14. The Impact of China's Economic Growth on its Water Resources:

A regional and sectoral assessment

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Introduction

With the astonishing speed of its economic growth during the past four decades, China has made unprecedented progress in national development and improvements in the living standard of its people. Alongside this achievement, however, there has been a continued intensification of water shortages and deterioration of water quality. Between 1980 and 2010, total water use increased by 35.8. per cent, from 443.7 billion cubic metres to 602.2 billion cu m (Liu and Chen 2001; MWR 1997–2010). Total industry and household wastewater discharge doubled during the same period.

China's water endowments are, overall, unfavourable. Average water resources per capita are a mere one-quarter of the world average. The uneven spatial and temporal distribution of water resources exacerbates the quantity problem. The bulk of water resources are concentrated in the southern part of the country, whereas the northern part has a much smaller share of the total water resources compared with its proportion of land. China is dominated by the East Asian monsoon climate, and a majority of its annual precipitation is concentrated in the summer months, leaving the rest of the year with little rainfall. Since the late 1980s, water shortages have emerged in many areas in China, particularly in the north. The problem has been worsening over the years in terms of intensity and coverage. It is reported that in some northern cities, the current water supply can barely meet 70 per cent of demand during the dry season. Out of 600 medium to large-sized cities, more than half of them have insufficient water supplies, and more than 100 of them are experiencing severe water shortage (Jiang 2009). Lacking water has caused hardships to people's livelihoods and losses of economic activity. In many northern cities, water scarcity has become a bottleneck to the continuation of economic growth. Competition for limited water resources has led to a reallocation of agricultural water to urban sectors, putting irrigation under great pressure in many areas in the north. Food production—a sector heavily dependent on irrigation—is

facing the challenge of producing more food with less water. The water that is needed for maintaining healthy environmental and ecosystem functions has been held back to give priority to meeting the demands of the economic sector.

Along with the intensification of water shortages, water pollution and environmental degradation have been serious across the country. Currently, many rivers and lakes in the eastern part of the country have water quality below Grade V, meaning that the water is too polluted to be suitable for any use. Degraded water quality further aggravates the problem of water shortages. In the North China Plain, most rivers are now dry either completely or seasonally. The ones with water are all heavily polluted and often cannot be used.

Water scarcity and pollution problems have drawn increasing attention in China since the late 1990s. Many measures aimed at increasing water supply and curbing demand have been put forward; yet the problems remain severe, and in many places are worsening. The serious water situation in China has raised questions about water and environmental sustainability. How China will deal with its water shortage and pollution problems will have significant implications for its long-term economic development.

China's water problems are also of global concern given the increasing connection of China with the rest of the world through the international trade of goods and services. International trade between countries entails flows of virtual water—that is, the water used for the production of traded products (Allan 1997; Yang and Zehnder 2007). An inflow of virtual water through trade reduces the pressure on household water resources, whereas an outflow of virtual water adds to the pressure. As the 'world's manufacturing factory', China uses a large portion of water for the production of its exports. Currently, China as a whole is a net 'virtual water exporter'—that is, the amount of water used for the production of exported products is greater than the amount saved on imported products. The intensification of water scarcity in China could impact on its international trade, which has been an important pillar of its rapid economic development since the late 1970s.

As China struggles to develop effective approaches to alleviate water shortages and pollution, a clear understanding of the water situation and its implications for economic development is important. The related questions include: how much water is available and in what quality across regions? How much water is used and for what purposes? Which economic activities are the major polluters of water? To what extent has China's international trade influenced its water uses? This chapter addresses these issues.

The Status of China's Water Resources with Respect to Quantity and Quality

Water Resources and their Spatial Distribution

The annual average volume of renewable water resources in China is approximately 2812 billion cu m per year, including surface and groundwater (MWR 1997–2011). Dividing this volume by the total population of 1.33 billion in 2010, average water availability stands at approximately 2100 cu m per capita. This figure is roughly one-quarter of the world average and one-sixth of the figure for the United States. Thus, China as a whole can be said to be a water-poor country by world standards.

