Chapter Five

WATER RESOURCES AND POLLUTION

Our analysis of China's complex water and pollution problems begins with estimates of the sharply differing water supply and demand conditions within China. The discussion then considers the economic effects of floods, water shortages, and pollution, concluding with an evaluation of alternative means and scenarios for addressing these problems and their respective costs and consequences.

ESTIMATING WATER SUPPLY AND DEMAND

Water Resources and Regional Disparities

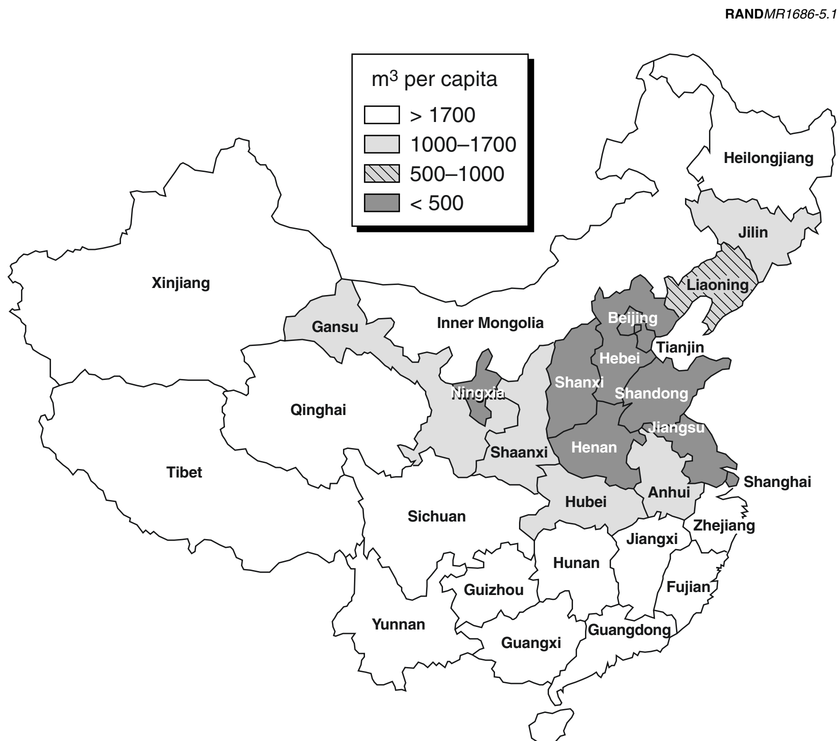
Global water resources amount to 42,655 billion m^3, and global water resources per capita in 2000 were 7,045 m^3 (World Resource Institute [WRI] et al., 2000). China's water resources are huge, 2,812 billion m^3, which is 6.6 percent of the world total and the fourth largest in the world. However, China's population is very large; hence, the annual flow of per-capita water resources in 2000 is 2,201 m^3 (WRI et al., 2000)—less than one-third the world average. According to the WRI water-criticality classification framework, current nationwide water availability per capita in China is slightly above the sufficiency threshold level (Yang and Zehnder, 2001), although it will eventually approach the alarmingly low level of 1,700 m^3 per capita by 2030, when China's population will exceed 1.5 billion.

China's natural and socioeconomic conditions vary substantially, and China especially suffers a major imbalance in the timing[1] and location of its water supply. As shown in Figure 5.1, Yang and Zehnder (2001) illustrate the spatial distribution of water resources per capita (without considering water inflow and outflow) across provinces using the water-criticality classification, revealing a serious water shortage in the North China plain. Many rivers of the 3-H basins (Hai-Huai-Huang Rivers) are dry for five to eight months of the year. The Yellow (Huang) River, the cradle of Chinese civilization and the country's second longest river, with a drainage area of about 750,000 km^2, has annual runoff of less than 7 percent of that of the Yangtze River. The Yellow River has been overused, and since 1985, it has run dry each year; in 1997, it failed to reach the sea for 226 days. The inflows into Shandong dropped from 40 billion m^3 in the early 1980s to around 25 billion m^3 in the 1990s (Yang and Zehnder, 2001), and a similar situation is evident in Hebei and Henan as well. With growing upstream claims, the Yellow River may at some point no longer reach Shandong province at all.

The problem is not simply regional but also national, because the North China plain is one of the nation's key economic areas, holding one-third of the nation's population (424 million people), 40 percent of the cultivated land, and 31 percent of total GDP. This region has been the "breadbasket" of China, producing over 67 percent of the nation's wheat and 44 percent of its corn. However, the rivers of the northeast basins account for only 7.5 percent of the country's total runoff discharge (see Table 5.1). The water shortage is particularly serious in the Hai River basin which has a population of 92 million and includes the Beijing-Tianjin region.

Compared with the average water use shown in Table 5.2, the annual withdrawal per capita in the Hai River basin region cannot reach even the level of low-income countries without mining groundwater stock, transferring water across the basin, or recycling used water, even assuming that annually renewable water resources were completely allowed for. Groundwater has been tapped to make up the

[1]China has a typical monsoon climate, and precipitation mostly concentrates during the rainy season, which lasts a maximum of four months. This rainfall accounts for 50–80 percent of the annual rainfall.



SOURCE: Yang and Zehnder, 2001.

Figure 5.1—Per-Capita Water Availability by Province, 1998

difference, resulting in overexploitation of subsurface water and ground subsidence, seawater intrusion, drying up of shallow aquifers, and falling water tables. The consequence of groundwater depletion is exhaustion and desertion of wells. In 1997, about 220,000 new wells were drilled, but at the same time, 100,000 old ones were deserted in the North China plain, and particularly in Beijing and Tianjin, the numbers of deserted wells exceeded those of newly drilled wells (Yang and Zehnder, 2001). Irrigation relying on overexploiting of groundwater stock is unsustainable, and the absolute decline that occurred in Beijing and Tianjin could occur in other provinces like Shandong and Hebei.

