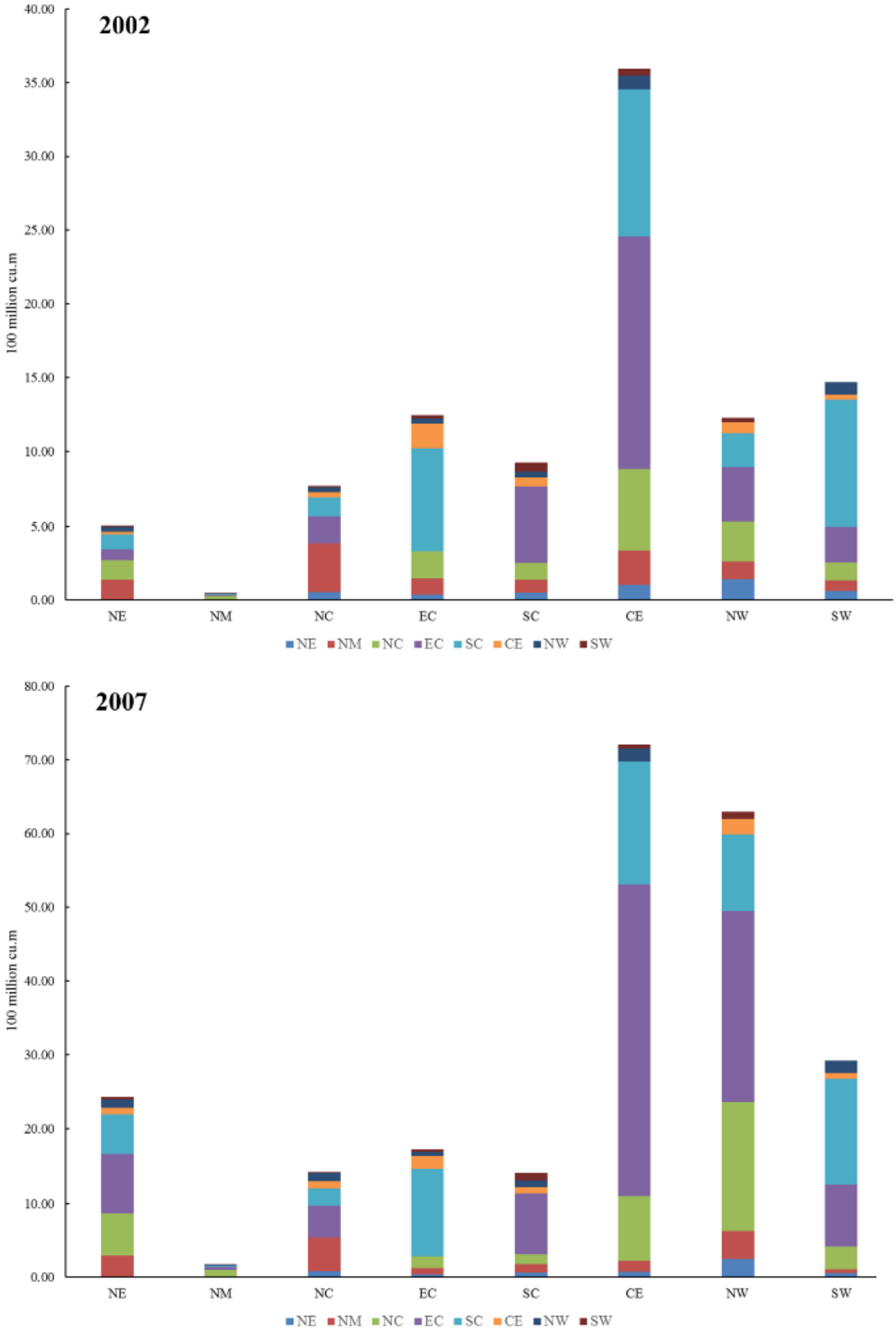

Figure 8. Gain Potential of Virtual Water Use by Regional Exports (2002, 2007)