China's water resources are geographically divided into nine major watersheds/river basins: the Yangtze, Yellow (Huang), Hai-Luan, Huai, Song-Liao, Pearl, South-East, South-West and North-West (Table 14.1). The spatial distribution of water resources is highly uneven. The Yellow (Huang) River Basin, Hai-Luan River Basin and Huai River Basin (hereinafter, the HHH region) have average water resources of between 300 cu m/year and 700 cu m/year—substantially below the water-scarcity threshold of 1700 cu m/year defined by Falkenmark (1995). The Inland region is dominated by arid and semi-arid climates where water is extremely scarce. The relatively large volume of per capita water resources in the region is mainly because of the sparse population relative to the vast territory. The South-West watershed is endowed with abundant water resources. Several international rivers originate here, including the Mekong, Thanlwin and Brahmaputra; however, most of the water in the south-west is not accessible to the rest of the country due to geographical barriers and, to a lesser extent, international political sensitivities over shared waters.

The ratio of water withdrawal to water availability is an indicator of the intensity of water use and the pressure on the ecosystem. Forty per cent (or 0.4) is a rule-of-thumb ratio commonly used as a benchmark for water criticality (Alcamo et al. 1999). The higher the ratio, the greater is the pressure of water withdrawal on the available water resources and dependent ecosystems. Table 14.1 shows the ratio of water withdrawal to water resource availability in the major river basins in China.

Table 14.1 Water Resources Availability and Water Withdrawal in the Major River Basins (average 2006–10)

	Per capita water resources availability	Water resources availability	Water use	Ratio of withdrawal to availability
Basins	cu m/capita	billion cu m	billion cu m	%
Song-Liao	1704	172.07	64.38	37.42
Hai	358	29.75 *	37.00	124.37
Huang	749	61.06	46.67 **	76.43
Huai	505	89.06 *	63.97	71.83
Yangtze	2388	839.60	197.04	23.47
Pearl	3327	453.62	87.68	19.33
South-East watershed	2962	173.52	34.36	19.80
Inland watershed	5270	132.34	64.13	48.46
South-West watershed	31 914	594.44	11.18	1.88
Nation	2100	2475.52	596.52	24.10

* including water transfer into the Hai River Basin and the Huai River Basin

** including water transfer out of the Yellow River Basin

Sources: MWR (1997–2011).

Currently, the ratios of water withdrawal to water resources availability in the Hai, Yellow and Huai Rivers are excessively high compared with the internationally recommended sustainable ratio of 40 per cent, indicating severe water stress in these basins. The Hai River Basin has a ratio of 124 per cent, meaning that the basin is using more water than it has. This is possibly mainly due to the exploitation of non-renewable deep aquifers in the North China Plain, supplemented with a small amount of desalinated seawater. The result has been a drop of the groundwater table at an alarming rate and a depletion of water resources in the region. It is estimated that the accumulated overdraft of groundwater during the past two decades in the North China Plain has exceeded 90 billion cu m (Yang and Zehnder 2005). The depletion of groundwater has serious consequences, including land subsidence, seawater intrusion and loss of ecosystem functions. With the excessively high level of water withdrawal, many rivers and their tributaries in the north have had extremely poor ecological status. The Yellow River has become a seasonal river, and sent little or no water to the sea for most of the late 1990s (MWR 1997–2011).

State of Water Quality

The rapid economic growth in China during the past four decades has been accompanied by a continuous deterioration of its water quality. In China, water quality is divided into five categories that can be described as 'good' (grades I, II and III) or 'poor' (grades IV and V or V+). As shown in Figure 14.1, China's water quality is characterised by extended sections of water of poor quality. At the national level, more than 40 per cent of river sections currently have poor water quality. In northern China, water-quality degradation is severe in all major rivers with the percentage of monitored water sections ranked poor exceeding 60 per cent. In the Yangtze and Pearl River Basins in the south, more than 30 per cent of the monitored water sections have poor water quality. Water-quality status presents a serious situation in China, where water shortages and degraded quality interact and reinforce the negative effects of each other.

It should be mentioned that the water-quality issue has drawn much attention in China and huge investment has been poured into the construction of wastewater treatment facilities since the late 1990s; however, little improvement has been made so far. In many areas, water quality has been deteriorating. This situation is of particular concern for the southern rivers. During the past two decades, there has been a clear trend of water-quality degradation in the Yangtze and Pearl River Basins (MWR 1997–2011).