Table 5.1

Annually Renewable Water Resources in China, 1993

Region		Surface Runoff (billions of m^3)	Ground-water (billions of m^3)	Total Water Resources[a] (billions of m^3)	Water Resources (percentage)	Population (percent-age)	Cultivated Land (percent-age)	Per-Capita Water Resources (m^3/yr/person)	Water Re-sources Per Crop Land (m^3/yr/ha)
I	Northeastern	165.3	62.5	192.8	6.9	10	19.8	1,479	9,560
II	Hai He-Luan He basin	28.8	26.5	42.1	1.5	10	10.9	225	3,760
III	Huai He basin	74.1	39.3	96.1	3.4	16	14.9	389	6,310
IV	Huang He basin	66.1	40.6	74.4	2.6	8	12.7	656	5,730
	II+III+IV	169.0	106.4	212.6	7.5	34	38.5		
V	Yangtze River basin	951.3	246.4	961.3	34.2	34	24.0	2,369	39,300
VI	Southern	468.5	111.6	470.8	16.8	12	6.8	3,465	67,950
VII	Southeastern	255.7	61.3	259.2	9.2	6	3.2	2,999	73,800
VIII	Southwestern	585.3	154.4	585.3	20.8	2	1.7	31,679	327,000
	V+VI+VII+VIII	2,260.8	573.7	2,276.6	81.0	54	35.7		
IX	Interior basins	116.4	86.2	130.4	4.6	2	5.8	4,832	21,850
	National total	2,711.5	828.8	2,812.4	100.0	100.0	100.0	2,323	28,000

SOURCE: Feilig, 1999.

[a]Total water resources are less than surface runoff plus groundwater because of some double counting in the latter two sources.

Table 5.2

Water Withdrawals

Group	Annual Withdrawal Per Capita (m^3)	Withdrawals by Sector (percentage)		
		Domestic	Industry	Agriculture
Low income	386	4	5	91
Middle income	453	13	18	69
High income	1,167	14	47	39
World (1995)	664	9	19	67
China (1993)	439	5	18	77

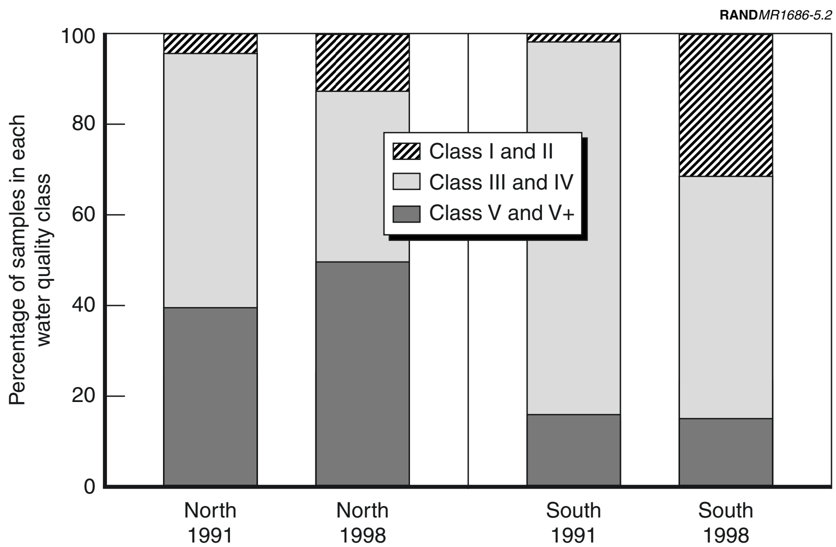
SOURCES: World Bank, 1994; World Resource Institute et al., 2000.

In addition, as growing wastewater discharges from the industrial and urban sectors exceed the capacity of treatment facilities, China's water shortage problems are aggravated by pollution. Since the volume of surface runoff is so small in North China, even a small amount of pollutant easily degrades water bodies below the quality level suitable for irrigation, and in turn, this pollution further aggravates the shortage of water resources. Figure 5.2 shows the trend of water quality in the seven main rivers in 1991 and 1998. The incidence of both good quality and poor quality increased during the 1990s in both North and South China. The incidence of class V/V+ (poor quality not even fit for irrigation) river water is three times higher in the north. In North China, while the Liao and Huai Rivers showed some improvement, conditions in the Hai, Yellow, and Songhua Rivers have deteriorated (World Bank, 2001b).

In sum, water shortages and pollution have become a serious limiting factor of the regional development of North China.

Demand Estimation for Agriculture, Industry, and Municipalities

China extracted 543.5 billion m^3 of water in 1998, a 22 percent increase from 443.7 billion m^3 in 1980. In 1993, total withdrawal was 518.7 billion m^3 (see Table 5.3), and 78 percent of this water was used by agricultural sectors (66 percent for irrigation); industry was the second largest user, but urban water supply systems used only 24



SOURCE: World Bank, 2001b.

NOTES: North China: 3-H, Songhua, and Liao Rivers; South China: Yangtze and Pearl Rivers.

Figure 5.2—Comparison of Water Quality in North and South China, 1991 and 1998

billion m^3. While agriculture is by far the dominant user, the growth in agricultural water use was very low—the increase between 1980 and 1993 was only 4 percent, despite increases in the area of irrigated fields, from 20.8 million hectares (ha) in 1985 to 22.5 million ha in 1995. By comparison, the increase in industrial water use was 94 percent, and urban water supply use increased remarkably by 256 percent, from 6.8 billion m^3 in 1980.

Domestic water consumption in urban areas has been rising due to both urbanization and increased per-capita consumption by urban residents (from 113 liters/day in 1980 to 230 liters/day in 1997). The highest share of urban water use was found in the Hai-Luan River basin, which includes Beijing and Tianjin (see Table 5.3).

Table 5.3

Water Use by Economic Sector in China, 1993
(billions of cubic meters)

Region		Industry	Urban Water Supply	Agriculture		Total	Industry (%)	Urban Supply (%)	All Agriculture (%)
				Irrigation	Others				
I	Northeastern	9.90	2.66	33.13	4.14	49.83	19.9	5.3	74.8
II	Hai He-Luan He basin	6.82	3.62	27.47	3.35	41.26	16.5	8.8	74.7
III	Huai He basin	6.08	2.29	39.86	8.68	56.90	10.7	4.0	85.3
IV	Huang He basin	4.86	2.07	29.88	3.37	40.18	12.1	5.2	82.8
	II+III+IV	17.76	7.98	97.21	15.40	138.34	12.8	5.8	81.4
V	Yangtze River basin	40.92	7.23	101.00	15.06	164.16	24.9	4.4	70.7
VI	Southern	13.88	4.22	48.00	6.56	72.66	19.1	5.8	75.1
VII	Southeastern	4.61	1.36	20.21	2.72	28.89	16.0	4.7	79.4
VIII	Southwestern	0.33	0.09	4.83	1.19	6.44	5.1	1.4	93.5
	V+VI+VII+VIII	59.74	12.90	174.04	25.53	272.15	12.1	5.2	82.8
IX	Interior basins	1.45	0.56	38.97	17.25	58.23	2.5	1.0	96.5
	National total	88.85	24.10	343.35	62.32	518.55	17.1	4.6	78.2

SOURCE: Feilig, 1999.