that the export market is mainly located in the coastal regions in China. The other reason is that the efficiencies of water use in the coastal regions have increased substantially. Analyzing the components of the results for the east and south coast regions' give-out potential, we find that the main provider of the virtual water was the central region in 2002, and it has been changed to the northwest in 2007. The centralized location and the large economy of the central region have caused it to be the primary water transfer region, through which it gains the most virtual water through inter-regional trade. The northwest has experienced a large increase of the gain potential of virtual water use, which indicates that this region provided increasingly more water-intensive intermediate products to be involved in the coastal regions' export products supply chains.

4.4. *Driving forces behind China's virtual water trade*

In general, the driving forces behind the virtual water flows can be attributed to a combination of reasons such as the differences of regional water use intensities, economic structures and the region's status in the supply chains.

Water use intensity, measured by water use coefficients, is one of the most important drivers for VWT, and water use coefficients allow us to quantify explicitly a final product's water demand in the supply chain. Among the eight regions in China, the northwest has the largest agricultural water use coefficient, which indicates that even if the same amount of agricultural products are exchanged, a large amount of virtual water would be transferred from the northwest to the other regions. Since the agricultural sector is the largest water-intensive sector, the northwest becomes the largest virtual water exporter in the inter-regional VWT. Technological difference and product mix are examples of important reasons for the differentiation of the water use coefficients across regions. With different technology levels, developed regions and less developed regions use different amounts of water to produce the same amounts of products. Different crops require different amounts of water per unit output. Therefore, the technological gap and product mix are the major contributors for inter-regional virtual water transfers.

The economic structure of a region includes the dominant economic sectors and the import–export structures. In China, the dominant economic sectors of the less developed inland regions are the traditional agriculture and energy sectors, which are the water-intensive sectors; the dominant economic sectors of the developed coastal regions are the industrial and tertiary sectors, which are the water-saving sectors. Moreover, whereas less developed regions export a large share of water-intensive products to the developed regions, more developed regions export more labor and technology intensive products to the less developed regions. Thus, a large volume of virtual water transfers from the less developed inland regions to the developed coastal regions in the VWT supply chain. Therefore, distinct economic structures between less developed regions and developed regions are the other contributor for virtual water transfers among regions.

VWT might be viewed by some as a partial solution to the water scarcity problem by transferring the water from water rich regions to water-scarce regions. However, the results of this study reveal a paradox in China. The main direction of the virtual water transfer is from water-poor inland regions to water-rich coastal regions. This could be explained by the region's general position in the supply chain. The water-rich coastal regions are in the downstream of the domestic supply chain, whose main products are industrial and tertiary products. These water-saving but high value-added products are exported to the inland regions. The water-poor inland regions are in the upstream of the domestic supply chain, whose main products are agricultural products. These water-intensive but low value-added products are exported to the coastal regions as either intermediate inputs or final products. Due to the high-level demand of the water-intensive products in coastal regions, the water-poor inland regions are locked into water-intensive production. Therefore, the region's position in the supply chain is another important factor of the virtual water transfers among regions.

5. Conclusions

While the virtual water embodied in the international trade has received much attention, domestic VWT embodied in inter-regional trade for all products has not been widely studied. Revealing the relative importance of international and domestic trade for local water use can help policy makers identify and rethink prior areas of local water problems. To assess the implications of the inter-regional VWT patterns and water conservation strategies, we evaluated the current inter-regional VWT structure by applying the extended IRIO model based on the most recently available MRIO data.

The results of this analysis suggest that water use efficiency has increased over time, reflected in the water use coefficients decrease for most sectors from 2002 to 2007, and indicating that less water is used to generate the same unit monetary output. This is mainly due to the improvement of water use efficiency in the important water-intensive sectors, such as agriculture, mining and quarrying, electricity, gas and water. However, the water use coefficients are uneven among the regions. The undeveloped inland regions have much higher water use coefficients than the developed coastal regions, which indicates that the inland regions have lower water use efficiency. This suggests that the inland regions should improve their water use efficiency, including both direct and indirect water use efficiency. For instance, change the water-intensive crop species to the species that require less water under the premise that basic food security could be enhanced. Further, it is important to encourage the water-saving production technologies, such as reducing material waste and managing plant operations more effectively. Another suggestion is to promote the sharing and exchange of information and technology across regions to relieve the technology gap.