Figure 14.1 Water Quality in the Monitored Sections of the Major Rivers in China, 2010

Source: MWR (1997–2011).

While the water quality in rivers is bad, the situation in lakes is generally worse because of the slow circulation of water and the high concentration of pollution sources in surrounding areas. Among 44 major lakes in China, 56 per cent have water quality of grades IV, V and V+. The water quality for the entirety of Tai Lake is below Grade III. In the Dianchi and Chao Lakes, water quality is below Grade V. The huge investment in the past decade in the improvement of water quality in the Tai, Dianchi and Chao Lakes has so far achieved hardly any result (MWR 1997–2011).

Changes in Water-Use Quantity and Value in Different Sectors

Trends in Water Use in Different Sectors

Rapid economic development together with continuous population growth have generated an increased demand for water. Figure 14.2 shows the changes in water use in different sectors between 1980 and 2010.

Figure 14.2 Trends in Water Use by Industry, Domestic (Households) and Agriculture, 1980–2010

Sources: Liu and Chen (2001); MWR (1997–2011).

Between 1980 and 2009, total water use in China increased by 34 per cent. The increase, however, is solely from the industrial and household sectors. The quantity of water use in the industrial sector increased from 45.7 billion cu m

to 139.1 billion cu m, or threefold. The household sector had a much faster increase, from 6.8 billion cu m to 74.8 billion cu m, or elevenfold. In contrast, agricultural water use has experienced a decrease of 5 per cent, from 391.2 billion cu m to 372.3 billion cu m. About 19 billion cu m of the agricultural water was reallocated to the industrial and household sectors during this period.

Despite the decrease in agricultural water use, the total irrigated area in China expanded by 34 per cent between 1980 and 2010, from 44.89 million hectares to 60.35 million ha (SSB various years). This has been achieved with improvements in water-use efficiency in irrigation. On average, water use per hectare of irrigated land decreased from 8240 cu m/ha (549 cu m/mu)¹ to 6280 cu m/ha (417 cu m/mu). The North China Plain has been leading the trend, with current irrigation water use of between 3000 cu m/ha and 4000 cu m/ha. In Beijing, irrigation water use efficiency is reported to be as high as 0.8 (*China Daily*, 2011). In most other regions, however, irrigation water-use efficiency remains low. In the upper and middle reaches of the Yellow River and the north-west inland areas, it is below 0.5. Hence, the potential for improving irrigation water-use efficiency is considered to be high.

The need to allocate (or reserve) water for environmental uses has received attention in recent years. There is some confusion/disagreement about the appropriate amount of water required for maintaining healthy ecosystem status and functions. This is partly because of the complexity of measuring the ecosystem's water use and partly because of the close relations between the ecosystem water requirement and the society's demand for the quality of the aquatic environment. The latter evolves with economic development, as described by the Environmental Kuznets Curve (Jia et al. 2006). Despite the difficulty of determining the appropriate amount of water for the environment, it is clear that with competition for water from the economic sectors, little water has been left in the rivers of the northern regions. As the environment cannot represent itself in the competition for water, it is ultimately the responsibility of the government to ensure the allocation of water for maintaining ecosystem health at a level that is acceptable to (and demanded by) the society.

Changes in Water-Use Values

The quantity of water use per RMB10 000 gross domestic product (GDP) value is an indicator used in China to measure the water-use value of the economic sectors. Hereinafter, this metric will be referred to as 'water intensity'. Figure 14.3 shows the changes in this metric from 1993 to 2010. Water intensity decreased from 771 cu m in 1993 to 382 cu m in 2010. In the industrial sector,

1 'Mu' is a measure of land area in China. 1 mu is equivalent to 1/15 ha.

the figures are 363 cu m and 230 cu m, respectively (note that the GDP figure comes from a constant price series based on the year 2000). The decrease in water intensity is rather slow. This concurs with the generally low efficiency of resource use in China.

Figure 14.3 Sectoral Water Use Per RMB10 000 GDP Values, 1993–2010

Sources: The data for 1993 are from Liu and Chen (2001). The rest of the data are from SSB (various years).