Two competing factors will affect China's future demand: (1) growing water demand in the urban and industrial sectors due to further economic development and rapid urbanization; and (2) implementation of programs for efficient water use and conservation measures, particularly in the irrigation sector but also in all other sectors. Without sufficient progress in water use efficiency, Brown and Halweil (1998) projected that water demand in 2030 may reach 1,068 billion tons, nearly twice the consumption in 1998, given that by 2030 there will not be 1.2 billion poor Chinese, but 1.5 billion rather affluent Chinese. Between 2000 and 2010, China's population is projected to grow by 126 million, and a World Bank paper (2000b) estimates that China's water needs will increase to 670 billion m^3 by 2010. Only one-half of this incremental demand can be met through additional development of water resources, while the remainder will need to be met through water savings, or "deficit irrigation."

World Bank (2001b) estimates the demand for water in the 3-H basins in 2000 at 169 billion m^3, exceeding the supply by more than 30 billion m^3. In normal years, the irrigated and urban areas nationwide report an annual shortage of 30–35 billion m^3 and 5–6 billion m^3, respectively (World Bank various estimates). Yang and Zehnder (2001) project that even if improvements in irrigation efficiency reduces water demand in agriculture, the increase in water demand in the municipal and industrial sectors (6.5 billion m^3) far exceeds such decline, and an additional 4 billion m^3 of water will be needed within the coming decade in Beijing, Tianjin, and the three 3-H basin provinces.

As water use increases, particularly in industrial and urban sectors, wastewater discharges are also rapidly rising (about 42 billion m^3 from the urban and industrial sectors according to the Statistical Agency of the PRC, 2000 and 2001). The most ubiquitous pollutant is readily degradable organic material from domestic and industrial sources (World Bank, 2001b). China generates the largest total emissions of organic water pollutants in the world—the equivalent to the emissions of the United States, Japan, and India combined, as shown in Table 5.4 (World Bank, 2000b). The three major sources of water pollution are industrial, municipal, and agricultural (including fertilizer, pesticide, and livestock production) wastewater discharges.

The total volume of industrial wastewater discharge declined over the 1990s, particularly after 1995, when the government enacted a series of emergency measures, including the closing of 15 types of small-scale township and village enterprises throughout the country. Industrial wastewater treatment ratios (i.e., the proportion of total wastewater that passes through a treatment plant) have increased over the 1990s, from about 20 percent early in the decade through 77 percent in 1995 to 95 percent in 2000 (Statistical Agency of the PRC, 2000 and 2001). However, wastewater treatment effectiveness (i.e., the proportion of treated wastewater meeting relevant national standards) declined, and the World Bank (2001c) claims that this observation supports the view that the regulatory system provides good incentives for installing treatment facilities, but far less incentive to operate them since pollution levies are set too low.

Total wastewater flows and loads from municipal sources (22.1 billion m^3) now exceed those from industrial sources (19.4 billion m^3) (Statistical Agency of the PRC, 2000 and 2001). Double-digit growth of municipal wastewater treatment significantly improved the wastewater treatment ratio from 4 percent in 1991 to 10 percent in 1998 (World Bank, 2001c), but nonetheless Chinese cities still need massive investment just to maintain the current wastewater treatment ratio. World Bank (2001c) estimates that installed treatment capacity has to increase by six- or seven-fold to double the service level over the next 20 years.

Table 5.4

Emissions of Organic Water Pollutants from Industrial Activities (kilograms per day)

		Total Emission		Emission Per Worker	
Rank	Country	1980	1993	1980	1993
1	China	3,358,203	5,339,072	0.14	0.15
2	United States	2,742,993	2,477,830	0.14	0.15
3	Japan	1,456,016	1,548,021	0.14	0.14
4	India	1,457,474	1,441,293	0.21	0.20
World total		18,745,247			

SOURCE: World Bank, 2000b.

Agriculture generates water pollution through nutrient runoff, pesticides, and emissions from intensive livestock production. It is especially noteworthy that World Bank (2001c) estimates the ratio of the chemical oxygen demand (COD) load because of untreated piggery wastes to total COD loads will increase from 28 percent in 1996 to 90 percent in 2010 in the central south, south, and east regions.

IDENTIFYING THE CONSEQUENCES OF FLOOD, WATER SHORTAGE, AND POLLUTION ON THE ECONOMY

Effects on Agriculture

Changes in diet and urbanization are the major driving forces for the restructuring of China's agriculture. Food preferences in China have rapidly changed to a more diverse diet—not only are Chinese eating more meat, but they are also increasing their consumption of vegetables, fruit, alcohol, sugar, eggs, and dairy products. Feilig (1999) points out that diet changes have affected agriculture in two ways: (1) conversion of land usage from grain production to production for vegetables, tobacco, orchards, or fish ponds; and (2) a massive expansion of feed grain cultivation to meet the increase in meat consumption. Because of the low energy efficiency of cycling grain through animals, more cropland is needed to support a meat-based diet than one based on grain.

Arable land is a precious resource for China's agriculture since most of the country is covered by mountains and deserts. For many years, the area of China's cropland was severely underestimated because it was based on the official estimates of about 95 million hectares from the Statistical Agency of the PRC. However, Feilig (1999) and World Bank (1997b) estimate the true area of China's cropland in the mid-1990s in the range of 132–136 million ha, and hence, grain yields per ha were overestimated and there is more room to increase productivity. According to the agro-ecological-zones model calculation (Feilig, 1999), potentially arable land for grain cultivation in China is estimated to be some 162 million ha and has the potential to produce 650 million tons of grain; so Feilig (1999) and World Bank (1997b) claim that the bottleneck for food production is not land, but the availability of investment capital, agricultural know-how, infrastructure in remote areas, and most importantly water.

China's water problems critically affect food production through droughts, flooding, and pollution (Feilig, 1999). Table 5.5 shows the areas affected by natural disasters out of about 130 million ha of the total farmland.