The results also suggest that the inter-regional TiVW at the national level has almost doubled between 2002 and 2007, and the major source of the regional VWT is domestic inter-regional trade, especially trade in intermediate products. Thus, it is important to improve water use efficiency of intermediate products. Policy suggestions could include more rapid adoption of water-saving materials in the production processes of intermediate products and greater improvement in the recycling rate of intermediate products.

Moreover, the results of this study reveal a paradox of VWT in China. The main direction of the virtual water transfer is from water-poor inland regions to water-rich coastal regions, which is unfavorable for water resource allocation and efficiency. This is due to the region's status in the domestic supply chain. Since government policies, such as price controls, have artificially lowered water prices, the current water price system does not consider the regional diversities of water scarcity. Thus, the water-poor inland regions keep producing water-intensive products and exporting them to the water-rich regions. This suggests that the Chinese government should consider a water pricing system reform to encourage the water-intensive products in the water-rich regions and the water-saving products in the water-poor regions. Moreover, this strategy should be applied mainly to the water-intensive sectors, such as agricultural and energy sectors.

Limiting water use while concurrently increasing water efficiency has been the focus of the new water policy framework in China. However, reshaping China's water-trade nexus, particularly in water-scarce regions, can provide alternative opportunities to address local water scarcity problems. Optimizing the water trade nexus may have more wide-spread socio-economic consequences than direct water conservation measures. The VWT pattern may be strengthened in the future as China's economy continues to grow rapidly and more people immigrate from inland regions to coastal regions for job opportunities. Therefore, shifting export-oriented sectors from the water-intensive products to the water-saving products could contribute to water conservation in China.

The main limitations within this study are due to data restriction. Longer time dimensions could and will provide a better overview of the VWT change over time.

However, the 2002 and 2007 data are the only available data for China as of this report. Given China's rapid economic advancements, the comparison results are perhaps telling of a trend of the VWT, which suggests that reshaping the water trade nexus is an important task for protecting the water-scarce regions. As additional data become available, it will be necessary for future studies to examine the trend further in China.

Appendix A. Region Classification and Basic Regional Dataset

MRIO Tables	Provincial IO Tables	Per Capita Water Resources (cu m)		Per Capita Water Use (cu m)		Per Capita GRP (Yuan)	
8 Regions	30 Provinces	2002	2007	2002	2007	2002	2007
Northeast (NE)	Heilongjiang, Jilin, Liaoning	4951.37	4615.46	458.33	493.02	10409.67	16567.80
North Municipalities (NM)	Beijing, Tianjin	539.01	645.29	224.61	208.42	25995.56	41298.42
North Coast (NC)	Hebei, Shandong	986.46	1584.55	293.20	258.76	10040.39	18433.05
East Coast (EC)	Jiangsu, Shanghai, Zhejiang	3246.74	2835.36	569.28	595.32	17081.29	29256.24
South Coast (SC)	Fujian, Guangdong, Hainan	7281.50	5823.76	513.67	499.74	13810.53	22862.21
Central (CE)	Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi	5778.43	4447.09	344.62	373.43	6217.95	11457.21
Northwest (NW)	Inner Mongolia, Shaanxi, Ningxia, Gansu, Qinghai, Xinjiang	11512.98	10578.80	830.54	840.67	8624.11	12492.06
Southwest (SW)	Sichuan, Chongqing, Guangxi, Yunnan, Guizhou	10502.20	9764.93	336.52	356.23	5214.40	9189.15

Note: Water resources include the surface water, ground water and the rain fall. Only consider the direct water use here.

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