Quantifying water intensity for individual economic sectors is complex because of the interconnection of water uses between sectors through the input–output relations. For example, the water used for a product in the textile industry might come partially from the agricultural sector through the raw materials it provided. Hence, the water-use value in the individual sectors can be accounted for by the direct water-use coefficient (DWUC) and the total water-use coefficient (TWUC), both of which are measured in the same fashion as aggregate water intensity. DWUC reflects the direct water intensity at the last stage of the production chain (the operational stage for a business or a factory), whereas TWUC reflects the water use throughout the whole production chain—for example, from cotton production to the final production of, say, a pair of jeans. Hence, it is also called the ‘life cycle water-use coefficient’. DWUC is the conventional measure for the sectoral water intensity; however, it does not reflect the total water embodied in final outputs because a large amount of water used is in the upstream supply chain. To this end, TWUC provides a more complete picture of water use. Based on China’s provincial input–output tables for 2002 and 2007 and the water-use quotas in individual economic sectors, DWUC and TWUC can be estimated. For simplicity, the full industrial classification has been compressed into 20 sectors. Table 14.2 shows DWUC and TWUC estimates for the individual sectors in 2002 and 2007.

Table 14.2 Water-Use Coefficient for 2002 and 2007 (cu m/RMB10⁴)

Sectors		2002		2007	
		DWUC	TWUC	DWUC	TWUC
1	Agriculture	1582	2068	924	1181
2	Coalmining and processing	38	268	22	140
3	Food and tobacco processing	39	991	23	523
4	Textile goods	37	652	21	520
5	Clothing	7	543	4	306
6	Sawmills and furniture	3	543	2	279
7	Paper and products	109	506	64	320
8	Petroleum processing	30	257	18	144
9	Chemicals	58	417	34	239
10	Non-metal mineral products	27	351	16	184
11	Metal smelting and products	49	386	29	217
12	Machinery and equipment	6	270	3	152
13	Transport equipment	7	291	4	147
14	Electrical equipment, telecommunications equipment	4	246	2	140
15	Other manufacturing	6	288	3	165
16	Electricity, gas and water production and supply	985	1251	575	840
17	Construction	5	271	3	159
18	Wholesale and retail trade and passenger transport	48	226	28	124
19	Restaurants and hotels	206	785	120	441
20	Other services	28	196	16	114

Sources: Zhang et al. (2011, 2012).

The difference between DWUC and TWUC is small in some sectors and large in others, reflecting different characteristics of water use in the production chain of each sector. In general, 'Agriculture' and 'Electricity, Gas and Water Production and Supply' (hereinafter, utilities) are direct water-use-dominated sectors, reflected by the high proportions of DWUCs in TWUCs. In contrast, most manufacturing sectors have large indirect water uses. In the sectors of 'Food and Tobacco Processing', 'Clothing', 'Sawmills and Furniture', 'Machinery and Equipment', 'Transport Equipment', 'Electrical Equipment' and 'Telecommunications Equipment', more than 95 per cent of the water use

takes place in an indirect way—that is, in the processing stages prior to the final stage. For example, clothing had a DWUC of 7 and a TWUC of 543 in 2002. This means that about 99 per cent of water use took place in the upstream supply chain of the industry.

For both 2002 and 2007, agriculture had the highest water intensity, with a TWUC of 2068 cu m per RMB10⁴ in 2002 and 1181 cu m/RMB10⁴ in 2007. This was followed by utilities, which had a TWUC of 1250 in 2002 and 840 in 2007. The other sectors with relatively high TWUCs are ‘Food and Tobacco’, ‘Textiles’ and ‘Restaurants and Hotels’, which are indirect water-use dominated. Their main water uses were incurred in the upstream supply chain, typically through raw materials from the agricultural sector.

Compared with 2002, in 2007, all the sectors showed notable reductions in both DWUC and TWUC. The scale of the reduction is mostly between 20 per cent and 50 per cent, indicating that considerably less water was used in the production of one unit of output in 2007 compared with that in 2002. The sectors with the largest reductions in TWUC are ‘Sawmills and Furniture’, ‘Transport Equipment’, ‘Coalmining and Processing’ and ‘Non-Metal Mineral Products’, where the reductions amounted to 49 per cent, 49 per cent, 48 per cent and 48 per cent respectively. The pace of the reduction in DWUC and TWUC, however, was not fast enough to offset the incremental water use due to the expansion of production. Total water use at the national level increased from 549.7 billion cu m in 2002 to 581.8 billion cu m in 2007.