1. *Water shortage/droughts in North China:* In the north and northwest, China's agriculture suffers from severe and increasing water shortages, especially in downstream areas. For instance, droughts in 1999 caused damage of 89.4 billion yuan (US$ 10.7 billion or 1.1 percent of China's 1999 GDP) (*China Daily,* 2000). This water shortage is exacerbated by inefficient irrigation systems in upstream areas, increasing water consumption in urban areas, and possibly declines in precipitation. Water deficit is not only a volume problem, but more often a timing problem, since during the dry season, the rivers dry up for several months. Building more reservoirs and dams could reduce this problem.
2. *Flooding:* A complex system of lakes and wetlands serves as a natural defense against flooding, supplemented by man-made reservoirs and dikes. However, this system has been weakened by unplanned land uses over the past four decades—especially excessive logging, cultivation, construction, and industrial development. As a result, increased silt, industrial waste, and other solids flowed into the rivers and wetlands, raising water levels and reducing the capacity of lakes and reservoirs. *China Daily* (2001d) reports that among 85,000 reservoirs in China, over 30,000 are in dangerously poor condition. A massive deluge of the Yangtze River in 1998 killed 4,000 people and caused US$ 30 billion (255 billion yuan) in damage.

Table 5.5

Areas in China Affected by Natural Disasters, 1978–1997

	Total	Drought		Flood		Other	
Year	(million ha)	(million ha)	%	(million ha)	%	(million ha)	%
1978	21.8	18.0	82.4	0.9	4.2	2.9	13.3
1988	23.9	15.3	63.9	6.1	25.6	2.5	10.5
1996	21.2	6.2	29.4	10.9	51.1	4.1	19.5
1997	30.3	20.3	66.8	5.8	19.3	4.2	13.9

SOURCES: Feilig, 1999; primary source: SSB, 1997.

3. *Water pollution from industrial and urban areas:* This type of pollution includes oil products, heavy metals, phenol compounds, cyanide, arsenic, chlorinated hydrocarbons, sulfates, and nitrates that pose a major risk for agriculture. World Bank (1997d) estimates that increasing wastewater treatment from 30 to 50 percent would increase grain production by about 24 million tons by 2020. Pollutants, especially heavy metals, can accumulate in irrigated fields and enter the human food chain, thereby threatening public health as well. According to WRI et al. (1998), numerous studies have shown significant increases in cancer rates and deaths and birth defects in sewage-irrigated areas.

As shown in Table 5.5, water shortage is a serious and widespread problem. Irrigated grain yields are nearly double those of rain-fed grain, and nearly triple those of poorly endowed loess plateau (World Bank, 1992a). The 3-H basins produce one-half of the major grains in China, and their annual output value is over 120 billion yuan (US$ 14.5 billion) (World Bank, 2001d). Irrigation agriculture accounts for two-thirds of all production in the 3-H basins, but the shortage of irrigation water was estimated at about 32 billion m^3 in 1997 by the World Bank.

Floods affect mainly the southern areas and the lower reaches of rivers, which are the central core of Chinese agriculture, and the area prone to flood disaster (30 percent or more decreases in yields) accounts for 8 percent of China's sown area (Zhang, 1999). Flooding leads to fluctuation in grain production and thus threatens food supply stability for the Chinese population. Increased emergency buffer stocks for grain, improved food logistics, and a flexible import policy could reduce the impact of flood-related harvest fluctuation.

The Three Gorges Dam is intended to regulate China's Yangtze River and provide energy. While the government claims that large dams, such as the Three Gorges Dam, will end centuries of deadly floods and landslides, environmentalists warn that large dams tend to decrease the frequency of small floods but increase the likelihood of big ones. For example, if the 27.5 billion m^3 of water to be contained by the Three Gorges Dam were ever unleashed, an unprecedented catastrophe would occur (Kriner, 1999).

Effects on Industry, Municipal Water Supply, and Public Health

Most of China's impressive economic growth since 1978 has occurred in the industrial and commercial sectors, and as a result, industrial and urban demand for water increased over 500 percent since 1978, but actual water supplies have increased only around 100 percent. Out of 668 major cities, the central government classified 300 cities as short of water, 108 of which as having serious problems, and 60 as being critically short of water.

In general, water consumption by industry per unit of output value is more wasteful in China than in developed countries, but in Beijing, factories recycled 91.4 percent of all the water they used in 1996, a substantial increase from 58.2 percent in 1980; water withdrawal per 10,000 yuan output value was decreased from 155 m^3 in 1980 to 44 m^3 in 1996 (Lee, 1998). Average productivity of water use for Chinese industry is 24 yuan or \$3 per m^3, but it is 67 yuan or \$8 per m^3 in North China. World Bank (1997f) and a Chinese source (WRI et al., 1998) estimate the annual loss of industrial output due to water shortage in cities at 120 billion yuan or US\$ 14.5 billion. However, these are overestimates since the marginal productivity is lower than the average productivity of water on which these estimates are based. Wang and Lall (1999) developed a production function using data from over 1,000 nationwide Chinese industrial plants in 1993, and they estimate the industrywide average output elasticity of water at 0.17 and the nationwide marginal productivity of industrial water use at 3.92 yuan/m^3 in 1993 prices, finding large variations across sectors and between regions, with the marginal value in the north being almost twice that of the south. World Bank (1997f) estimates the shadow price (i.e., marginal return) of water to industries in Shanxi province at 42 yuan/m^3 at the 1995 price level, using input-output analysis and the Linear Programming model. Water shortages also affect service industries in North China, and for instance, Beijing has been imposing strict water quotas on hotels, shops, government offices, and others (e.g., 100 liters of water per capita for public bathrooms, and 8 liters per car wash) since the beginning of 2002 (*China Daily,* 2001f). Water shortages in North China cities are already serious, estimated at approximately 5–6 billion m^3. Assuming the current marginal productivity of water in North China industries is 8–10 yuan/m^3 as a conservative estimate, we would calculate the lost industrial output to be annually well over 40–60 billion yuan. Without proper measures to mitigate this problem, economic losses in North China will rise as growing industrial and urban water demand increases both the volume of the water shortage and the marginal value of water.

Water shortages also affect municipal sectors. Household consumption in North China cities averages between 20 and 50 liters per capita per day (l/c/d), which barely exceeds the absolute minimum of 20 l/c/d for physiological and personal hygiene needs (World Bank, 1997d). Again, water pollution makes these public health problems worse. WRI et al. (1998) quote the estimate of Chinese sources that the impact of water pollution on human health is valued at about US$ 4 billion annually and claim that this is an underestimate. World Bank (1997d) also estimates the cost of water pollution in China at US$ 3.9 billion annually, using forgone wages as a conservative estimate of the essential value of human life. Even these conservative estimates amount to 1 percent of GDP as of 1995. While the majority of urban and some suburban residents now have access to tap water, more than one-half (53 percent) of the rural population does not. Only 6 of China's 27 largest cities meet the state standards for drinking water quality, and around 700 million people (half of China's population) drink water that fails to meet state standards (WRI et al., 1998).

China may need to increase its water supply capacity by 25 percent by 2010, an equivalent to building 600–800 new water treatment plants (each having a capacity of 400,000 m^3/day) (Silk and Black, 2000). Approximately US$ 700 million will be needed annually to meet projected municipal wastewater treatment demand in China in 2000 and beyond (*China Daily,* 2001f). According to *Xinhua* (2001a), Beijing plans to invest 17 billion yuan (US$ 2 billion) in the next five years to build 136 water saving projects in the industrial sector, to build 16 sewage treatment plants to ensure that 90 percent of sewage is treated, and to increase water prices from the current 2 yuan/m^3 to 6 yuan/m^3 in 2005. Since 1998, Shanghai has invested 1.4 billion yuan (US$ 169 million) to treat its rivers, especially Suzhou Creek, and the city's rivers have become noticeably clearer (*China Daily,* 2001a).

ALTERNATIVES TO ABATE THE PROBLEM, AND THE EXPECTED COST AND BENEFITS

Water Diversion from South to North

While medium-distance transfers from the Yellow River to large cities have been carried out as shorter-term projects, the Chinese government is about to start a massive water transfer from South to North as a longer-term strategic project. This project is composed of eastern, central, and western routes and is designed to divert water separately from the upper, middle, and lower reaches of the Yangtze River to meet the needs of North and Northwest China. The 500 billion yuan (US$ 60 billion) project will divert 38–48 billion m^3 of water, 5 percent of the Yangtze annual flow (*China Daily,* 2001d).

Construction is planned to begin in 2002 on the 715-mile eastern route and 774-mile central route, and it is expected to be completed by 2010 at an approximate cost of 180 billion yuan (US$ 22 billion), which will divert 16 billion m^3 or more (MacLeod, 2001). The western route, the most costly leg, still remains on the drawing board. World Bank (2000a) estimates the investment, operation, and maintenance cost roughly at 2 yuan/m^3 on average in 2000 prices.

The central government will share 60 percent of the total investment, and local authorities who will benefit from the project will pay the rest. To raise part of the investment, local governments will gradually increase present water-use charges, and the price for water will vary from region to region. The water price for residents in Beijing is expected to increase from 2 yuan in 2001 to 6 yuan per m^3 in 2005 (*China Daily,* 2001f). While irrigated farming can be quite profitable near large cities if high-valued fruits and vegetables are grown, average returns of irrigation water are as low as 2 yuan/m^3 (World Bank, 1997d). Raising prices is an incentive for people to conserve water, but some users, particularly farmers, may not be able to afford the water supplied by the project and instead will rely on pumping groundwater. Nevertheless, farmers will benefit indirectly since the shares for irrigation water from local sources will be preserved and there will be greater supplies of treated sewage water available for irrigation.

Beside construction cost, other costs such as for resettlement, the environment, and regional opportunity should be considered as well. About 370,000 people will be displaced in the transfer region along the eastern and central routes (*China Daily,* 2001h).

Brandon and Ramankutty (1993) note possibly serious environmental effects: (1) In the water exporting region there will be a reduction of flow in the Yangtze River, especially during the dry season, leading to possible seawater intrusion, with negative effects on delta fisheries and urban water supply in the Shanghai region. (2) In the transfer region, there will be a significant disturbance of aquatic ecology along the canals passing through major watersheds, secondary salinization of soil, and pollution of water by urban or industrial areas along the routes. However, Liu (1998) claims that most of the above adverse effects can be mitigated by proper technical measures (e.g., stopping water diversion when the flow to the lower Yangtze River falls below a critical level, lining the conveyance channel, and digging drainage canals), and that the south-north water transfer can instead yield environmental benefits, such as improving the channel of the lower Yellow River, enhancing the micro-climates of irrigated areas, ameliorating land subsidence and groundwater depletion, and replacing poisonously polluted water.

The opportunity cost of South China's regional development should also be considered. South China has more-abundant water resources than North China, but it also has a lot of industrial cities and irrigation fields. Therefore, although the marginal value of water resources is lower than in North China, water is not free in South China, and the amount of water available from South China is uncertain and limited. It is also doubtful that the Chinese government includes all of these nonconstruction costs into the project plans and budgets. Most of all, water supply from the project will be available only after 2010 and, therefore, cannot resolve imminent water shortages in the North China plain for the current decade.

Water Saving Technologies and Flood Control

Irrigation efficiencies vary depending on the irrigation technology used: 45 percent for earth canals, 70 percent for canal linings, 80 percent for low-pressure pipes, 85 percent for sprinklers, and 90 percent for micro-drip irrigation.

Considering that irrigation accounts for about 80 percent of China's total water use, a large-scale application of water-efficient irrigation technologies could save a huge amount of water. In Beijing, water saving irrigation technologies have been diffused since the mid-1980s and especially, sprinkler irrigation, which has reached over 30 percent of its total irrigated fields. Most of all, many farmers are willing to pay for the installation of water saving technologies to irrigate their fields. However, according to the concept of "real" water savings, which includes the return-flow factor (World Bank, 2000a), the net savings in the entire basin could be lower than expected because part of the water is lost upstream—because of old irrigation systems, returns by the hydrologic cycle, and through percolation and seepage—only then becoming available to downstream users (Yang and Zehnder 2001).

In the municipal sector, systems need to be set up to conserve water during distribution and consumption. Industrial development through restructuring improves water use efficiency and reduces water demand and pollution.

Flooding risk can be significantly reduced through modern flood mitigation technologies and reinforced levees. The *China Daily* (2001f) reports that since 1998, the central government has stepped up the development of water projects, with a total input of 136.4 billion yuan (US$ 16.4 billion)—reinforcing 30,000 kilometers of dikes and more than 450 reservoirs.