Major Sources of Water Pollution

Sources of water pollution are mainly wastewater discharge from industrial and household sectors and non-point source pollutants from agriculture (for example, from fertiliser, pesticide, processing residuals, and so on). The official statistics on wastewater discharge include only industrial and household wastewater. In the industrial sector, statistics for wastewater discharge account for only the enterprises at and above county level. Enterprises at the township level and below are not included. No information on agricultural water pollution is reported partly because of the difficulty of measuring the non-point source pollution from agriculture. Figure 14.4 shows the trend in wastewater discharge from the industrial and the household sectors during 1981 and 2010.

Figure 14.4 Trends in Industry (Enterprises at or Above the County Level) and Domestic (Household) Wastewater Discharge, 1981–2010

Source: SSB (various years).

The quantity of industrial wastewater discharge has not changed significantly over the years, while household wastewater discharge has increased rapidly. In the 1980s, industrial wastewater dominated the total wastewater discharge. The household wastewater discharge surpassed the level from industry in the 1990s to become the major source of wastewater discharge. Part of the discharged wastewater from industry and households is after treatment and meets the state discharge quality requirement. According to the official Chinese statistics, the proportion of the wastewater discharge meeting the effluent standard has increased steadily in the industrial sector. Currently, about 92 per cent of industrial wastewater discharge meets the requirement (SSB various years); however, as the wastewater discharge and the treatment rates are reported by local government agencies, there is a high possibility of underreporting in the official statistics. This is because of a strong incentive for reporting smaller wastewater discharges, especially of the amount below the effluent standard. In reality, the treatment rates for both industrial and household wastewater are probably much lower.

Adding to the problems of measurement is pollution from rural enterprises that is not accounted for in the official statistics. It must be pointed out that the exclusion of wastewater discharge from these enterprises substantially understates the intensity of industrial water pollution. Small scale and low technology are the common features of rural enterprises. They are notorious for releasing heavily polluted wastewater without any treatment.

Unlike industrial wastewater discharge, which in general requires treatment within the system before release into waterways, household wastewater is collected and treated on site or transferred to centralised wastewater treatment plants. In reality, due to the lack of collection networks and treatment facilities/capacities, as well as the generally poor economic returns of the wastewater treatment business, a high proportion of household wastewater is released to water bodies without treatment. In small cities, the untreated component of household wastewater can be as high as 90 per cent (SEPA 2010).

Table 14.3 Major Polluting Sectors and their GDP Values, 2010

	Industrial wastewater discharge	Gross industry output value	Wastewater/ output value
Sector	10 ⁴ tonnes	RMB10 ⁸	cu m/RMB10 ⁴
Mining and washing of coal	80 235.5	16 404.27	48.91
Mining and processing of non-ferrous metal ores	37 307.31	2814.67	132.55
Processing of food from agricultural products	143 837.66	27 961.03	51.44
Manufacture of foods	52 699.09	9219.24	57.16
Manufacture of textiles	239 115.6	22 971.38	104.09
Manufacture of leather, fur, feather and related products	24 964.32	6425.57	38.85
Manufacture of paper and paper products	392 604.14	8264.36	475.06
Manufacture of raw chemical materials and chemical products	297 061.66	36 908.63	80.49
Manufacture of medicines	52 718.39	9443.3	55.83
Manufacture of chemical fibres	43 854.81	3828.32	114.55
Smelting and pressing of ferrous metals	125 978.31	42 636.15	29.55
The sum of the above sectors	1 490 376.79	186 876.92	
Average			79.75
Percentage of national total	71	34	

Source: SSB (various years).

The wastewater discharge intensity varies among industrial sectors. Table 14.3 shows the large contributors to industrial wastewater discharge. At the national level, the sectors encompassed in Table 14.3 account for 34 per cent of the total gross industrial output value, whereas they produce 71 per cent of the total industrial wastewater discharge. The sectors with very high wastewater discharge intensity are Mining, Textiles, Paper and Chemical-related industries. Bearing in mind that small rural enterprises are highly

concentrated in these sectors, the untreated wastewater discharge from these enterprises has a significant impact on water quality. This perhaps partially explains the situation that the observed water quality is often worse than that reported in the official statistics.