A Market Approach to Demand and Pollution Management

As water saving technologies mature, supply management becomes more expensive, and the costs are largely borne by nonbeneficiaries (Nickum and Easter, 1994). So far, government controls and water quotas have been the norm for demand management, especially in regulating industrial water demand. However, more-effective measures of demand management would be full-cost water pricing, which provides three substantial advantages: (1) providing water agencies with increased financial resources or enabling their privatization, (2) facilitating the reallocation of water to those with a greater willingness to pay (Nickum and Easter, 1994), and (3) reducing water demand and thereby postponing the need for investment, which releases financial resources for other activities and buys time for the development of improved technologies (Brandon and Ramankutty, 1993). In short, full-cost water pricing is a key link between supply and demand management—to finance urgent water supply projects and to defer less essential water demand.

Although many cities have increased water prices, the price of clean water is still low. While the marginal cost of new water projects is generally more than 1.20 yuan per m^3, the water tariffs range from 0.5 to 0.9 yuan per m^3 (World Bank, 1997f), discouraging wastewater reuse and the installation of water saving systems. Therefore, in the absence of water pricing reform, the success of other water saving measures is unlikely.

In the industrial sector, water pricing would be a more cost-effective way of water saving than regulatory methods such as water quotas. Pricing in urban areas may meet social resistance, and care must be taken to ensure the provision of the underprivileged with basic water and sanitation at affordable prices.

Pricing in rural areas will be difficult for cultural and technical reasons. Brown (2000) warns of the political risks of increasing water prices—the public response to raising water prices in China is akin to that of raising gasoline prices in the United States. However, beyond the cultural resistance, the increased water price may have detrimental effects on agriculture. Yang and Zehnder (2001) find that the share of irrigation costs in the total material cost (excluding labor) is about 10 percent for wheat and over 10 percent for corn in the North China plain provinces. By comparison, the proportion of irrigation cost is less than 2 percent in the United States, the European Union, Canada, and Australia. Therefore, it is claimed that increasing the price of irrigation water may further disadvantage grain farmers in North China and may reinforce the ongoing trend of substituting high-value cash crops for grain because of higher marginal returns to water from cash crops. In fact, in the past two years, Beijing has removed more than 10,000 ha of rice fields of the total 23,300 ha and plans to eliminate all rice from the fields by 2007 (*China Daily,* 2002).

A tradable water permit is another alternative for demand management. When water rights can be bought and sold, the market will naturally reallocate water to uses with higher economic value if transaction costs are low. In the long run, it also makes sense to concentrate water-intensive industries and urban development projects in the water-abundant south as people move from the agricultural to the industrial and service sectors.

Confronted with the concurrent needs to reduce pollution and increase industrial output and employment, the Chinese government has become interested in cost-effective pollution control. The current regulatory system provides a partial economic incentive to abate pollution by charging a levy on pollution only in excess of a given standard. Dasgupta et al. (2001) point out that the benefit of stricter effluent standards should be weighed carefully against the costs, and they conclude that changing to a full emissions charge system would greatly reduce abatement costs (for instance, at a 73 percent lower cost from their econometric case studies). Charges of between $3 and $30 per ton would be sufficient to induce 90 percent abatement of total suspended solid and other pollutants (Dasgupta et al., 2001).

Water Treatment and Recycling

Water recycling is a very cost-effective demand management approach, and moreover, wastewater reuse measures can tackle water pollution problems, too. Wastewater reuse can be applied to agriculture, industry, and municipalities.

The farmers in Beijing and Tianjin have used municipal wastewater for irrigation since the 1950s. Along with development of industries, the characteristics of municipal wastewater became more complicated and toxic. Because most wastewater was untreated and directly used for irrigation, it has seriously polluted soil, crops, and groundwater. To increase agricultural output and improve public health, municipal wastewater treatment should be strengthened and the quality of irrigation water should constantly be improved.

Industries can reuse wastewater inside factories after treatment or reuse treated municipal wastewater. Because industrial water uses are restricted by water use permit, wastewater reuse after treatment inside factories is highly developed. For the past 15 years, the industrial output in Beijing has increased by 650 percent, but total water withdrawal for industrial purpose has decreased by 57.5 percent. In 1996, the average recycling rate of industrial wastewater in Beijing was 91.4 percent, compared with about 40 percent for the national average and about 70 percent in OECD countries (SSB, 1997; World Bank, 1997d).

By 2000, 427 urban wastewater treatment plants had been built in China, and more than 300 are under construction. By 2005, China will double the daily capacity of wastewater treatment in cities throughout the nation, a great increase from 15 million m^3 in 2000 to 40 million m^3 in 2005. According to *China Daily* (2001a), Beijing's sewage treatment capacity reached 356.6 million tons in 2000, but only 18 million tons (less than 6 percent of the total) were recycled.

Lee (2000) claims the net present value of recycling projects is substantially higher than that of transfer projects. Moreover, the huge transfer project across the nation is associated with higher risk due to its size, its interdependencies among many regions, and its longer construction period. By contrast, the recycling project involves numerous small plant constructions; it has lower risk because each project is smaller in size and is independent from other regional projects and because the associated risks can be pooled among many plants. In addition, the transfer project involves a high risk of an irreversible environmental disaster, while the recycling project provides valuable environmental services, thereby contributing to public health and to increased productivity. Moreover, the water recycling project is more compatible with a market-based water resources management system (including full cost pricing and pollution charge) and should enhance municipalities' financial strength.

ECONOMIC AND SECURITY IMPLICATIONS

Effect of Water Problems on Productivity, Capital, and Labor

Our earlier sections estimate that the annual loss of unrealized industrial and agricultural potential due to water shortages already exceeds 100 billion yuan (more than 1 percent of the 2000 GDP), even without including labor loss due to public health damage. If effective policy measures are not taken, these water shortages and pollution will be magnified to the point of crisis in this decade and will seriously depress productivity growth, therefore reducing capital investment and increasing unemployment in North China. On the other hand, if proper measures are taken, water shortages could be a new growth opportunity.

To analyze the effects of water problems on the economy, this chapter focuses on the agricultural and industrial sectors. Once agricultural and urban users accept water as an economic commodity with a price, progress, including reallocation, will be possible. However, as Brown and Halweil (1998) maintain, unlike small countries such as Japan, Korea, and Taiwan, China is too big to simply divert irrigation water to urban and industrial water and to import most of its grain. Moreover, growth of agriculture and growth of industry are not mutually exclusive. Yao (1996) finds, using long-run regression data with national income indices of five sectors over 1952–1992, that agriculture has had a strong and positive effect on industrial growth and that simultaneous and mutually beneficial effects between agricultural and nonagricultural sectors (particularly township and village enterprises) have emerged since the economic reforms in 1979.