The Impact of China's International Trade on its Water Resources

International trade between countries entails flows of virtual water—that is, the water used for the production of traded products. With world markets filled with ‘made in China’ products on the one hand and the increasingly severe water stress and pollution endured in most parts of China on the other, the impact of China's international trade of goods and services on its water resources warrants scrutiny. The input–output tables for the 30 provinces (excluding Tibet) in 2002 and 2007 are used for the investigation.

Sectoral Assessment

The virtual water trade by sector is quantified for the whole production chain, instead of just the final stage of the process—that is, these are comparable in breadth with the TWUCs estimated above. In so doing, the total water use for the final products in individual sectors can be better reflected. The virtual water associated with the trade of the products in individual sectors includes the water used for the production of the input materials that are from other sectors—typically from the primary sectors. Table 14.4 shows the estimated virtual water flows associated with China's international trade.

China as a whole is a net virtual water exporter. The annual net virtual water export was estimated at 39.04 billion cu m in 2002 and 68.18 billion cu m in 2007. This represents an increase of 74 per cent over five years. The situation coincides with the trend seen in the national total water use mentioned earlier. The improvement in water-use efficiency in individual sectors has not been able to offset the additional virtual water exported due to the expansion of international trade during this period.

Of the 20 sectors in the study, only Agriculture, Petroleum Processing, Machinery and Equipment and Utilities are net importers of virtual water. The remaining sectors are net exporters. Textiles, Clothing, Electrical Equipment, Telecommunications Equipment, Wholesale and Retail Trade, Passenger Transport and Metal Smelting and Products are the five major net virtual water exporters. Their net virtual water export accounts for more than 85 per cent of the national total. These sectors are also mainstay industries in China, greatly contributing to China's role as the ‘world's factory’.

Table 14.4 Sectoral Virtual Water Trade in 2002 and 2007 (10⁶ cu m)

Sectors	2002			2007		
	Virtual water export	Virtual water import	Net virtual water export	Virtual water export	Virtual water import	Net virtual water export
1 Agriculture	7080	10 247	-3167	18 212	21 137	-2924
2 Coalmining and processing	273	27	246	678	123	555
3 Food and tobacco processing	5595	2783	2812	7288	5137	2151
4 Textile goods	11 644	829	10 815	6329	313	6015
5 Clothing	8375	700	7675	19 392	1363	18 029
6 Sawmills and furniture	2833	469	2364	5239	402	4837
7 Paper and products	3446	785	2661	4928	753	4175
8 Petroleum processing	499	1536	-1037	1139	3167	-2028
9 Chemicals	6635	4107	2528	10 430	4653	5777
10 Non-metal mineral products	1383	390	992	2170	434	1736
11 Metal smelting and products	4059	2321	1738	13 278	4493	8785
12 Machinery and equipment	2286	5858	-3572	6085	6990	-905
13 Transport equipment	1344	1337	7	3735	1334	2400
14 Electrical equipment, telecommunications equipment	12 575	5011	7564	32 067	10 028	22 039
15 Other manufacturing	2802	1761	1042	1532	736	796
16 Electricity, gas and water production and supply	60	3193	-3133	1325	7090	-5765
17 Construction	124	89	35	481	2352	-1871
18 Wholesale and retail trade and passenger transport	6449	375	6074	5074	1431	3643
19 Restaurants and hotels	1749	18	1730	1184	291	893
20 Other services	3430	1765	1665	2067	2229	-163
Total	82 641	43 602	39 038	142 634	74 457	68 177

Sources: Zhang et al. (2011, 2012).

It is worth noting that Food and Tobacco Processing and Textiles and Clothing are typical downstream industries of agriculture—that is, using raw materials from agriculture as inputs. Although the agricultural sector is a net importer of virtual water, its downstream industries are not. The situation implies that part of the imported virtual water in agriculture is re-exported through the exports of products in its downstream sectors.

Net virtual water exports are highly concentrated in Textiles, Clothing and Electrical Goods and Communication Equipment. These sectors are typically labour intensive, employing a large number of rural migrant workers. In terms of water use, Textiles and Clothing are rather water-intensive sectors with high TWUCs. The share of these sectors is often high in water-scarce regions, such as Tianjin, Hebei and Shandong. The impact of international trade on water resources in the water-scarce provinces is therefore more significant.

In addition to the impact on the quantity of water resources, China's international trade also impacts on its water quality. The wastewater discharge from Food and Tobacco Processing, Textiles, Clothing, Paper and Products, and Metal Smelting and Products accounts for a large percentage of the total industrial wastewater discharge (Table 14.3). Small-scale and low-technology rural enterprises are mostly concentrated in these sectors. Hence, China is exporting a large amount of virtual water to other countries while keeping heavy water pollution to itself.

Regional Assessment

With total water resources of 2812 billion cu m per year in China, the net virtual water export of 68.2 billion cu m/year (in 2007) is about 3.1 per cent of its total water resources. As a large portion of the country's water resources are not accessible to the water-poor regions due to geographical barriers, the impact of China's international trade on water resources is, however, much more significant when viewed at the regional level. In the extremely water-scarce Huang–Huai–Hai (HHH) region, 5.1 per cent of the region's water resources are forgone due to virtual water exports.

Total water use in China was approximately 526 billion cu m in 2007 (SSB 2008). The net virtual water export accounted for 11.5 per cent of total water use (Table 14.5). In the water-scarce HHH region, roughly 7 per cent of the total water use was for export. The share in Tianjin—an extremely water-scarce city in this region—was 63 per cent. In Beijing and Shandong, the shares were 17.9 per cent and 20 per cent, respectively. The results suggest that China's economic gains from being the 'world's manufacturing powerhouse' (McKay and Song 2010) have been attained at a high cost to its water resources and environment, particularly in the northern regions.

Table 14.5 Water Resources (WR), Water Use (WU) and Net Virtual Water Export (NVWE) in Different Regions, 2007

Regions	Provinces	NVWE	NVWE/WR	NVWE/WU
		10 ⁶ cu m	%	%
North China Plain	Beijing, Tianjin, Hebei, Shanxi, Shandong and Henan	5240	5.1	6.9
North-East	Liaoning, Jilin and Heilongjiang	378	0.3	0.7
East and Middle	Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei and Hunan	21 662	3.5	10.8
South	Fujian, Guangdong, Guangxi and Hainan	26 044	5.2	25.7
South-West	Chongqing, Sichuan, Guizhou and Yunnan	423	0.1	0.8
North-West	Inner Mongolia, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang	14 429	5.6	14.2
Nation		68 177	3.1	11.5

Sources: Data for WR and WU are from SSB (2008); data for NVWE are from Zhang et al. (2012).

Balancing Water Needs Between Society and Nature

China's water problems are characterised by insufficient quantity and poor quality. Rapid economic development and urbanisation combined with population growth continue to intensify the conflict between water supply and demand; and adverse future climate change is expected to increase China's vulnerability to water scarcity.

Poor management is one of the important factors responsible for the water problems in China. Hence, improving water resource management is crucial for alleviating China's water vulnerability. Addressing China's water problems requires a holistic, integrated and scientific approach with long-term and coordinated efforts. In recent years, some efforts have been made to improve water resource management to support long-term economic growth and restore aquatic ecosystem functions.

China is making efforts to improve institutional systems that regulate water withdrawal and uses. River basin conservation commissions, under the Ministry of Water Resources, have been entrusted with more power over the administration and management of the water defined by basin boundaries and consistent with the hydrological cycle of water resources. Issuing water

withdrawal permits has been gradually implemented in some river basins. In this respect, the Yellow River Conservancy Commission (YRCC) has been at the forefront. The current Yellow River water allocation plan is enforced with both total quantity control and cross-provincial border discharge monitoring. In recent years, a so-called 'investment for water saving and water rights transfer measure' has been put forward in the Yellow River Basin. It mainly concerns water reallocation from agriculture to industry. As obtaining additional water in the water-scarce basins has been difficult, the increase in industrial water demand has to be met with the transfer of water from the agricultural sector. Given the widespread low efficiency in irrigation, the potential for water saving is considered high (Yang and Jia 2008). Industries, especially large enterprises, are encouraged to invest in water-saving projects in the existing irrigation schemes in exchange for the rights for the use of part of the saved water. The measure is regarded as a 'win-win' solution for low water-use efficiency and water shortages in water-scarce regions. So far, however, all the water rights transfers have been conducted within individual provinces. Cross-provincial water rights transfers have not taken place. In general, provinces are not willing to give up their entitled shares of water. This is partly because of the increased administrative complexity in water rights transfer across provincial boundaries. More importantly, recognising that water scarcity is a long-term trend in many parts of China, individual provinces all want to hold their shares of water for their own economic development. Water rights transfer is still in its infancy. Its scale and overall effect on improving water use efficiency remain to be seen.