Water constraints in North China critically affect the total factor productivity of the agricultural sector. On the other hand, given the relatively high proportion of irrigation cost in grain production in North China, increasing the price of irrigation water is likely to reinforce the ongoing trend of shifts toward high-value cash crops. Average water use on irrigated land is about 4,500–6,000 m^3/ha, and the average yield of grain on this irrigated land is around 6,000 kg/ha in North China (roughly 1 kg grain to 1 m^3 water considering loss of water during transfer). Brown and Halweil (1998) and Yang and Zehnder (2001) point out that importing 20 million tons of grain per year from other provinces or the international market would free up 20 billion tons of water at a much lower cost than diverting water from the south, and this saved water could support urban and industrial water supply and the shift toward higher-value crops. Along with a trend toward an open economy, this transformation toward cash crops could increase productivity of China's agriculture if sufficient investment were made to help such transformation.

Along with water shortages, stricter pollution control is becoming an additional burden on industries, and this burden may reduce industrial productivity growth. However, as noted earlier, social costs of pollution treatment can be greatly reduced by a market approach. In fact, industrial pollution was disproportionately generated by a narrow section of the industry. By 1998, six industrial subsectors (pulp/paper, food, chemicals, textiles, tanning, and mining) accounted for 87 percent of total industrial carbon dioxide load but only 27 percent of gross industrial output value. In particular, the pulp/paper sector accounted for nearly half of the carbon dioxide load while contributing only 2 percent of output value (World Bank, 2001c). Many enterprises in these sectors are small-scale and locally owned by county and township governments. Since they are important generators of local employment, it is difficult for local environmental protection bureaus to shut them down. However, since many of them are unprofitable, closing or consolidating them will improve both economic and environmental situations. The earlier section also mentioned that increasing wastewater treatment from 30 to 50 percent would increase grain production by about 24 million tons by 2020, an equivalent benefit from the south-north water transfer project. In sum, stricter pollution control probably has negative effects on employment, but not necessarily on industrial productivity growth, and it obviously has positive effects on agricultural productivity.

Agricultural employment is expected to fall from more than one-half of total employment in 1995 to one-quarter in 2020. Since a large majority of farmers' income still comes from farming, particularly in the interior provinces, scarce water resources in North China sharply limit agricultural income. Moreover, a substantial part of the migrant population and of the migration of farmers to urban centers is due to drought, desertification, and soil erosion and degradation (Economy, 1997). If irrigation water prices increase, many farmers are likely to quit producing grain, and emigration from rural areas will be accelerated. On the other hand, if agricultural restructuring from land-intensive grain production to labor-intensive cash crop production in the North China plain is successfully made, the expected agricultural unemployment would be eased.

Security: Food Sufficiency and Regional Conflicts

China experienced an unprecedented population increase from the 1950s to the early 1970s, creating a strong population momentum that is now driving China's population growth despite already low levels of fertility. Most projections assume that China's population will increase to some 1.48 billion by 2025. This causes a major problem for China's food supply: Within only three decades, the country will have to feed an additional 260 million people, a number roughly equivalent to the total population of the United States (Feilig, 1999). See Table 5.6.

By the end of 2000, China claimed to have about 500 million tons of grain in stock, enough to sustain consumption for a year. *China Daily* (2001e) reports the World Bank view that although China should increase its grain imports for the next 20 to 30 years, doing so would not present an undue financial burden within an importing range of 20–50 billion tons annually.

One major concern about reliance on increased grain import is "food security," but the strictly economic basis for this concern is dubious. Many Chinese policymakers consider that China needs to maintain a high level of self-sufficiency in grain (about 95 percent). However, Yang and Zehnder (2001) claim that it is wise for China to opt for increased grain imports, not only because the imports can alleviate water stress in North China, but because they also conform with the general idea of an open economy. Since China has limited land but an abundant population, it does not have a comparative advantage in land-intensive crops like grain, but it does have a comparative advantage in labor-intensive crops such as animal husbandry, horticulture, aquaculture, and processed agricultural products, making net trade surplus in agriculture from $57 million in 1980 to $6.8 billion in 1999 (Lin, 2000). Having joined the World Trade Organization (WTO), China will gain increased access to foreign agricultural product markets. If it can thereby increase its exports of labor-intensive agricultural products, the result will tremendously benefit rather than hamper Chinese agriculture in the long run (Lin, 2000).

Future Scenarios and Possible Adversities

If proper measures are taken, the water crisis in China can be avoided, or at least mitigated. The effects on economic growth of possible alternative scenarios are summarized in Table 5.7. During the 10th five-year plan (2001–2005), the Chinese government plans to invest over 400 billion yuan (US$ 48 billion) in water conservation projects (*China Daily,* 2001a), such as dike reinforcement and

Table 5.6

China's Food Demand, 1995–2020: Various Projections Compared (millions of tons)

	Brown			Rosegrant et al.			Huang et al.			USDA			World Bank		
Year	P	D	I	P	D	I	P	D	I	P	D	I	P	D	I
1995	355	375	20	355	375	20	355	375	20	355	375	20	355	375	20
2000	342	405	63	385	403	18	410	450	40	362	387	25	411	420	9
2005	329	437	108	418	434	16	438	480	42	382	414	32	445	459	14
2010	317	472	155	453	468	15	469	513	44	403	443	40	483	502	19
2020	294	549	255	541	565	24	552	594	42	449	506	57	568	600	32

SOURCES: Feilig, 1999; primary source: OECD, 1997.

NOTES: P = production; D = demand; and I = imports.

shoring up reservoirs, and soil and water conservancy projects in the western region. If these moderate water conservation efforts are made as planned, a water crisis is unlikely to occur in the coming decade, and the base estimate of economic growth can be achieved. Moreover, under scenarios 2–4, if effective measures like full-cost pricing, water recycling, and pollution charges are successfully implemented (as assumed in scenarios 2–4), an even higher growth can be achieved. All these measures conform to market reform, decentralization, and an open economy.