Since the late 1990s, economic incentive-based approaches—typically water pricing and wastewater charges—have been given much emphasis in the effort to build a 'water-saving' society. With the exhaustion of suitable sites for water projects on the major rivers, as well as the very high withdrawal ratios from the northern rivers, augmentation of water supply becomes more and more difficult and costly. The economic incentive-based approaches are implemented to allow the market to adjust water demand and supply. Increasing water prices have been a general trend seen in all economic sectors; however, the pricing mechanism alone has not been effective in capping total water use within a sustainable amount. In many places, total water use has been rising continuously while water pollution has been worsening. The situation suggests that integrated approaches, including economic and non-economic measures, are necessary to tackle the water shortage and pollution problems, which are often interconnected.

Environmental water use and ecosystem water requirements have received increasing attention since the late 1990s. The criteria used for estimating ecosystem water demand are often subjective. Thirty per cent of the average river flow is commonly used as a rule-of-thumb percentage for the amount

of water required to maintain healthy aquatic ecosystems. As mentioned earlier, the ratios of water withdrawal to water resources in the major northern rivers all exceeded 70 per cent, meaning that less than 30 per cent of water is left for ecological maintenance. In the Hai River Basin, where the ratio exceeded 100 per cent, the environment is left with essentially no water. It is interesting to note that the argument for the need to meet the ecosystem's water demand in the rivers of the North China Plain has been an important factor in the decision on the construction of the South–North Water Transfer Project (Yang and Zehnder 2005).

Facing the enormous challenges of water shortages and pollution, the Chinese Government has been implementing more stringent controls over water uses and wastewater discharges. In January 2012, the State Council released a 'Red Head' document (No. 3), in which several ambitious controlling Red Lines are set. For the year 2030, total water use will be capped at 700 billion cu m, compared with approximately 600 billion cu m in 2010. Water intensity will be reduced to 40 cu m (GDP being measured at 2000 prices). Agricultural irrigation water-use efficiency will be lifted to above 0.6, compared with the current 0.5. Water quality will be 'good' in 95 per cent of water bodies (SC 2012). There are many challenges to surmount before these targets can be reached. It requires the establishment of accountable water resource management and evaluation systems, sound monitoring systems, investment mechanisms, regulations and laws, enforcement agencies and social scrutiny. How successful China will be in achieving these goals remains an open question.

Conclusion

China's water endowments are unfavourable in terms of both the quantity (relative to its population) and spatial distribution. Water pollution due to the rapid pace of industrialisation and urbanisation has also aggravated the physical scarcity by reducing the availability of useable water. In many regions, water shortage has become a bottleneck to economic development, while water pollution has posed an increasingly high risk to human health as well as threatening environmental sustainability. As the major exporter of low value-added and high water-use intensity manufactured products, China has been exporting a large amount of virtual water, while keeping heavily polluted water to itself.

The low efficiency of water use in China concurs with the generally low efficiency of resource use and the dependence of economic growth on the expansion of resource supply. This calls for an integrated approach, including economic (such as water pricing) and non-economic measures. An integrated

approach is necessary to tackle the water shortage and pollution problems simultaneously. Decoupling economic growth from increasing water use and pollution is important for long-term economic development. A regional economic structural adjustment taking into consideration water resource endowments would be conducive to reducing pressure on the limited water resources in the water-scarce regions. Also important is the establishment of enabling institutions that can ensure the effective enforcement of the required measures for improving water resources management.

Water shortages and water pollution are serious problems. How China deals with these challenges will be vital for its long-term economic development and environmental sustainability. Given its central position in the world economy, China's degree of success in overcoming these challenges will have material implications for the rest of the world.

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