Nonetheless, there still exists a possibility of serious economic adversities resulting from a water crisis. Construction of two routes of a gigantic south-north water transfer project started in 2002, and it is estimated to cost 180 billion yuan over the decade. But the real cost may escalate substantially, as was the case in the Three Gorges Dam project. Since the benefits of the transfer projects will not be realized until 2010, problems may arise if increased investment in the south-north water transfer substantially reduces investments in other water conservation projects. The adverse effects may be even worse than simply reducing water conservation efforts by one-half, since the costs of the transfer projects will displace other productive investments. Moreover, increasing the water price to collect the long-term construction costs will accelerate the collapse of grain production unless the investment in high-value-added agriculture is made. In this case, growth of total factor productivity (TFP), capital investment, and employment will decline, thereby seriously reducing sustainable economic growth of North China, which provides one-third of the national economy.

Moreover, Economy (1997) contends that while Beijing aggressively pursues plans for the river diversion, other provinces are resisting the project for political, economic, and environmental reasons and are, therefore, reluctant to contribute funds and manpower to the project. She warns, if these other provinces were forced to contribute, serious regional resistance and conflicts may develop. In other words, overenthusiasm of the central government may result in more serious economic problems if the large and expensive river diversion and water transfer projects are pursued in favor of the less dramatic but more efficient recycling and conservation efforts.

Table 5.7

Effects of Possible Alternatives and Scenarios on Economic Growth

	Scenario	Factor Growth		Explanation
1	Base estimate (business as usual)—moderate water conservation efforts	TFP	1.0–1.5	
		K	8.0–9.0	
		L	1.0–1.2	
2	Full-cost pricing with investment in high-value-added agriculture, reduction of grain production in north, and increase in grain imports	TFP	1.2–1.4	Increased agricultural productivity as well as efficient resource allocation
		K	8.5–9.5	Benefit from productivity increase, and relieved capital reserves from irrigation investment to more productive investment in industry and high-value-added agriculture
		L	1.2–1.7	Decreased grain-production labor offset by increased labor-intensive cash crop production
3	Increasing treatment capacities faster than wastewater increase, and reuse of municipal wastewater for irrigation	TFP	1.1–1.3	Increased agricultural productivity
		K	7.5–9.5	Mixed effects: displacement of other industrial investment, but more investment in irrigation facilities along with increased productivity
		L	1.2–1.7	Contingent on an increase in agricultural production
4	Shift from regulation to market-based pollution charge, leading to industrial restructuring	TFP	1.1–1.3	Efficient resource allocation among manufacturers and increased agricultural productivity
		K	8.5–9.5	Environmental goal achieved with less wastewater treatment costs, and more productive investment available from savings
		L	0.8–1.3	Unemployment from closing labor-intensive and pollutive small firms

Table 5.7—continued

	Scenario	Factor	Growth	Explanation
5	Full-cost pricing without investment in high-value-added agriculture	TFP	1.1–1.3	More efficient resource reallocation
		K	8.5–9.5	Benefit from productivity increase and better financing of public work
		L	0.0–0.5	Sharp decrease of labor in grain production
6	South-north transfer	TFP	1.0–1.2	No benefit until 2010
		K	7.5–8.5	Productive investments displaced by 180 million yuan investment over 10 years
		L	1.2–1.7	Employment growth due to this gigantic public works project
7	Water conservation efforts reduced by one-half	TFP	0.5–0.6	Agricultural and industrial productivity growth seriously limited by the constraints of water shortage and pollution
		K	7.0–8.0	Under serious water constraints, capital investment also decreased although reduced water projects release other productive investments
		L	0.0–0.5	Unemployment from decreased (public) investment
8	Worst case: south-north transfer project displaces half of water conservation efforts, while increasing water prices	TFP	0.5–0.6	The same as reduced water projects case (scenario 7)
		K	6.5–7.5	Problems in reduced water projects case plus displacement of productive investment
		L	0.0–0.5	Decrease in other water projects offset by south-north transfer project, but higher water prices lead to decreased agricultural labors

NOTES: The base estimate of factor growth is from Wolf et al., 2000. K = capital growth. L = employment growth. The respective weights on employment growth and capital growth are 0.6 and 0.4.

Combining the most adverse scenarios in Table 5.7 (7 and 8), we estimate that China's economic growth would decrease by between 1.5 and 1.9 percent annually from the baseline annual growth of about 5 percent associated with the base case (scenario 1).

Table 5.7 summarizes the content and effects of eight scenarios (including the base case, scenario 1), which vary in their assumptions about China's adoption of the most efficient or least efficient policies and projects to relieve its serious water and pollution problems through the next decade.

Scenario 1 summarizes the base case drawn directly from prior RAND forecasts of China's macroeconomic growth through 2015.[2] Salient aspects of each scenario are summarized in the first column (Scenario) and final column (Explanation). The factor growth columns refer respectively to TFP, growth of capital (K), and employment growth (L). The estimates of these parameters in the base case (scenario 1) are drawn directly from the previously cited RAND work.

In scenarios 2 through 8, we describe circumstances in which China opts for differing, and successively less efficient, policies and projects for water pricing and pollution charges, wastewater treatment, water recycling, conservation, and south-north water transfers. If China opts for the more efficient policies, the risk of water and pollution crises would be substantially reduced, if not completely averted. That it might nevertheless choose less efficient ones, while not inevitable, is not implausible. Their plausibility might be traced to regional, provincial, bureaucratic, and political rather than economic considerations.

Indeed, recent statements from China's ministry of water resources indicate that the State Council has approved massive and costly transfer projects to channel water from the largest rivers in the south to northern cities like Beijing and Tianjin.[3]

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[2] See Wolf et al., 2000, Table B.1, pp. 88–89, and Table 7, p. 36.

[3] See WSJ, November 27, 2002.

The parameter reestimates for each scenario (diverging from the base case) are based on the authors' judgments about how and how much the parameters for productivity, capital growth, and employment growth would be affected in the successive scenarios. For example, in the worst case—scenario 8—total factor productivity growth would decrease by between 0.5 and 0.9 percent annually (from an annual rate of 1.0 to 0.5 percent, or from 1.5 to 0.6 percent), growth of the capital stock would decrease by 1.5 percent annually (from 8.0 to 6.5 percent, or from 9.0 to 7.5 percent), and annual employment growth would decline by approximately 0.7 percent (from about 1.2 to 0.5 percent annually). Assuming that the factor shares are 60 percent for the labor income and 40 percent for the capital—which were used in RAND's prior work on China's economy[4]—would reduce the estimate of China's annual GDP growth by an upper-bound estimate of 1.9 percent. For scenario 7—also an adverse case—similar calculations yield a lower-bound estimate of forgone economic growth of 1.5 percent.

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[4]Wolf et al., 2000, Table B.1, p. 88.